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Carlos GONZALEZ REGALADO

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Composition du jury :

Christophe BENAVENT Professeur, Université Paris- Dauphine - PSL	*Président*
Simon PORCHER Professeur, Université Paris 2 Panthéon-Assas	*Rapporteur*
Francesc TRILLAS Professor, Autonomous University of Barcelona	*Rapporteur*
Carlos PEREIRA Professeur, Getulio Vargas Foundation (FGV) - Rio de Janeiro	*Examinateur*
Emmanuelle MATHIEU Maître d'Enseignement et de Recherche, Université de Lausanne	*Examinatrice*
Éric BROUSSEAU Professeur, Université Paris- Dauphine - PSL	*Directeur de thése*

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Acronyms

ACER Agency for the Cooperation of Energy Regulators. xxiii, 9, 11, 22

CEC Commission of the European Communities. 13

CEER Council of European Energy Regulators. 102

CEP Clean Energy Package. 18, 99

DSOs Distribution System Operators. 18, 98

EC European Comission. 12, 101

ECJ European Court of Justice. 13

ENTSO-E European Network of Transmission System Operators for Electricity. 9, 11

ETS European Trading System. 101

EU European Union. 13

GDP Gross Domestic Product. 1, 57

IRA Independent Regulatory Agency. 21, 22, 104, 114

IRT Item Response Theory. 26

ISO Independent System Operators. 18, 99

LCS Least Common Subsumer. 43, 44

LDA Latent Dirichlet Allocation. 46, 47, 73, 76

MCA Multiple Correspondence Analysis. 26, 65, 77

MS Member State. 13–23, 124, 127

NI Network Industries PMR. 38

NLP Natural Language Processing. 5, 27, 29, 121, 126

NRA National Regulatory Agency. 95, 96, 98, 100, 104, 107, 108, 118–120

OECD Organization for Economic Cooperation and Development. 4

PCA Principal Component Analysis. 26, 35, 37, 65

PMR Product Market Regulation. 26, 27, 32, 34–38, 47–49, 64–66, 105, 108, 110, 116

POS Position of Speech. xi, 42, 43

RA Regulatory Agency. 69, 78, 79, 85, 86, 88, 91, 107

RIQ Regulatory Inquiry Questionnaire. 4, 6, 27, 31, 36, 39–41, 43, 123, 124

SES Single European Sky. 14, 15

TPA Third-Party Access. 39, 42

TSOs Transmission System Operators. 18, 98

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Résumé

Mon travail de doctorat, tel qu'il est présenté dans ce document, évalue les réformes du marché dans les industrie de réseau en Europe (tels que l'énergie, le gaz, les télécommunications, le transport aérien et ferroviaire) à l'aide de nouveaux indicateurs. Cette étude a été motivée par mon intérêt pour les changements institutionnels et la manière dont ils affectent les performances économiques dans des contextes profondément politisés, mais également par mon intérêt pour les méthodes de traitement du langage naturel et la manière dont elles peuvent être utilisées pour répondre aux préoccupations économiques et de gestion.

Motivation

Il est difficile de sous-estimer l'importance des institutions dans le fonctionnement d'une société. Les règles du jeu, qui contrôlent les différentes d'incitations disponibles pour les acteurs (économiques) et qui auront nécessairement un impact sur leur conduite, sont déterminées par les institutions. Celles-ci contrôlent non seulement le comportement individuel mais aussi les actions des entreprises, des syndicats et des gouvernements (North, 1990). Les différences dans les institutions devraient révéler des changements dans le fonctionnement de ces sociétés si les institutions peuvent influencer la façon dont les agents interagissent dans une société, en particulier dans une économie. Les institutions, selon Acemoglu et al. (2001), expliquent une part importante des disparités de richesse mondiales sur le long terme. Les disparités concernant les performances sociales et économiques soulèvent des inquiétudes, tout d'abord sur l'état et le développement des réformes : quelles institutions sont encore en place, pourquoi le sont-elles, qu'elles sont celles remplacées, dans quelle mesure les institutions actuelles influencent-elles la mises en œuvre des réformes et les parties prenantes changent-elles les institutions ? (Loasby, 1993)

Dans le but de résoudre ces problèmatiques, les chercheurs, les gouvernements et les organisations internationales ont comparé divers cadres institutionnels ; or, leur évaluation implique de contraster leurs nombreuses caractéristiques. Les caractéristiques les plus importantes des institutions et leurs changements peuvent être saisies et réduites à un nombre acceptable de composants en utilisant des mesures quantitatives. Ces synthèses permettent de comparer l'état et l'évolution des institutions entre les nations, les régions et

les secteurs. Contrairement aux mesures de résultats, ces comparaisons révèlent non seulement les caractéristiques de la façon dont les institutions évoluent dans le temps, mais fournissent également un éclairage sur la viabilité des améliorations institutionnelles. Les fonctionnaires et les hommes politiques s'intéressent à ces mesures en raison de leur importance et parce qu'ils les utilisent comme guide pour créer des objectifs politiques et choisir le meilleur plan d'action pour une certaine circonstance (OECD, 2008). En outre, en surveillant si les changements sont effectués et s'ils sont pertinents pour leurs intérêts, les citoyens et les universitaires peuvent tenir les gouvernements responsables. Dans l'ensemble, les indicateurs quantitatifs nous aident à comprendre les réformes du marché, à déterminer s'il s'agit de solutions universelles et à identifier comment les circonstances nationales et institutionnelles affectent la portée, la vitesse et les particularités des changements d'un marché.

Parmi les principaux changements institutionnels récents, la libéralisation des marchés a fait l'objet de travaux empiriques. La libéralisation des marchés a eu une influence considérable sur les performances économiques des nations, des industries et des citoyens. La productivité et le bien-être des consommateurs sont fortement influencés par les politiques libérales, qui favorisent la mise en œuvre de la concurrence et la réduction ou la suppression de toute distorsion potentielle de la concurrence (Djankov et al., 2006). Dans le monde entier, les nations ont réduit de manière drastique les tarifs commerciaux et les barrières non tarifaires, supprimé les obstacles à l'entrée et ouvert leurs marchés à la concurrence nationale et extérieure. L'augmentation du commerce transfrontalier de biens et de services sur tous les continents au cours des 30 dernières années est la preuve de l'ouverture du marché (World Trade Organization, 2019). Les services publics et d'autres secteurs où la concurrence était auparavant considérée comme impossible ont été inclus dans le champ d'application de la libéralisation (Newbery, 1999).

Le paradigme libéral a renforcé le soutien à la restructuration des secteurs des services publics et des transports, qui étaient auparavant gérés par des "champions" (d'État) verticalement intégrés, en plus de la pression des consommateurs pour une meilleure qualité de service, de la demande de l'industrie pour des coûts de fabrication plus bas et des possibilités d'innovation technologique. En réponse au climat politique, l'Union européenne a poussé à la libéralisation des marchés nationaux en tant qu'étape initiale et essentielle à la création d'un marché intégré à l'échelle continentale. Cela vise à offrir un véritable choix à tous les consommateurs de l'Union européenne, qu'il s'agisse de citoyens ou d'entreprises, de nouvelles opportunités commerciales et davantage d'échanges transfrontaliers, de la réalisation de gains d'efficacité, de prix compétitifs et de normes de service plus élevées, ou encore à contribuer à la sécurité du continent. Les industries de réseau européennes ont connu une transition considérable depuis la fin des années 1980. La réforme visait à mettre en œuvre quatre étapes transformatrices : i) l'ouverture du marché dans les segments où la concurrence était possible ; ii) la séparation du monopole intégré ; iii) la privatisation du monopole de l'État ; et iv) la délégation des tâches de réglementation à des organismes de réglementation indépendants. Chaque industrie de réseau possède des caractéristiques techniques uniques qui nécessitent son propre processus de libéralisation.

La restructuration de l'industrie ayant été planifiée et mise en œuvre à l'échelle continentale (à travers des directives et des règlements de l'UE), le processus de réforme européen offre une occasion unique d'évaluer la portée, l'impact et les implications de la réforme. Cependant, la mise en œuvre n'est pas uniforme entre les secteurs et les États membres. Les variations dans les progrès observés de la réforme ont été causées par la force des autorités nationales législatives, opérationnelles et réglementaires (Conway et al., 2005; OECD, 2016). L'étude de Boylaud and Nicoletti (2000), Alesina et al. (2005), ou Vitale et al. (2020) en particulier documente les disparités nationales et sectorielles dans la mise en œuvre de la réforme européenne. Ces disparités ont été largement utilisées dans la littérature (voir Broughel and Hahn (2022) pour une vue d'ensemble) pour évaluer les causes des variations de la réforme entre les États membres et les industries ainsi que l'efficacité des réformes. Selon la littérature, la libéralisation a un bon impact sur les investissements, la croissance et l'efficacité industrielle. Cependant, au-delà des impacts macroéconomiques de la réforme, de nombreuses ramifications et éléments liés à l'influence sur la tarification, la qualité des services et les répercussions environnementales sont encore indéniables.

La réforme

Les réformes du marché progressent

Après la libéralisation des États-Unis dans les années 1970, celle du Chili au début des années 1980 et celle du Royaume-Uni à la fin des années 1980, l'Acte Unique Européen de 1986 a légalisé la libéralisation du secteur des réseaux. La restructuration visant à créer un marché unique comprenait une réforme de ces secteurs. La réforme initiale visait la réduction des droits de douane et la mobilité illimitée des capitaux, des services et des personnes. L' Union européenne (UE) a encouragé les industries de réseau à se faire concurrence pour améliorer les coûts, la qualité et la fiabilité. L'approche de la mise en œuvre de la réforme de l'UE doit s'adapter aux puissants pouvoirs réglementaires nationaux des États membres, contrairement aux États-Unis, qui disposent d'entités fédérales dotées de vastes capacités d'exécution du changement. Au vu des directives et des règlements à l'origine de la réforme de l'UE, les États membres doivent satisfaire aux objectifs des directives pour la réforme de l'industrie des réseaux. Chaque État membre peut élaborer des lois et des politiques pour atteindre ces objectifs (transposition). Les approches de mise en œuvre des pays affectent les niveaux de réforme. Les règles de l'UE remplacent les lois. Les règlements de l'UE doivent être correctement appliqués. Ainsi, les règlements de l'UE deviennent des lois nationales. La description de la réforme ci-dessous met l'accent sur ces deux mécanismes juridiques en raison de leur capacité de transformation.

La libéralisation a restructuré les industries de réseau et les marchés. La réforme a réduit les obstacles juridiques à l'entrée dans l'industrie et a créé des marchés qui fonctionnent bien (Joskow, 2009). La libéralisation du marché, le dégroupage vertical et le détachement de l'État sont trois de ces mouvements (Geradin, 2006). La concurrence favorise l'efficacité dans les trois activités.

Premièrement, la réduction des barrières d'entrée/sortie et des réglementations inefficaces permet à de nouvelles entreprises d'entrer sur le marché. La concurrence tri les entreprises efficaces et inefficaces sur un marché (Alesina et al., 2005; Égert, 2009; Égert, 2018). La concurrence fait baisser les coûts des services et améliore la qualité, dissipant les rentes de monopole qui sont désormais répercutées sur les clients. La concurrence affecte différemment les différentes industries. Le monopole inhérent au réseau limite les entreprises efficaces sur le marché à une seule. Dans ce cas, les entreprises ont besoin d'accéder au réseau central des services du monopole naturel pour être compétitives sur leurs marchés et la société pour bénéficier des gains d'efficacité du mode de marché concurrentiel. Avant la libéralisation, les monopoles d'État, verticalement intégrés, dominaient la production, la transmission / distribution et la vente au détail. Les entreprises d'État exploitaient le réseau de composants de l'industrie et y investissaient. La segmentation divise les activités de production, de transmission / distribution et de détail. Cette branche s'occupe de l'exploitation autonome du réseau et de la réglementation de l'accès. La division garantit un accès "équitable" à toutes les entreprises concurrentes, y compris les entreprises publiques historiques dans le segment concurrentiel restant. L'accès "équitable" élimine la discrimination de l'opérateur de réseau, qui peut consister à refuser aux rivaux en aval l'accès au réseau, à réduire la qualité des services d'accès et à faire payer plus cher aux concurrents en aval l'accès au réseau. Enfin, la privatisation croissante a modifié la structure de l'industrie. La privatisation est considérée comme naturellement compatible avec la concurrence (Newbery, 1999) parce que les incitations de la gestion privée à maximiser la valeur pour les actionnaires, y compris les incitations à suivre des pratiques d'entreprise efficaces, améliorent la rentabilité dans un cadre concurrentiel. Contrairement aux deux révisions précédentes, l'UE est agnostique sur la propriété des entreprises et n'a pas décidé de promouvoir ou d'interdire la participation de l'État dans les industries de réseau.

Industries avant la réforme

Au milieu des années 80, des pressions politiques, économiques et techniques ont réformé les secteurs européens de l'aviation et des télécommunications. Après avoir constaté des gains d'efficacité et des avancées technologiques aux États-Unis et au Royaume-Uni, la Commission européenne (CE) a révisé ses objectifs politiques et donné la priorité à la réforme de ces deux secteurs afin de promouvoir le marché unique européen. Le Mémorandum sur l'aviation civile (Commission des Communautés européennes, 1979, 1984, ci-après CCE) et le "Livre vert" sur les télécommunications ont défini les objectifs, les principes et les premières initiatives de la CE (Council of the European Union, 1987). Ces documents encourageaient la discussion sur la manière dont l'UE pouvait améliorer la qualité des services, les coûts pour les consommateurs et l'efficacité industrielle. Les textes insistaient également sur la conception d'une réforme qui tienne compte des économies européennes et des objectifs du marché unique. Ils soulignaient notamment l'importance des réformes du marché qui suivent le progrès technologique et des politiques qui aident l'UE à profiter de la transformation technologique. À la fin des années 1980, l'augmentation du commerce, des télécommunications, des technologies de l'information et des investissements

a nécessité une appropriation des avantages économiques.

Difficultés techniques de la séparation verticale

Contrairement aux secteurs des télécommunications et du transport aérien, la libéralisation des secteurs de l'énergie et du rail a été remise en question en raison des limites de la concurrence dans les industries où les coûts sociétaux inhérents au monopole ne pouvaient être dépassés par une structure industrielle alternative. En d'autres termes, les "champions" nationaux verticalement intégrés produisaient/négociaient des articles ayant des caractéristiques physiques (par exemple, l'électricité ou le gaz) et ne permettaient pas l'existence de marchés concurrentiels (Glachant and Perez, 2011) ou contrôlaient étroitement le réseau (industrie ferroviaire) (Casullo, 2016).

Les États membres considèrent que ces industries - électricité, gaz et transports - sont cruciales pour leur économie et leur sécurité nationale, en particulier le secteur de l'énergie. L'UE utilise ses outils juridiques pour promulguer le changement après que des préoccupations nationales l'aient retardé. Les conséquences sociales prévues d'une libéralisation complète dans les secteurs de l'énergie et des transports, notamment les pertes d'emplois, ont également retardé le changement (Geradin, 2006).

Restructurer la gouvernance réglementaire

La plupart des pays ont entamé la libéralisation économique dans les années 1990. Les gouvernements ont renforcé cette tendance en créant des organismes de réglementation indépendants afin de promouvoir une concurrence équitable entre les nouveaux entrants et les opérateurs historiques et de protéger les consommateurs (Levi-Faur, 2005). La plupart des services publics étaient administrés par des organismes publics ou privés sous la supervision du ministère, soit par le biais d'un système de commandement et de contrôle, soit par des accords contractuels. Les organismes de réglementation indépendants ont été créés en réponse à l'examen (Stigler, 1971) de la capture des organismes de réglementation par les entreprises et pour préconiser une forme d'agence qui résiste à l'influence excessive des gouvernements lorsqu'ils tentent de s'écarter des jugements d'intérêt public (Majone, 1996).

En Europe, où les industries de réseau étaient des monopoles d'État intégrés verticalement, la réforme du marché nécessitait une agence indépendante pour mettre en œuvre la législation de manière transparente et non discriminatoire afin de protéger la concurrence, les intérêts des clients et la durabilité du système. Ainsi, le régulateur fonctionne sous la tension des entreprises privées/publiques concurrentes, du gouvernement / des politiciens (représentant les consommateurs), et des investisseurs. L'Union européenne a adopté le modèle de "l'agence indépendante de régulation" (IRA) comme moyen de modérer ces demandes. L'agence de régulation indépendante (IRA) est une entité bureaucratique au-delà de la sphère du contrôle présidentiel, disposant de pouvoirs réglementaires et de procédures décisionnelles indépendantes (Thatcher, 2002; Alesina and Tabellini, 2008). Les directives relatives au marché unique

ont conféré aux IRA l'autorité et les pouvoirs réglementaires nécessaires pour piloter et surveiller le marché unique (dans les secteurs des réseaux) sur la base de trois principes : i) introduire et encourager la concurrence, ii) créer des systèmes de réseaux stables et puissants/sécurisés et maintenir la qualité des services, et iii) accomplir les tâches réglementaires de manière non discriminatoire, en particulier lorsque la compensation financière ou l'accès au réseau sont en jeu. Les IRA pratiquent la durabilité environnementale. Les directives ne confèrent pas aux IRA de responsabilités en matière de durabilité environnementale. Contrairement à la mise en œuvre progressive de la régulation du marché par le biais de plusieurs directives et règlements, l'UE a mandaté la mise en œuvre juridique du modèle des IRA aux état membre (EM) en utilisant des directives spécifiques (les directives successives ont mis à jour la liste des tâches assignées en fonction des besoins de l'UE et des nouveaux défis) : pour les télécommunications, l'article 8 de la directive European Parliament, Council of the European Union (2002c), pour l'électricité, l'article 35 de la directive European Parliament, Council of the European Union (2009b), pour le gaz, l'article 39 de la directive European Parliament, Council of the European Union (2009c), et pour le rail. Au-delà des principes, la délégation de pouvoir s'est également appuyée sur trois piliers, l'indépendance décisionnelle des agences, qui comprend les ressources (humaines et financières) nécessaires à l'accomplissement de leur travail, un ensemble défini de pouvoirs délégués et des dispositions en matière de responsabilité pour limiter les actions discrétionnaires potentielles de l'IRA allant à l'encontre de l'intérêt public (Koske et al., 2016).

Les pouvoirs exécutif et législatif peuvent passer outre, réviser par voie ministérielle ou nommer ou révoquer les organes de décision de l'IRA, même si les régulateurs étaient constitutionnellement séparés du gouvernement. Le droit européen et les agences internationales ont suggéré de limiter l'influence du gouvernement et des entreprises sur les décisions des régulateurs (Koske et al., 2016). Les directives ont limité les révisions ex post des décisions réglementaires en définissant des processus d'annulation explicites. Les directives ont en outre conseillé aux EM de minimiser l'influence des comités ad hoc ou des agences ministérielles dans la prise de décision de l'agence et de laisser les tribunaux gérer les différends entre les parties prenantes. L'UE a protégé les organes directeurs des régulateurs contre toute révocation arbitraire afin d'éviter toute ingérence politique et tout contrôle privé. Lorsque les préférences du régulateur et du gouvernement diffèrent beaucoup, ces règles sont bénéfiques. Les règlements limitent les droits de licenciement du gouvernement, établissent les conditions de la tête et du conseil d'administration, et fournissent des normes de sélection explicites. Ainsi, le leadership de l'IRA n'est pas affecté par la politique (Gilardi, 2005). L'approche de gouvernance réglementaire inclut des restrictions sur la participation du secteur privé. Les membres du conseil d'administration ne peuvent pas travailler dans l'industrie après leur mandat. Cette phase est fréquemment qualifiée de période de " pantouflage ". Enfin, les directives nécessitent des ressources financières et humaines suffisantes. Une agence qui ne dispose pas des bons outils risque de ne pas être performante ou de prendre de mauvaises décisions (Glachant et al., 2013). Lorsque le régulateur reçoit une grande partie de son budget du gouvernement ou du secteur privé, la situation peut s'aggraver. Réduire le budget du régulateur pourrait affecter son programme ou son efficacité. De même, le secteur privé peut faire pression pour

son programme lorsque le financement du régulateur repose sur des taxes ou des droits payés par les entreprises réglementées.

Les directives ont également spécifié les tâches sectorielles des régulateurs en plus de la séparation juridique. La liste comprend généralement une réglementation fondée sur les coûts, des capacités de fixation des prix et d'autres mesures qui ont aidé l'agence à atteindre ses objectifs, quel que soit le secteur. Les directives européennes confèrent aux agences la capacité d'arbitrer les litiges entre les acteurs du marché, d'établir des exigences techniques et de sécurité, et de créer et transmettre des informations sur le marché aux parties prenantes. Le troisième paquet "électricité" a confié aux régulateurs nationaux la responsabilité de gérer et d'attribuer la capacité d'interconnexion, de garantir la transparence et la concurrence et de calculer les tarifs (article 36 de la directive European Parliament, Council of the European Union (2009b)). Les directives prévoient également des mesures de responsabilisation et de transparence afin de maintenir les agences sur la bonne voie et de limiter leurs pouvoirs discrétionnaires. Parmi ces mesures, on peut citer la mise en œuvre d'auditions parlementaires obligatoires, de rapports, l'explication des décisions réglementaires et la publication des méthodes (Koske et al., 2016).

En plus de l'application du modèle IRA, les directives européennes ont créé des organisations européennes qui permettent la convergence réglementaire sur des marchés de taille continentale sans régulateur européen unique (voir Glachant (2021) pour un exemple dans le domaine de l'énergie). Les régulateurs nationaux et d'autres acteurs sectoriels ont développé ces entités pour mettre en œuvre les nouvelles idées de réglementation européenne, fournir des normes, déterminer les bonnes pratiques réglementaires, harmoniser les techniques et partager les expériences. Les paquets réseau ont besoin de ces forums. Le groupe des régulateurs indépendants (IRG) a été créé pour échanger des expériences et développer des connaissances réglementaires communes dans les secteurs des télécommunications et du rail (directive European Parliament, Council of the European Union (2016a)). Le troisième paquet "électricité" a créé l'Agence indépendante de coopération des régulateurs de l'énergie (ACER) pour conseiller les États membres sur l'intégration et l'harmonisation des marchés dans les secteurs de l'électricité et du gaz.

Le secteur avant la réforme, les moteurs de la réforme et le droit européen ont été abordés dans les parties et sous-sections précédentes. Cependant, l'état d'avancement de la mise en œuvre et le développement de la réforme et de son modèle de gouvernance diffèrent grandement entre les secteurs et au sein de ceux-ci. Les forces politiques et techniques, les caractéristiques physiques des services et les outils de l'UE produisent des disparités de mise en œuvre sectorielle Geradin (2006). La Commission européenne a utilisé la politique de concurrence (décisions contraignantes) pour intégrer les marchés dans les secteurs des télécommunications et de l'aviation, tandis que les directives (qui fixent des objectifs pour les EM mais ne limitent pas la marche à suivre) régissent l'intégration sectorielle dans les secteurs de l'électricité et du gaz (Glachant, 2021). Les distinctions se poursuivent également au niveau national, où l'équilibre politique, le pouvoir des acteurs ayant un droit de veto, la dotation naturelle et la tradition juridique ont un impact sur le cours du changement (Gilardi, 2002). Les chercheurs et les universitaires établissent un

lien entre les divergences et les performances de l'industrie malgré les tentatives de l'UE d'appliquer le modèle de réforme et de gouvernance réglementaire.

L'examen empirique de la réglementation économique dans les secteurs de réseau a montré que les réformes du marché stimulent le développement économique (Broughel and Hahn, 2022). Les réformes du marché incitent la direction des entreprises à maximiser la valeur pour les actionnaires, ce qui stimule les investissements (Alesina et al., 2005). La réforme augmente également la productivité des facteurs (Nicoletti and Scarpetta, 2003; Bouis et al., 2016, 2020) et l'efficacité allocative des secteurs qui utilisent des intrants de réseau (Bourlès et al., 2013; Cette et al., 2017). Dans la partie suivante, nous examinons comment les mesures de réforme et de gouvernance de la littérature peuvent limiter notre compréhension de la transformation.

Évaluation de la réforme

L'étude de l'état et de l'évolution de la réforme dans une nation ou une industrie particulière peut fournir des informations importantes concernant la mise en œuvre de la réforme du marché dans les industries de réseau. En outre, une évaluation comparative est avantageuse pour déterminer l'état de la mise en œuvre de la réforme dans les différents pays, ainsi que les raisons probables du niveau de mise en œuvre et de l'évolution ; plus important encore, une évaluation comparative pourrait fournir des informations perspicaces concernant les effets de la réforme sur la performance de l'industrie. Les idées glanées à partir d'une telle analyse pourraient aider les décideurs politiques à formuler et à exécuter des politiques qui soutiennent au mieux les objectifs politiques souhaités. L'objectif est de fournir un cadre qui nous permette de saisir et de résumer les éléments les plus significatifs des réformes du marché, que nous évaluions une nation ou un secteur particulier ou que nous comparions les changements entre les EM européens.

La littérature se concentre sur les indices synthétiques et les mesures permettant de simplifier la compréhension d'informations complexes, d'établir des priorités, de planifier et de mettre en œuvre des politiques, et d'évaluer leur efficacité. Ces mesures contribuent également à la diffusion de l'information, à la responsabilisation et à l'élaboration de récits instructifs pour les clients, les médias et les électeurs (OECD, 2008). En outre, les indices synthétiques peuvent être utilisés pour évaluer la mise en œuvre des réformes dans un secteur ou une nation particulière et pour identifier les opportunités de croissance future. Par conséquent, les techniques utilisées pour agréger les données doivent être sélectionnées avec prudence. Une mauvaise approche de l'agrégation des informations peut aboutir à des résultats inexacts. Plus précisément, des indices médiocres ou biaisés peuvent :

- Déformer l'opinion publique en faveur de la politique souhaitée.
- Communiquent des messages politiques peu clairs ou peuvent encourager des conclusions politiques naïves.

- Augmenter la complexité de la détermination de la meilleure ligne d'action ou aboutir à des politiques inadaptées.

Les préoccupations antérieures ont mis l'accent sur les dangers que peuvent présenter des mesures insuffisantes ou biaisées pour la prise de décision publique et privée. Il est possible d'incorporer des biais dans les mesures agrégées en appliquant des critères arbitraires pour résumer et pondérer les éléments de la réforme. Les critères de pondération peuvent accorder une priorité plus élevée à certaines qualités de la réforme qui favorisent une position politique ou idéologique particulière. En 2018, le cycle actuel de critiques visant les métriques "Doing Business" de la Banque mondiale a mis en évidence ce problème. Le score a été critiqué pour refléter la position pro-déréglementation de la Banque mondiale, qui s'aligne davantage sur les régimes réglementaires libéraux (par exemple, les États-Unis et le Royaume-Uni). Par conséquent, l'indicateur indique la distance par rapport à un paradigme réglementaire "idéal" plutôt qu'une mesure précise du changement. L'indicateur classe les nations dont les scores sont les plus élevés comme étant plus proches du modèle libéral et celles dont les scores sont les plus bas comme ayant des cadres alternatifs. Ce classement a des conséquences pour les nations. Par exemple, le classement "Doing Business" a une influence considérable sur le calcul de la note de crédit d'un pays et, par conséquent, sur son accès aux financements étrangers. En outre, les organisations internationales et les politiciens utilisent ces indices comme des outils de "dénonciation" pour promouvoir des améliorations politiques favorables à leurs opinions politiques (Erkkilä, 2020). Les réformes dans les secteurs des réseaux ont été réalisées par le biais de directives et de règlements visant à créer une concurrence dans les domaines où elle est possible et à régir l'accès "équitable" des entreprises aux services de réseau. Les États membres ont toutefois adopté ces normes dans leur législation nationale à des rythmes très variables. Des mesures et des indicateurs spécifiques qui utilisent les directives et règlements européens comme référence (un marché concurrentiel) sont établis pour évaluer l'état et le développement des réformes nationales / sectorielles (OECD, 2008) La comparaison avec des marchés concurrentiels peut fournir des indications précieuses sur les réformes du marché, mais elle soulève également des problèmes concernant le processus de comparaison : i) Quelles sont les qualités ou caractéristiques significatives lorsqu'on compare l'état actuel de la réforme au modèle de référence ? ii) La mesure utilise-t-elle une seule dimension pour résumer et expliquer la réforme, ou d'autres dimensions sont-elles nécessaires ? iii) Les traits ou aspects pertinents ont-ils la même importance ? Les réponses ne sont pas simples puisque les critères utilisés pour choisir les caractéristiques significatives, évaluer leur effet pertinent et définir la réforme ont une influence sur la mesure / les métriques que nous voulons produire et le message qu'elles transmettent. Les première et deuxième questions portent sur des problèmes conceptuels et théoriques, tandis que la troisième question couvre des problèmes méthodologiques. L'objectif de nos trois recherches est d'analyser les réformes du marché en utilisant des algorithmes NLP afin de minimiser l'influence d'un éventuel biais de mesure. En outre, nous analysons le développement et la performance du secteur à l'aide de mesures traitement automatique du langage naturel (TALN).

Les documents

Document 1: Mesurer la réglementation des marchés dans les pays de l'OCDE : Une analyse transnationale

La première étude examine les différents environnements réglementaires présents dans les 24 nations de l'OCDE et les compare et les oppose. Dans le document, les méthodes de traitement du langage naturel sont suggérées comme méthode d'automatisation du codage des enquêtes. Grâce à cette approche, les chercheurs auront moins d'impact sur le codage et il sera possible de comparer les dispositions réglementaires entre les secteurs, les nations et les périodes. L'article présente les chaînes lexicales comme une technique de codage des caractéristiques. Dans cette approche, les informations contenues dans le texte sont agrégées en concepts génériques d'ordre supérieur. Ces concepts regroupent un certain nombre d'expressions communes (par exemple, le mot "prix" est lié à des termes tels que "coûts", "charge" et "marge"), ce qui permet de condenser les informations en un plus petit nombre d'aspects similaires dans toutes les industries. Le questionnaire d'enquête réglementaire QER de l'OCDE permet d'identifier les idées communes (1998, 2003, 2008, 2013, 2018). Dans une phase ultérieure, nous utilisons la modélisation thématique (Blei et al., 2003) afin de trouver des idées et des facteurs de régulation co-occurrents.

Selon les résultats de notre recherche, les réformes du marché peuvent être réparties en trois dimensions distinctes :

- le niveau de propriété /influence de l'État dans l'industrie
- le traitement juridique équitable accordé aux entreprises nouvelles / existantes dans le secteur (accès au réseau)
- l'influence des entreprises en place pour contrôler les caractéristiques / conditions des produits / services sur le marché

Ces aspects de la réforme du marché semblent englober, à long terme, les caractéristiques tant nationales que sectorielles du marché. Au niveau du secteur, le développement de la réforme dans les secteurs de l'énergie et des télécommunications suit une trajectoire similaire dans deux dimensions : l'accès au réseau et le contrôle des caractéristiques des produits. Contrairement aux secteurs des transports, les premières étapes de la régulation du marché dans ces industries ont été marquées par un effet comparativement plus important de l'accès au réseau et une influence comparativement moindre du contrôle des caractéristiques. Les différences entre le premier groupe (industries des télécommunications et de l'énergie) et les industries du transport se sont réduites ; toutefois, les deux groupes semblent converger à différents niveaux dans les deux dimensions. La période d'analyse s'étend de 1998 à 2018, et toutes les industries ont signalé une augmentation de l'accès au réseau et une diminution du contrôle des caractéristiques au cours de cette période. Bien que les premières disparités puissent avoir été causées par la variété des circonstances de départ de la réforme ainsi que par l'approche et les instruments européens utilisés pour

mettre en œuvre le changement dans chaque secteur, Geradin (2006) a constaté que, dans l'ensemble, la réforme a été un succès. Il est possible que les niveaux de convergence reflètent les différentes normes de service exigées par chaque secteur. Comparé au secteur du transport ferroviaire, le secteur du transport aérien semble évoluer vers un modèle libéralisé à un rythme plus rapide que celui observé dans le secteur du transport ferroviaire. Même lorsqu'on le compare aux secteurs des télécommunications et de l'énergie, le secteur du transport aérien a adopté la réglementation de l'accès et supprimé le contrôle caractéristique du marché plus rapidement. Cela s'explique par l'accent mis par le secteur sur la déréglementation. Ces changements correspondent à l'introduction de nouveaux modèles commerciaux dans le secteur (compagnies aériennes à bas prix et développement d'aéroports filiales), à une baisse persistante du prix des billets Fu et al. (2010), mais contrastent avec une hausse des redevances aéroportuaires (Wiltshire, 2018).

La propriété de l'État, en revanche, ne présente pas de grandes disparités sectorielles, contrairement aux deux autres dimensions. Au début de la période étudiée, tous les secteurs présentaient des niveaux d'influence de l'État beaucoup plus élevés qu'à la fin. Le contrôle exercé par l'État sur l'industrie du transport aérien au début de l'ère était nettement moins important qu'il ne l'est devenu par la suite (Nicoletti et al., 2000; Koske et al., 2016). La différence entre nos résultats et la progression de l'indice Réglementation des marchés de produits (RMP) de l'OCDE est visible dans le graphique A.17 de la section annexe. Selon leurs conclusions, le secteur où la participation de l'État est la plus élevée est le transport ferroviaire, tandis que le niveau de participation de l'État dans l'industrie des télécommunications est le plus faible au début de l'ère. Ces disparités peuvent être dues au fait que nos classements tiennent compte de la manière dont les gouvernements peuvent considérablement influencer les choix du plus grand opérateur historique. Contrairement au score de propriété de l'OCDE, qui affiche une mesure continue de la propriété gouvernementale, plus importante dans le secteur ferroviaire, notre technique de codage des données attribue le même poids aux entreprises, quel que soit le pourcentage de l'entreprise qu'elles détiennent la majorité des actions de la société (50,1% - 100%) ou rien du tout.

Nos dimensions et nos notations mettent également en lumière les grandes tendances de l'évolution du marché au niveau national. Contrairement au pouvoir de l'opérateur historique de définir les attributs du produit, les dispositions relatives à l'accès ne sont à l'origine des systèmes réglementaires que dans quatre pays. Il s'agit d'un groupe beaucoup plus petit que le nombre total de pays dotés de systèmes réglementaires. Les régimes des autres pays sont contrôlés par la puissante influence des opérateurs historiques étatiques ainsi que par la capacité substantielle de ces opérateurs à imposer des exigences distinctives aux biens et services disponibles sur le marché. En ce qui concerne l'évolution des régimes entre 1998 et 2018, les nations européennes membres de l'OCDE semblent s'être rapprochées des configurations favorables à la concurrence. Ces configurations se caractérisent par des niveaux plus élevés d'accès aux réseaux et des niveaux plus faibles de contrôle des caractéristiques et de propriété de l'État. D'autre part, les caractéristiques structurelles du régime réglementaire ne semblent pas être en mesure de prédire le type de développement dans la majorité des na-

tions qui composent notre échantillon. Par exemple, il ne semble pas que les régimes ayant une forte influence structurelle de la propriété de l'État ou du contrôle distinctif convergent plus rapidement ou plus lentement que les autres régimes. Il est possible que ces tendances à la convergence soient dues à d'autres caractéristiques nationales qui n'ont pas encore été détectées.

En outre, il existe un lien considérable entre nos mesures et le succès global de l'industrie. Une partie de nos découvertes sont conformes aux données du passé indiquant que les réformes du marché sont liées à une amélioration des performances dans de nombreux secteurs (Broughel and Hahn, 2022). Néanmoins, les résultats de notre recherche indiquent que des différences significatives peuvent être constatées entre les différents types d'entreprises. Il est possible que cela soit dû, du moins en partie, à des objectifs et des normes différents au sein du secteur. Bien qu'il semble que les réformes du marché dans les secteurs de l'énergie et des télécommunications aient mis en harmonie les performances du système, les objectifs de fiabilité du système et les limites physiques du système, les changements apportés dans les secteurs du transport, qui semblent être en contradiction avec les réglementations strictes en matière de sécurité pour les industries aéronautique et ferroviaire. Étant donné que des efforts supplémentaires pour promouvoir les changements de libéralisation pourraient potentiellement mettre en danger les normes de sécurité dans les opérations, ce conflit semble même restreindre le degré auquel les réformes du secteur des transports peuvent être mises en œuvre. Cet impact est particulièrement évident dans le secteur de l'aviation, qui est confronté à la possibilité que l'augmentation du trafic aérien entrave les opérations aéroportuaires et abaisse la barre des niveaux de sécurité acceptables (IATA, 2007).

Document 2 : Analyse comparative des régimes de gouvernance réglementaire dans l'OCDE

Le deuxième article fait quelques suggestions pour un système de codage qui pourrait être utilisé pour traduire l'enquête de l'OCDE sur la gouvernance des régulateurs en documents textuels. Ensuite, il utilise la modélisation thématique (Blei et al., 2003) sur les données codées afin de déterminer les caractéristiques de gouvernance qui coïncident et suggère ensuite la présence de quatre dimensions qui représentent les régimes de gouvernance des agences de régulation. De plus, l'analyse de régression démontre qu'il existe une relation considérable entre les indices résultants et le succès du secteur.

Notre recherche propose d'utiliser ces quatre variables indépendantes pour classer les différents types de systèmes de gouvernance :

- l'indépendance vis-à-vis du gouvernement
- le niveau de discrétion de l'agence de régulation (qui peut également être interprété en termes d'informalité de ses pouvoirs)
- la portée des capacités de surveillance du marché du régulateur
- la capacité et l'obligation de l'Agence de Régulation (AR) d'imposer la

transparence entre l'offre et les autres parties prenantes du jeu réglementaire, en particulier les autorités publiques et les utilisateurs.

Ces caractéristiques de la gouvernance réglementaire semblent intégrer, à long terme, des considérations sectorielles aussi bien que nationales. L'industrie de l'énergie et celle des communications électroniques reflètent toutes deux une logique de gouvernance réglementaire comparable au niveau sectoriel. Cela s'explique par le degré élevé d'indépendance et le faible pouvoir discrétionnaire des AR. Ces dernières bénéficient de capacités importantes pour encadrer le comportement des acteurs du marché, et depuis plusieurs années, elles ont étendu leur position de garant de la transparence. Les structures de régulation et de gouvernance des différents secteurs du transport sont distinctes les unes des autres. Les organismes de réglementation du secteur ferroviaire sont souvent tout aussi autonomes que leurs homologues des secteurs des communications électroniques et de l'électricité ; néanmoins, ils ont un statut moins formel et une délégation de responsabilité moins explicite que leurs homologues de ces autres industries. Cela est particulièrement vrai en ce qui concerne les AR responsables des aéroports, qui continuent de relever de la compétence du gouvernement.

Les structures institutionnelles qui contrôlent le statut des AR ont tendance à être assez différentes d'un pays à l'autre, et ces divergences semblent être là pour rester. Dans le même temps, on observe une tendance générale au développement de la fonction des AR en tant qu'agents de transparence, qui va de pair avec leur capacité à surveiller les marchés et l'économie des opérateurs. Cela va de pair avec le développement du rôle des AR en tant qu'agents d'ouverture.

En outre, des liens étroits peuvent être observés entre nos dimensions de gouvernance et de portée et le succès global de l'industrie, tant en termes de structure de ces dimensions que de leur développement. Cependant, il existe des différences significatives entre les différents secteurs, ce qui conduit à penser que la véritable fonction des régulateurs varie d'un secteur à l'autre. Cela peut être dû en partie à des différences de "maturité" étant donné qu'en Europe, la mise en place d'agences de régulation sectorielles indépendantes a commencé avec la libéralisation des marchés des télécommunications dans les années 1990, suivie par le secteur de l'énergie dix ans plus tard, et par les chemins de fer et les aéroports principalement à partir des années 2010. Aux États-Unis, ce processus a commencé avec la libéralisation des marchés financiers dans les années 1980. Les organismes de réglementation plus jeunes semblent avoir une tradition plus informelle et avoir accès à une boîte à outils plus limitée de mesures réglementaires. Étant donné que les régulateurs sectoriels travaillent dans des secteurs dont les économies sont très différentes les unes des autres, il n'est pas garanti qu'ils convergent vers un modèle commun. Dans le domaine des communications électroniques, il semble qu'un contrôle réglementaire efficace soit essentiel à la performance en termes de qualité du service fourni (large bande). En revanche, dans le secteur de l'électricité, la préoccupation première des AR semble être le coût de l'énergie, même si cela se fait au détriment de la qualité environnementale de l'énergie. Les secteurs du transport mettent de plus en plus l'accent sur le volume du trafic et sa croissance, ainsi que sur

l'amélioration de la sécurité.

Nos résultats, bien qu'ils soient quelque peu corroborés par les conclusions d'autres recherches qui ont cherché à établir une relation entre la gouvernance réglementaire et la performance, se distinguent de ces études antérieures pour deux raisons principales. Tout d'abord, nous souhaitons souligner à nouveau le fait que le degré de discrétion et de formalisation des pouvoirs de l'AR est un facteur important, malgré le fait que l'indépendance vis-à-vis du gouvernement ait déjà été reconnue comme un élément clé. En outre, nous soulignons le fait que les AR ont un rôle dans la promotion de l'ouverture en plus de la structuration des marchés et de l'établissement des tarifs. En outre, les innovations les plus importantes dans les cadres réglementaires au cours des dernières années en Europe ont porté sur deux aspects des régimes de gouvernance réglementaire qui sont souvent négligés : la discrétion / le formalisme et l'ouverture.

Document 3 : Impact des régimes de gouvernance réglementaire sur les énergies renouvelables : Une analyse empirique des agences nationales de régulation européennes de 2013 à 2018

Le troisième article examine l'effet que le système de gouvernance a sur les Agences de régulation nationale (ARN) européennes en termes de proportion de sources d'énergie renouvelables en analysant l'influence de quatre aspects : l'indépendance, la discrétion, la transparence et la portée de la surveillance du marché. Les années 2013 à 2018 servent de cible principale à notre enquête. Selon les résultats, il existe une relation inverse entre le degré de variabilité de la fraction d'énergie renouvelable et l'indépendance de l'ARN. En outre, nous sommes arrivés à la conclusion qu'il existe une relation inverse entre la transparence et les tarifs d'électricité pour les utilisateurs industriels.

Selon nos résultats, les régulateurs indépendants semblent être attachés à leurs exigences en matière de concurrence et d'efficacité, ce qui ralentit l'entrée des fournisseurs d'électricité verte à des niveaux efficaces. Cet effet suggère qu'une partie de l'impact positif de la libéralisation du marché dans la production d'électricité verte, comme la réduction des barrières à l'entrée des producteurs propres (Nicolli and Vona, 2019), pourrait être compensée par le régime de gouvernance actuel.

L'impact que l'atteinte de l'indépendance aura sur les objectifs fixés pour les énergies renouvelables à l'heure actuelle dépendra de l'analyse coûts-avantages de l'augmentation de la proportion d'énergies renouvelables. Nos conclusions impliquent que, pour les objectifs de 2020, les compromis dans la majorité des nations n'ont pas été assez sévères pour empêcher les gouvernements d'atteindre leurs objectifs climatiques. Cela est confirmé par le fait que l'UE a réussi à atteindre son objectif pour 2020. La Belgique, la Roumanie et la Slovénie restent proches de l'objectif (1%), tandis que la France et la Pologne étaient les pays les plus éloignés de leur objectif pour 2020 (plus de deux pour cent en dessous, Agence européenne pour l'environnement (2020)). Selon l'Agence européenne pour l'environnement (2020), 22 États membres ont atteint leur objectif pour

2020, la Roumanie et la Slovénie restent proches de l'objectif, et la Belgique reste proche de l'objectif.

L'idée que les régulateurs ont pour mission d'imposer la concurrence, de faire baisser les rentes des services publics anciennement détenus par l'État au profit des clients et d'améliorer les investissements, ce qui conduit finalement à la fiabilité, est la pierre angulaire de la thèse principale que nous exposons dans notre travail. Par conséquent, nous cherchons à savoir si les régimes de gouvernance sont liés ou non à une meilleure performance du secteur au cours de la période considérée. Selon les résultats présentés au tableau C.5 de l'annexe C, il existe une corrélation entre les régimes qui présentent une indépendance et une transparence remarquables et des coûts finaux plus faibles pour les consommateurs (le coefficient d'indépendance n'est toutefois pas significatif aux niveaux conventionnels). La corrélation entre les deux est évidente, malgré le fait que l'étude de tarification ne soit pas exhaustive. Les ARN qui sont plus indépendantes et transparentes (ce qui signifie qu'il y a une plus grande circulation de l'information de l'industrie vers le corps législatif comme une sorte de responsabilité) sont plus susceptibles d'adhérer à l'une de leurs missions les plus importantes, qui est de servir leurs clients à des tarifs moins chers.

La principale contribution de cette recherche est constituée de données quantitatives suggérant que l'adoption de sources d'énergie renouvelables dans le secteur électrique a chuté entre 2013 et 2018 en raison des régimes de gouvernance des ARN. À la fin, nous avons parlé de nos résultats et les avons comparés aux recherches précédentes dans le domaine. Nous avons découvert de nombreux éléments suggérant qu'il serait plus difficile de respecter les futurs engagements climatiques. En ce qui concerne les effets de la modification de l'exigence de l'ARN pour l'aligner sur l'expansion des sources d'énergie renouvelables, il existe encore des préoccupations non résolues.

Implications et Limites

Implications politiques

Les implications politiques de nos résultats sont examinées ici. Le questionnaire QER de l'OCDE a été collecté pour la réforme du marché entre 1998 et 2018 et les caractéristiques du régime réglementaire entre 2013 et 2018. Cette thèse privilégie la recherche exploratoire à l'investigation causale. Notre échantillon de nations européennes limite les implications politiques.

Les deux premières études ont examiné les réformes du marché dans 24 pays européens de l'OCDE. Les changements spécifiques à l'industrie et les structures de gouvernance varient considérablement. Les objectifs européens et les différences technologiques limitent la transformation de l'industrie. La libéralisation, la réforme et la mise en œuvre dans les transports ne doivent pas compromettre la sécurité (IATA, 2007). Les décideurs politiques doivent trouver un équilibre entre les objectifs politiques et les facteurs sectoriels lorsqu'ils créent une nouvelle législation nationale et européenne.

La troisième étude a examiné la gouvernance réglementaire et les proportions d'énergies renouvelables dans 24 pays européens de l'OCDE entre 2013 et 2018. Nous avons constaté que les régulateurs indépendants favorisent les marchés de mérite marginalistes, qui récompensent les centrales comme les sources hydroélectriques et de CO2 qui peuvent répartir l'électricité à tout moment. L'éolien et le solaire sont incompatibles avec de tels marchés. Cette incompatibilité a un impact sur la fiabilité du système, le prix pour le consommateur et les objectifs de décarbonisation. Les producteurs d'énergie renouvelable obtiennent des subventions opérationnelles payées par les utilisateurs grâce à l'ouverture. Les opérateurs de systèmes doivent gérer davantage d'énergie renouvelable pour garantir la stabilité. Les autorités doivent donc trouver un équilibre entre la libéralisation, la tarification de l'électricité et la décarbonisation. Si la part des énergies renouvelables augmente, l'indépendance (qui profite aux consommateurs et à l'efficacité du marché) peut entrer en conflit avec les sources d'énergie renouvelables. Les responsables politiques doivent également évaluer les modalités de gouvernance et les objectifs des réseaux électriques nationaux et européens.

Limites de la recherche

De nombreux éléments peuvent limiter cette recherche de thèse. Cette section décrit ces contraintes. Nous n'avons aucune raison de croire que ces limites mettront en doute nos résultats, mais nous ne pouvons pas l'exclure. L'endogénéité et les ensembles de données contraignants peuvent limiter la recherche de cette thèse.

Contraintes de données

La durée des études constitue la première limite. Notre ensemble de données sur la réglementation du marché s'étend sur cinq années (1998, 2003, 2008, 2013 et 2018). Les intervalles d'enquête restreignent les observations. Nous avons fait correspondre nos mesures à des indices de réforme annuels et à des indicateurs de qualité institutionnelle pour remédier à cette restriction. Nous avons comparé nos tendances à d'autres recherches et constaté que la quantité d'observations n'affecterait pas nos résultats. La qualité des données est un autre problème. Le QER de l'OCDE analyse les systèmes de réglementation et de gouvernance tous les cinq ans. Des fonctionnaires nationaux désignés par le gouvernement remplissent les enquêtes. La personne qui répond peut réagir en fonction de sa propre interprétation (contextuelle) du sondage, et les réponses peuvent représenter un point de vue national sur la réforme plutôt qu'une évaluation "juste" des conditions du pays. L'enquête REQ de l'OCDE aide les EM à fournir les informations pertinentes, et elle offre une technique de validation ex-post qui compare les réponses des pays à d'autres sources officielles (Vitale et al., 2020). Ainsi, nous pensons que les données de l'OCDE soutiennent les changements actuels et l'identification des dimensions.

Notre ensemble de données manque de deux caractéristiques cruciales des corrélations entre réglementation / gouvernance et performance industrielle.

Premièrement, nous négligeons les systèmes informels de réglementation et de gouvernance des marchés. Les développements de marché qui nécessitent des règles explicites pour encourager la concurrence et les échanges commerciaux sont moins critiques (Glachant, 2021). Cependant, les modèles de gouvernance réglementaire mettent l'accent sur les pratiques informelles ou de facto. L' indépendance des régulateurs est importante. Les dispositions légales d'indépendance peuvent impliquer une protection, mais la capacité du régulateur à utiliser ses pouvoirs sur la base de son propre jugement détermine l'indépendance dans la pratique (Maggetti, 2007). Notre métrique formelle montre que les deux formes d'indépendance sont positivement corrélées. D'autres caractéristiques des pays expliquent l'indépendance de facto (Koop and Hanretty, 2018) (le cycle de vie des agences, les acteurs du veto et les réseaux européens d'agences). Nos modèles économétriques corrigent ces facteurs en intégrant des mesures de qualité institutionnelle et plusieurs effets fixes. Deuxièmement, nous ne pouvons pas visualiser ou évaluer les mandats des régulateurs, qui dictent les activités quotidiennes de l'agence. Cette composante manquante nous empêche de faire la distinction entre les dimensions de notre régime de gouvernance et les mandats ou objectifs du régulateur. Cette distinction est cruciale pour déterminer si les régulateurs sectoriels suivent les directives européennes ou les agendas nationaux.

Notre troisième analyse ne tient pas compte des subventions totales que chaque gouvernement verserait pour promouvoir les énergies renouvelables. Bien qu'elle ne soit pas liée à l'indépendance, cette variable peut fausser nos estimations en raison du biais de la variable omise. Nous avons utilisé des indicateurs de soutien politique issus de la littérature pour tenir compte de cette variable. Nos tests montrent que la variable politique que nous avons créée— le nombre total d'années pendant lesquelles les programmes d'aide aux énergies renouvelables sont en vigueur —capte le soutien politique à l'électricité renouvelable. La quantité de programmes d'énergies renouvelables et les dépenses publiques en pourcentage des dépenses globales ne sont pas des facteurs significatifs.

Endogénéité

Nos trois enquêtes recherchent des liens substantiels entre les caractéristiques estimées de la réglementation et de la gouvernance et les performances de l'industrie qui devraient être étudiées plus avant. Notre étude a des limites, même si nous ne prouvons pas la causalité. Des recherches antérieures, notamment celles portant sur les implications macroéconomiques des changements, complètent nos résultats. Nos approches économétriques vont dans ce sens. La première recherche utilise des moindres carrés ordinaires (MCO) dynamiques avec des effets individuels et temporels fixes. Les disparités de tradition institutionnelle, régionale et juridique sont contrôlées par notre méthode. Nous ne tenons pas compte des variables non observées qui varient dans le temps, notamment les objectifs de la politique nationale, les informations sur le cycle macroéconomique et d'autres changements susceptibles d'affecter le progrès des réformes et le succès de l'industrie. La deuxième étude utilise la régression linéaire pour évaluer la relation entre la moyenne des dimensions de gouvernance et les taux de croissance et les variables de résultat. Nous appliquons un

large éventail de variables spécifiques à l'industrie basées sur la littérature, mais comme la recherche précédente, nous ne contrôlons pas les objectifs réglementaires, les avancées techniques ou les impacts de la spécialisation de l'industrie en raison de problèmes de disponibilité des données.

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La troisième recherche examine l'indépendance réglementaire et les énergies renouvelables dans 24 pays européens de l'OCDE. Après avoir corrigé les divers déterminants de la performance en matière d'énergies renouvelables issus de la littérature, il est à craindre que les variables d'efficacité institutionnelle influencent nos notes en matière de réglementation et de gouvernance, tout comme nos notes influencent nos évaluations de la qualité des institutions. Nous examinons la sensibilité de nos estimations aux indicateurs d'efficacité institutionnelle, notamment la protection des droits de propriété et la prévention de la corruption. La causalité inverse pourrait également remettre en question nos estimations. L'énergie renouvelable peut symboliser la force de lobbying des producteurs d'énergie renouvelable pour influencer les améliorations en matière de réglementation et de gouvernance. Notre ensemble de données manque d'une variable liée à la gouvernance, donc nous ne pouvons pas utiliser une technique IV pour analyser ce problème. Pollitt (2019) montre déjà que le modèle de marché de l'électricité libéralisé est en conflit avec les objectifs de décarbonisation, nous sommes donc confiants quant à la direction de nos estimations.

Implications pour la recherche

Enfin, nous discutons des directions de recherche possibles. Développements méthodologiques et empiriques. Les deux premières recherches sur la TALN ont codé et résumé les données d'enquête. Malgré les méthodes, une vérification humaine du processus de codage était nécessaire. Les quelques mots /concepts de l'enquête ont permis la vérification. Les enquêtes dont le vocabulaire est vaste ou étendu peuvent être plus difficiles à évaluer. Lorsque les termes sont nombreux, d'autres méthodes de codage des données d'enquête peuvent être utilisées.

Nous analysons d'abord deux relations. Selon la littérature, les industries d'État sont moins performantes que les entreprises privées en raison d'un manque de pression pour améliorer les approches organisationnelles et techniques. Les découvertes en matière d'énergie et de télécommunications appuient la littérature. La propriété de l'État augmente le trafic aérien. L'accès au réseau affecte le coût de l'énergie et des télécommunications. Comme dans le secteur de l'énergie, l'accès au réseau accroît la concurrence et l'efficacité allocative, ce qui fait baisser les prix. La corrélation positive des télécommunications soulève la question de savoir si elle est due à une variation non observée ou au fait que les investisseurs profitent du coût des clients. Les corrélations du contrôle des caractéristiques des produits avec les paramètres du trafic de transport diffèrent

pour le trafic de passagers aériens et le trafic de marchandises. La cause du conflit d'association doit être étudiée plus avant. Les résultats peuvent éclairer l'influence des réformes sur diverses industries.

La deuxième analyse montre que les priorités réglementaires varient. Les autorités de transport mettent l'accent sur la sécurité, tandis que les régulateurs de l'énergie et des télécommunications préfèrent l'efficacité du marché. Notre modèle économétrique n'inclut pas de variables permettant de suivre les objectifs des politiques nationales. Ainsi, des extensions pour analyser de tels traits peuvent nous aider à comprendre les régimes de gouvernance et leurs objectifs.

L'étude finale établit un lien entre l'indépendance réglementaire du gouvernement et la production d'énergie renouvelable. Deux approches pour élargir l'étude. Premièrement, découvrir des candidats d'instruments métriques d' indépendance. Cela semble être la meilleure façon de traiter tout problème d'endogénéité étant donné les données. Selon un argument de difussion de la gouvernance réglementaire (Levi-Faur, 2005), la réforme du transport ferroviaire ou aérien peut être une variable instrumentale utile. D'autres déterminants formels de l'indépendance pourraient également être des instruments. Les caractéristiques nationales peuvent affecter le succès de l'industrie. Les résultats peuvent également susciter un débat sur la libéralisation du marché, l'efficacité et les objectifs environnementaux. Si des frictions apparaissent à tous les niveaux du partage des énergies renouvelables, un changement de paradigme de gouvernance pourrait être nécessaire pour les résoudre. L'Europe a atteint ses objectifs de décarbonisation pour 2020 et 2021. La proportion européenne moyenne d'énergies renouvelables est de 9 à 10%. (selon la méthode de calcul). Cette moyenne implique que la conception du marché, la fiabilité et les tensions liées aux énergies renouvelables n'ont pas nui au marché ou aux objectifs environnementaux des EM. Les tensions augmentent et leurs solutions ne sont pas prouvées. Pour la deuxième question, Bartle and Vass (2007) examinent les moyens d'adapter le "paradigme du régulateur indépendant" à la décarbonisation. Une étude empirique devrait évaluer les impacts environnementaux de ces réformes de la législation et de la gouvernance.

Chapter 1

Introduction

My doctoral research, presented in this dissertation, uses novel reform metrics to assess market reforms in European network industries (such as energy, gas, telecommunications, air, and rail transport). My interest in institutional reforms and their effects on economic performance in highly political environments, as well as my interest in natural language processing techniques and their potential applications to economics and management issues, served as the inspiration for this work. Chapter 3, Chapter 4, and Chapter 5 focus on the three distinct but related studies in a three-paper format. There are four sections to this introduction. We start by looking at the driving forces behind the European reform of network industries in Section 1.1. The reform and the complexity of summarizing its characteristics are briefly explained in Section 1.2. Section 1.3 discusses the connections between the dissertation papers. Finally, the papers' contributions to the existing body of literature are presented in Section 1.4.

1.1 Motivations for the reform

There are many motivations for why network industries were structured as state monopolies. In exchange for exclusive rights, governments had access to the financial resources necessary to make investments in assets that were highly specialized and difficult to redeploy. Monopoly rents could be passed on to customers through the provision of high-quality services and the imposition of a "public service obligation" in less profitable areas. But perhaps most crucially, this was because state monopolies are extremely valuable from a strategic and economic perspective. To begin, having a powerful state incumbent was important for strategic reasons. This allowed governments to maintain control over critical infrastructure during unexpected shocks such as wars or natural disasters. Second, the integrated firm was economically significant to the extent that their operations frequently involved the employment of considerable shares of the working population and that their operations affected a significant portion of the GDP (Geradin, 2006).

By the late 1970s, however, new political, economic, and technological fac-

tors began to undercut the idea that network industries required state operation and vertically integrated monopolies. These factors included ideological motivations, challenges with vertically integrated system efficacy, and advances in information and communication technologies (Newbery, 1999). Furthermore, academics, consumers, and large manufacturing firms (involved in intense international competition) campaigned for improvements in network industry operations. Economists began to argue that not all network industry segments had inherent monopoly characteristics and that certain areas were contestable. For example, whereas transmission infrastructure cannot be replicated by prospective new players, generation and retail services may be opened to competition because of low entry costs. Consumer groups also expressed dissatisfaction with the performance of network industry services (high prices and poor quality). At the same time, large manufacturing enterprises that faced fierce global competition in manufacturing industries demanded that their input prices (electricity, gas, and transportation) be reduced. If these industries wanted to compete effectively (in a globalized economy), they had to decrease their costs.

To respond to reform claims and in light of previous reforms in the United States, Chile, and the United Kingdom, the EU attempted to reform their network industries to increase operational and economic efficiency, secure long-run service supply, shift investment risks to the private sector, and provide higher-quality services to customers. Furthermore, rapid technological advancements, along with the desire to overcome weak regulation, prompted European governments to engage in the industry change.

1.2 The reform and its measurement

Europe's network industries are being transformed as part of broader plans to attain a single liberalized market. From the point of view of implementing the European single market, the two most important changes to the sector are the liberalization of the market and the introduction of a single regulatory framework.

Opening up the market, also known as "liberalization," entailed a series of procedures designed to introduce competition into industry segments previously dominated by a vertically integrated monopoly. Reform activities can be divided into three categories. Vertical monopoly unbundling, removal of competitive barriers, and increasing industrial separation from the state In a competitive market with a dominant network, vertical integration increased the possibility that an incumbent would discriminate between its downstream operations and those of its competitors. Vertical integration mitigation actions attempt to disconnect the integrated business structure and, if possible, outsource network administration to an independent system operator. Second, to fully benefit from competition, liberalization initiatives seek to remove barriers (abolish exclusive rights) that restrict companies' entry or exit. Third, while there is no conceptual relationship between liberalization and privatization because the former refers to market opening measures while the latter refers to the sale of public assets, there was a view that when rivals are private, liberalization (and competition) could cause an efficient resource allocation (Newbery, 1994). As a result, considerable

efforts to sell public assets have been made; nevertheless, these moves differ greatly between sectors and industries.

To accomplish these actions, European member states constructed (and are still constructing) a uniform regulatory framework through a succession of Directives and Regulations (a more extensive overview is provided in Chapter 2). The legislative framework contains rules requiring governments to establish independent regulatory agencies [1]. In a liberalized market, regulatory interventions by independent agencies should ensure fair competition between incumbents and new entrants. These agencies must be independent not merely of market participants but also of the government (the latter generally has a stake or an economic interest in the incumbent). The "independent regulatory agency" model was introduced following the United States model and emphasized the agency's decision-making autonomy protection while providing sufficient resources to carry out its primary goal, which was to implement competition [2].

Many of the previously discussed market reform aspects are difficult to measure in particular units. As a result, it is impossible to compare the state and development of changes across countries and sectors without a robust approach. To capture the diverse facets of market transformation, a substantial body of work has relied on survey data (Nicoletti et al., 2000; Koske et al., 2015; Bouis et al., 2016). The number of reform characteristics varies between studies, reflecting the reform's multifaceted nature. Even if an analyst can capture many reform elements, the criteria used to summarize and select the most important elements are critical for conducting a "reasonable" assessment of reforms. Inappropriate aggregation methods can influence the results by including the analyst's ideological bias in the estimates. This study acknowledges the difficulties in measuring institutions and proposes an alternative method for determining the degree and depth of transformation. We estimate summary scores by recoding survey data and using word count-based topic modeling approaches (Blei et al., 2003). Furthermore, our approach identifies key components of the reform and enables comparison across countries, sectors, and time.

1.3 Structure of the dissertation

The dissertation is organized into three distinct but related studies. The three studies use country and time variation to assess market reform progress. The reform's success or failure is not evaluated by any of the three studies, which rely on quantitative indicators to judge institutional progress. In addition, the three studies apply a New Institutional Economics (NIE) framework to understand disparities in the reform's levels and speed of implementation across industries and nations. Within an NIE framework (North, 1990), baseline conditions (such as geography, wealth, technology level, and political climate, among others) are crucial for the status and progress of reforms. Our research examines market

[1] Their initial roles were related to pricing control and quality of service regulation under the monopoly system (which were commonly carried out by a ministerial department).

[2] Agencies or regulators are given additional mandates, i.e., guarantee security of supply, consumer satisfaction, and environmental sustainability

reforms using a group of countries from the same region (OECD European member states) to better distinguish the reform's impacts from other causes of institutional change, such as regional development differences.

Despite their parallels, the studies vary in the reform aspects explored, the methods employed, the time frame examined, and the results. The first study assesses the development of the regulatory change and the potential connections between the reform and the performance of the energy, telecommunications, and transportation industries (rail and air). The second article assesses the implementation of the "independent regulator model" as a separate part of the regulatory reform process. The third article examines the regulatory governance of the electricity sector and its implications for the European Union's decarbonization goals.

The first and second studies examine market reform, but they differ in their focus. The first article examines the progress of privatization and competition in the network industries, while the second paper assesses the implementation of the "independent regulator mode" as the governance model that monitors, steers, and enforces competition. The distinction is made to analyze the development of sector transformation (i.e., the introduction of competition and network access regulation) and the regulator's governance features individually. The findings of the first article concentrate on the reform area: *state ownership*, *network access*, and *product/service characteristics control*. In contrast, the second article defines the regulator's governance in terms of its relationship with the state (*independence from the government* and *discretion*) as well as the means available to achieve its objectives/ mandates (*scope of market monitoring* and *transparency* tools). The coding approach used in the papers also differs. The first study employs automated techniques applied to the Organization of Economic Cooperation and Development Regulatory Inquiry Questionnaire survey (hereafter OECD RIQ) (Nicoletti et al., 2000) to extract and discretize its main textual/semantic properties. The technique accounts for major variances in concepts/terms between industries and survey updates over time. The results of the second article are based on a data coding technique that identifies governance characteristics and institutional actors associated with them. This coding scheme is useful to compare homogeneous sectoral characteristics, as in the case of regulatory governance. The studies also differ in their investigation period due to data coverage issues; the first paper examines reforms in network industries from 1998 to 2018 [3]. The second paper examines the governance of regulators between 2013 and 2018 [4]. The discrepancies in analysis periods impact the methodology used to assess potential links between the reform and industry performance. The first paper uses time variation and employs a two-way fixed-effects dynamic OLS estimator, whereas the second uses score averages and growth rates from 2013 to 2018 to uncover probable correlations.

The third study partially overlaps with the second paper in two ways: both examine the governance of the energy sector and its repercussions from 2013 to 2018. Their approaches, however, are dissimilar. The second paper ana-

[3] Starting from 1998, every five years, the OECD examines the regulatory reform's progress through the RIQ survey

[4] In 2013, the OECD included regulatory governance questions in the OECD RIQ. The governance questionnaire update follows the same calendar as the OECD RIQ

lyzes the reform's development and its consequences for industry performance, while the third paper delves further into regulatory governance features and their connections with decarbonization in the European Union (EU). The third study uses a two-way fixed effect panel data model to reduce any individual and temporal effects in order to determine a causal link between governance characteristics and decarbonization. The third paper confirms the second paper's findings, demonstrating that independent electricity regulators favor the current market paradigm, centered on central CO2-based sources, at the expense of decarbonization.

1.4 Contributions to the existing literature

Even though the initial reform began more than 30 years ago, a full examination of the reform's success and consequences is required, particularly in light of the new issues that European network industries are already experiencing, such as decarbonization and energy security. Several empirical studies have evaluated the reform's development in several dimensions (entry, price control, and vertical integration) by developing summary indexes and sub-indexes (Nicoletti et al., 2000). The measurement precision of these indexes and subindices is limited because, first, the reform's aspects /dimensions utilized to summarize qualitative information are either based on expert considerations or the institution's political preferences; and second, the qualitative information aggregation methods rely on arbitrary weighting schemes given the chosen aspects. Nicoletti and Scarpetta (2003), Hanretty et al. (2012), and Jordana et al. (2018) employ latent factor techniques to estimate the significance of reform characteristics within each aspect /dimension. However, no data-driven approaches have been applied to identifying the reform features in network industries so far. Data-driven factors may provide fresh insights into measuring the reform's progress and, more importantly, assessing the reform's implications. Using natural language processing (NLP) approaches (coding methodologies and topic modeling) and survey data, this dissertation seeks to address this gap. This is the first attempt of its kind in the empirical literature on network industries.

The first study assesses the progress of market reform in the electricity, gas, telecommunications, air, and rail industries. The study attempts to answer the following questions: i) Can alternative dimensions characterize market reforms in network industries? ii) If various reform dimensions are relevant to describe the reform, does their evolution reflect convergence toward a single market regulation model, or do national and sectoral disparities emerge? iii) Do alternative dimensions affect industrial performance? Are the implications consistent across industries? The second article focuses on implementing the "independent regulator model" in the energy, telecommunications, air, and rail industries and aims to investigate: i) Could alternative dimensions describe regulatory governance arrangements? ii) Are the alternative aspects/dimensions' progress uniform, or do they vary among countries and / or sectors? iii) Are the alternative dimensions related to industry performance? Are the connections similar across sectors? The third study investigates the (possible causal) relationships between regulatory governance aspects / dimensions and the electricity

sector's performance. The research seeks to answer the following questions: i) Do various regulatory governance features influence electricity generation (the electricity fuel mix)? If so, are the associations positive or negative? iii) Does the governance reform promote or impede the decarbonization of the European Union's electricity systems? iv) Does regulatory governance influence electricity prices? If so, are the associations positive or negative?

The thesis papers propose unique reform metrics and examine market regulation in 24 European OECD nations in the power, gas, telecommunications, air, and rail transportation sectors. Besides their importance for the European economy, these sectors have experienced significant degrees of market reform despite the significant differences in their technological and institutional structures. Moreover, our study's nations and sectors record substantial proportions of complete data in the OECD RIQ survey, minimizing the influence of missing data in our analysis. Our estimates for reform aspects /dimension measurements are based on the status and progress of market reforms. No single dimension completely defines the status or development of reform in a specific country or sector. While our aspects and estimates partially differ from the scores produced by similar studies (e.g., Nicoletti et al. (2000),Wölfl et al. (2009)), we acknowledge that our aspects / dimensions show convergence to an "ideal" model. Our estimations do not account for whether a country/sector has successfully or unsuccessfully implemented reform, and we make no attempt to benchmark sectors and countries. We aim to uncover new dimensions and test their relevance for further empirical studies. [5]

The thesis is structured as follows. Chapter 2 briefly summarizes the reform progress, the metrics used to track its evolution, and the potential issues with the current measures. Chapter 3, Chapter 4, and Chapter 5 present the first, second, and third papers, respectively. Chapter 6 concludes with policy implications and the main findings of the three papers.

[5]For interpretation and graphical representation purposes, our raw estimates (0-1) are normalized (mean = 0, variance = 1)

Chapter 2

The measurement of regulation and governance in network industries

2.1 Motivation

The role of institutions in the everyday activities of a society cannot be understated. Institutions are responsible for setting the game's rules, which govern the structure of incentives accessible to (economic) agents and affect their behavior. Institutions not only limit individual behavior (North, 1990); they also direct the activity of enterprises, labor organizations, and governments. If institutions can drive agents' interactions in a society, particularly in an economy, discrepancies in institutions should reflect variations in the functioning of such societies. According to Acemoglu et al. (2001), institutions explain a large share of long-run wealth discrepancies between countries. Disparities in social (and economic) performance raise concerns, first regarding the state and development of reforms: what institutions remain, why they remain, what is replaced, and to what extent current institutions affect implementations and implementations change institutions (Loasby, 1993). Second, inquiries concerning the relationships between institutions and performance, as well as what institutional changes should be undertaken to achieve specific goals.

Researchers, governments, and international organizations attempt to address these concerns by comparing diverse institutional frameworks, yet, comparing them necessitates contrasting their numerous qualities. Quantitative metrics provide a tractable approach to capturing the most significant qualities of institutions and changes and synthesizing them into a smaller number of elements. These summaries make it possible to compare the state and evolution of institutions across countries, regions, and industries. Contrasted to outcome indicators, these comparisons not only disclose features of how institutions evolve over time but also provide insight into whether institutions and reforms can achieve their intended aims. Given their importance, officials and politicians

are interested in these metrics since they are used as references for formulating policy objectives and devising appropriate policies for a certain situation (OECD, 2008). Furthermore, individuals and academics are interested in the metrics because they can hold governments accountable by determining whether reforms are implemented and relevant to their interests. Overall, quantitative indices enable us to learn about market reforms, assess whether reforms are one-size-fits-all approaches, and comprehend how national /institutional contexts influence the extent, pace, and specificities of market changes.

Among the recent institutional changes, the application of liberal policies and, in particular, market liberalization, has had a significant impact on the economic performance of countries, industries, and citizens; market liberalization has been the subject of empirical literature. Liberal policies, which advocate for the implementation of competition and the reduction /elimination of all possible distortions to competition, dramatically impact productivity and consumer welfare (Djankov et al., 2006). Countries worldwide have significantly opened their markets to national and international competition, removed entry barriers, and decreased tariff and non-tariff barriers to trade. Evidence of the market opening is the increase in the cross-border exchange of products and services between all regions of the world during the last 30 years (World Trade Organization, 2019). The scope of liberalization extended to utilities and sectors where competition was previously thought to be impossible (Newbery, 1999).

The liberal paradigm, combined with consumer pressure for superior service quality, industry demand for lower manufacturing costs, and technological innovation opportunities, increased support for restructuring utilities and transportation sectors previously operated by vertically integrated (state) "champions". As a response to the political environment, the European Union has pushed the liberalization of national markets as a previous and necessary step to construct a continental-scale integrated market, which aims to *deliver real choice for all consumers of the European Union, be they citizens or businesses, new business opportunities, and more cross-border trade, to achieve efficiency gains, competitive prices, and higher standards of service, and to contribute to the security of supply and sustainability (Directive EC/72/2009)*. Since the late 1980s, the European network industries have experienced significant transformation. While each network industry has its own technical characteristics that require its own liberalization process, the reform aimed at the implementation of four transformative steps: i) market opening in segments where competition was possible), ii) separation of the integrated monopoly, iii) privatization of the government's monopoly; and iv) the delegation of regulatory tasks to independent regulatory agencies.

The European reform process offers a particular opportunity to evaluate the extent and impact of the reform and its implications, because while the industry restructuring has been designed and enforced at a continental scale (EU Directives, Regulations), the implementation is far from homogeneous across sectors and member states. The strong national legislative, operational, and regulatory powers have determined the differences in the observed reform progress (Conway et al., 2005; OECD, 2016) [1]. In particular, the work by Nicoletti et al. (2000),

[1]For a reference, see Glachant (2021). The author explains how the EU used its different legal

Alesina et al. (2005), or Vitale et al. (2020) document national and sectoral differences in the European reform implementation. These differences have been widely used in the literature (see Broughel and Hahn (2022) for a summary) to evaluate the determinants of the reform differences across member states and industries and to evaluate whether the reforms have impacts on the performance of industries. The literature shows that liberalization positively affects industry efficiency, investments, and growth. However, beyond the macroeconomic effects of the reform, other implications and aspects related to the impact on prices, service quality, and environmental effects remain undisputed.

In part, the current empirical literature presents caveats that limit their usage in reform evaluation. In particular, current methods used to produce summary indicators present issues that condition the measure's validity and interpretation. First, the indicators follow a theoretical / conceptual framework to determine the important attributes to consider in market reforms. This theoretical / conceptual lens could drive us to arbitrarily include and exclude reform characteristics that threaten to bias the aggregated indexes and reflect our political or ideological view. This issue is explained by Arruñada (2007), who points out that pro-reform indexes tend to limit / restrict the importance of legal instruments that impact industry performance but are claimed to increase entry barriers (as in the case of business registries). For instance, following the idea that regulation is the outcome of a bargaining process between private firms and strategic politicians (Stigler, 1971), the World Bank has developed market reform indicators that focus on the removal of entry barriers, i.e., the Doing Business indicators [2] designed indicators that contrast economies and industries with a competitive market paradigm. Then the contrasts are used to rank countries. Similarly, the OECD produces the Product Market Regulation scores that focus on the reform policy objectives, i.e., a decrease of entry barriers, vertical separation of the integrated incumbent, government involvement, market structure, and price controls. The second source of bias comes from the methods used to estimate the importance of the reform characteristics. The characteristic importance can be either imposed or estimated. Each alternative presents problems. When weights are arbitrarily chosen, the resulting metric might reflect our subjective criteria about the (national) institutional environment and not the "true" extent of the (industry) reform. New methods seem effective in reducing political and ideological bias and arbitrary weighting issues by allowing the data set structure to determine the characteristics' importance. However, these new methods (usually based on factor analysis) also present problems; the methods rely on stringent distributional assumptions and do not fully support time comparisons, especially when surveys that track reform progress change over time.

In this context, this chapter describes the European reform progress and the instruments used for its implementation in Section 2.2. The description aims to highlight the various characteristics of market reforms, their similarities,

instruments (Directives and Regulations) and other European institutions (ACER, ENTSO-E) strategically to implement the necessary actions to establish a single integrated electricity market.

[2] Recently, these indicators have been contested because they focus on ranking countries according to a liberal fully competitive market paradigm and not necessarily the indicators attempted to evaluate reforms.

and differences between sectors (electricity, gas, telecommunications, air, and rail industries). We distinguish between the market opening reform / vertical separation of the monopoly and the implementation of independent regulators. Section 2.3 discusses the problems of producing aggregated indexes and their potential issues to measure reforms that motivated this dissertation.

2.2 Reform in network industries

In this section, we define the core terms used in this chapter and the doctoral dissertation. Second, we present a summary of the implementation and progress of market reform in the electricity, gas, telecommunications, air, and rail transport industries. Our objective is to present the multidimensional aspects of reforms, the common framework that steers the liberalization process in Europe (the European Directives and Regulations), and their similarities and differences across sectors.

2.2.1 Considerations

First, we must define the network industry. According to Newbery (1999), network industries are public utilities that rely on a (fixed) network to offer their services. The networks are permanent assets with significant sunk costs that yield economic rents (they are easily re-deployable for other purposes). The transmission lines, the telecommunication wires, and the rail tracks are examples of such networks in the electricity, telecommunications, and rail transport industries, respectively. Once the investments are made, the rent-negotiating advantage shifts from the investor(s) to the customers. These clients are numerous, politically significant, and have no option but to use the network. Investors and consumers have competing interests in this situation. Investors want to maximize their returns, while customers want high-quality services at reasonable prices. *Liberalization / market reform* (terms that will be used interchangeably along the dissertation) are the chosen institutions to balance the interests and powers of both investors and consumers. The reform aims to increase competition in industries, particularly in segments with lower entry costs, at least when compared to network entry costs. For instance, in the electricity sector, generation and retail services' entry costs allow many firms to compete in the market. Thus, the first step in the reform is to open markets where possible. *Market opening* refers to the actions aimed at constructing a market, which include the removal of entry barriers (technical requirements, legal protection for incumbent firms), and particular forms of price controls. Also, *market opening* refers to the regulatory provisions to construct those markets, which are based on their technical industry particularities. This is particularly evident in the electricity sector, where several markets (the electricity and the capacity markets) have been implemented to cope with electricity's physical characteristics [3]. Due to the high entry costs, the operation of the network is considered a

[3]Electricity is non-storable and non-monitorable. These two characteristics demand that countries either use generation sources that produce electricity continuously (hydroelectric, CO2 intensive) to meet their electricity needs (that are costly to forecast) or use intermittent

natural monopoly, i.e., only one firm serves the market efficiently. This natural monopoly characteristic calls for regulation to profit from the benefits of competition in other segments. The *access regulation to the core network* refers to the provisions that create separation between the industry segments and the network (vertical separation) to prevent the network owner from exploiting its incumbent's advantage and avoid the network owner's potential discriminatory treatment of particular firms in other segments. A final aspect of *liberalization* is the call for *privatization* of the industry's assets. *Privatization* refers to the actions that aim to shift the governing power of the state towards the private sector. Such actions might include the increase of managerial freedom in state-owned firms or the sale of the company.

2.2.2 Progress of market reforms

The European Union (hereinafter EU) legally began reforming its network sectors with the Single Act of 1986, following the successful liberalization experiences of the United States in the 1970s, Chile in the early 1980s, and the United Kingdom in the late 1980s. The network industry reform was a component of a larger restructuring aimed at creating a single market. Initially, the broad reform pushed for lower customs tariffs and unrestricted mobility of capital, services, and people. The European Union wanted to create competition in network industries in order to increase cost-effectiveness, service quality, and reliability. However, unlike the United States, which has federal authorities with broad powers to execute change, the EU's reform implementation strategy had to be adapted to deal with the member states' broad national regulatory powers. The European Union began the reform process with Directives and Regulations. Directives are critical for network industry reform because they establish targets that member states must meet. However, each member state can develop its own laws and strategies to attain such goals (transposition). The level of reform varies among countries in part due to the implementation approach that each country employs. The EU uses regulations as an alternative legislative tool. Regulations are legally binding acts that *must* be strictly enforced throughout the EU. In other words, the legislative text in an EU Regulation becomes part of national legislation [4]. Because both tools have transformative power, the reform summary below focuses on both legal instruments.

Various substantial changes in the organization of network industries, as well as market structures, have come from liberalization. The reform centered on reducing legislative barriers to entry in industries and establishing well-functioning markets (Joskow, 2009). Three of these shifts are: i) market liberalization and increased competition, ii) vertical unbundling of infrastructure and services, and iii) the growing detachment of the state from these businesses [5] (Geradin, 2006). The three disruptive actions are designed to create

sources (such as solar / wind) with the opportunity to access continuous sources in case of unexpected changes of demand

[4] Glachant (2021) the EU has used other legislation tools (Decisions or Recommendations) and other soft power tools (the work of DG Energy, DG competition, ACER, ENTSO-E) to implement the single market in electricity. Although we acknowledge the influence of such legislative tools, Directives, and Regulations focus on the core aspects of reforms

[5] While the previous two actions have been ruled upon in Directives and Regulations, the

efficiency through competition. First, the reduction of entry / exit obstacles and ineffective regulation allows new enterprises to enter the market. When there are several enterprises in the market, competition distinguishes between efficient and inefficient firms (Alesina et al., 2005; Égert, 2009; Égert, 2018). In the long run, only cost-effective enterprises serve the market; competition dissipates the monopoly rents that are now passed on to consumers by lowering service prices and/or boosting service quality. The introduction of competition, however, does not have the same results in all industry segments. The network's natural monopoly features limit the number of enterprises that can serve the market efficiently to one. In this situation, access to the core network of natural monopoly services is critical for enterprises to compete in their marketplaces and for society to benefit from the efficiency advantages gained from the competitive market model. Before the start of the liberalization process, services were provided by state-owned, vertically integrated monopolies that controlled the production, transmission / distribution, and retail components. The state-owned enterprises were also in charge of operating and investing in the network that linked the industry's components. Segmentation aims to separate manufacturing, network (transmission / distribution), and retail operations into distinct divisions. This division focuses on autonomous network operation and network access regulation. The division is important for competition since it ensures "fair" access conditions for all competing companies in all sectors, including state-owned incumbents in the remaining competitive segments. The "fair" access prevents network operator discrimination that can manifest in several ways, such as denying downstream competitors access to the network, decreasing the quality of the access services offered to downstream competitors, and charging downstream competitors a higher rate for network access, among others. Finally, the increasing separation of the state (privatization) has altered the structure of industries. Privatization is thought to be inherently compatible with competition (Newbery, 1999) since private management's incentives to maximize stakeholder value, including incentives to implement efficient practices within the firm, are thought to promote cost-efficiency in a competitive setting. In contrast to the previous two modifications, the EU is agnostic regarding business ownership and has not ruled on any reform that would encourage or limit state engagement in network industries.

The following section describes the progress and particularities of market reform in each industry, focusing on market opening, access to network regulation, and regulatory governance.

Early industries in the reform

Telecommunications and air transport reform in Europe resulted from a combination of political, economic, and technological factors in the mid-1980s. The European Commission (EC) considered that both sectors were crucial to promoting the European common market; thus, the EC updated its policy priorities and moved the reform upward in both sectors following the evidence of efficiency improvements and technological developments after the reforms in the United States and the United Kingdom. The EC expressed its intentions, principles,

decision to privatize public utilities or services remains within each national country.

and preliminary steps through a series of documents such as the Civil Aviation Memorandum (Commission of the European Communities, 1979, 1984, hereafter CEC) and the "Green Paper" in the case of telecommunications (CEC, 1987). The documents aimed to elicit debate on the steps that the EU should take to improve service quality, consumer prices, and industry efficiency. The documents also placed a strong emphasis on the design of a reform that considers the particular characteristics of European economies and the common market objectives. Moreover, the documents stressed the importance of market reforms that cope with the speed of technological changes and of the strategies that allow the EU to obtain economic benefits from technological change. The appropriation of economic benefits was particularly important in the context of trade, telecommunications, information technology, and investment expansions, particularly at the end of the 1980s.

Air transport

Prior to the reform, the air transport industry was characterized by state-owned careers that operated under highly regulated bilateral price regimes (CEC, 1979). As a result, careers competed in quality, i.e., by offering a wide set of schedules for their bilateral connections. The previous characteristics resulted in the operation of flights with low occupancy rates and excess capacity. Moreover, governments used their state-owned airlines to serve unprofitable routes, procure from local providers (including aircraft), and maintain many employees, usually unionized with substantial benefits. Besides, regulatory setting powers remained within national jurisdiction without any mention of the EU in sector competition rules, with the EU excluding the application of the single market principles to the air transport sector. The EU claimed that industry regulation preserved the stability and governance of the air industry (O'Reilly and Stone Sweet, 1998). Regarding airport usage, its operation and slot assignment were totally in the hands of national authorities, with scarce facilities shared between MS. During the early stage of liberalization, national authorities were reluctant to share airport facilities under the claim that their capacity would be insufficient to support any traffic increase. The aforementioned characteristics limited the expansion of the single market, not only for the air sector operators (private investments), but for other industries such as international trade. Furthermore, far from being profitable, airline operations in such conditions put significant strains on public expenditure policies, resulting in high prices and poor service quality (for example, overbooking on most busy routes and schedules) for consumers.

The process of market opening began in 1986, when the European Court of Justice (ECJ) ruled that the EU treaty applied to the air transport sector after concluding that the current French Civil Aviation Code, which supported concerted prices, restricts and/or distorts competition within the Common Market. This ruling reduced the control that national regulatory authorities had over prices and endorsed the EU Commission's efforts to actively verify the compliance of competition and anti-trust laws in the sector. Besides, the ruling pushed MS to establish a common air transport policy for the EU instead of applying national rules (with the threat of legal action from the private operators or inter-

est groups) (O'Reilly and Stone Sweet, 1998). Despite government opposition, the European Commission's Second Civil Aviation Memorandum (CEC, 1984) focused on the Commission's view of the air industry and opened the debate to begin a gradual industry restructuring (removal of entry barriers) through the application of successive European packages. The first (1987) and second (1990) packages focused on price and capacity constraints. In particular, the Council Decision 87/602/EEC granted access to air careers to exercise the third and fourth "Freedoms of the air" [6]. In other words, the Decision allowed careers from one MS to put down and take in passengers to and from a second MS, considering a balanced bilateral relationship. The Council Decision 2343/90/EEC further integrated the air market by implementing the Fifth Freedom of the Air, which allowed carriers to transport passengers or cargo between the MS and a third MS country via a connecting port in a second MS. In 1992, the Third Package (Council Regulations 92/2407/EEC, 92/2408/EEC and 92/2409/EEC) focused on license harmonization, granting career cabotage rights in any MS for licensed EU aircraft, and eliminating price distortions by conceding contracting parties freedom to set service prices. Market integration was consolidated by implementing Regulation 2008/1008/EC in 2008. The Regulation strengthened the community's rights to licensed air careers by limiting national authorities' ability to demand requirements beyond those requested to obtain national licenses. Currently, the EU has implemented legislation that protects and enhances competition in the community airspace (Regulation 2019/712/EU).

The market reform, as envisioned, expanded intra-community air traffic for people and freight, developed industry business models, such as low-cost airlines, and lowered consumer prices. In 1992, 12 nations participated in the Single Aviation Market, but by 2007, 27 countries had participated. Furthermore, intra-community routes with more than two occupations increased by 385 percent between 1992 and 2007 (Fu and Oum, 2014). The development of the European market and air traffic imposed stress on airports and traffic management operators, who had to deal with the constant rise in traffic while adhering to tight safety and operational requirements. In this context, the EU prioritized the establishment of a unified regulatory framework for air service support. In 2004, the European Commission created the Single European Sky (SES) [7], which was later modified with Regulation 2009/1070/EC in 2009. The

[6] The International Civil Aviation Organization (ICAO) recognizes five "Freedoms of the air." The First Freedom of the Air is the right or privilege one state provides to another state or states to fly through its territory without landing in the case of scheduled international air services. The Second Freedom of the Air refers to the right or privilege provided by one state to another state or states to land in its territory for non-traffic reasons concerning scheduled international air services. The Third Freedom of the Air is the right or privilege provided by one state to another state in respect of scheduled international air services to lay down traffic from the carrier's home state on the territory of the first state. The Fourth Freedom of the Air refers to the right or privilege given by one state to another state with respect to scheduled international air services to take on traffic intended for the carrier's home state on the territory of the first state. Finally, The Fifth Freedom of the Air is the right or privilege provided by one state to another state in respect of scheduled international air services to put down and take on traffic arriving from or headed for a third state on the territory of the first State (ICAO, 2016)

[7] The SES package is comprised of four fundamental Regulations 2004/549/EC, 2004/550/EC, 2004/551/EC and 2004/552/EC. The SES II package, which sought to boost operational security, minimize management costs and delays, and lessen the environmental effect of air traffic, was upgraded by the SES II package (2008/389/COM).

SES, based on safety and incentive-based regulation, established uniform rules for air navigation services, airspace organization and usage, and interoperability of traffic management systems. The SES was also tasked with implementing steps to maintain operational safety, environmental sustainability, and airport infrastructure efficiency. However, with increased traffic, the EU has remained concerned about airport infrastructure optimization (slot allocation). The need for slots is critical for the industry to reap the benefits of liberalization since traffic cannot be handled unless airports offer adequate slots. In this regard, MS regulators have granted enough negotiating powers to the airlines to negotiate with airports about slot allocation on a competitive basis [8]. Through these arrangements, traditional airlines consolidated national and regional hubs (i.e., Air France in Paris Charles de Gaulle airport or KLM in Amsterdam Schipol airport) and consolidated significant market power in airport usage [9] (Fu and Oum, 2014). However, the entry of new airlines gave bargaining power to careers that could change operations to alternative regional airports (Thelle and Sonne, 2018). Currently, the EU discusses how to manage demand shocks in the current competitive system. The COVID-19 pandemic reduced air traffic dramatically and highlighted the drawbacks of the competitive system. Under the system, a significant drop in demand threatened careers with losing their airport slot allocations, with the risk that the rest of the firms would not be able to satisfy such a demand.

Telecommunications

The theoretical justifications that support the operation of monopolies (private in the case of the US) were challenged at the end of the 1970s by a reassessment of the monopoly restrictions that prevented firms from participating in the market. Competitors in the service equipment industry and several institutional economists claimed that the social (static) benefits of declining unit costs of the monopoly could be eroded by the dynamic negative effects of monopoly operation on competition and service quality. These justifications and the legal pressure exerted by new players in the market prompted the Federal Communication Commission (FCC) and the Department of Justice (DOJ) to get involved in limiting the market power of AT&T [10]. As a result of such pressures, AT&T was divided into seven regional monopolies, as well as national and international network services, in 1984. After this agreement, the industry's performance improved significantly in the following years. The national and interstate markets expanded the competition, and innovation possibilities in network services and terminal equipment diversified the services offered to consumers and reduced

[8] In the EU, slot allocation is granted by the 80/20 rule, which mandates airlines to use 80 percent of their takeoff and landing slots or lose them to a rival airline next year

[9] There are several arrangements that rule the relationships airline-airport: Lease and use contract, direct control of the airport, long-term use contracts, airports issuing revenue contracts to airlines, revenue sharing (Starkie, 2008). These arrangements favor or restrict competition between airlines and also provided different incentives to airports to invest in operational and safety infrastructure.

[10] The economic regulation criteria to govern the telecommunication industries changed significantly, especially during the Reagan Administration. During his period, competition was considered a means to achieve regulatory objectives, which later evolved to a doctrine where free markets replace regulation (Melody, 2011)

prices (Melody, 2011). All of the industry transformation and the superior number of available telecommunication services not only attracted significant flows of investment to the sector, but also transformed the operations of other industries that rely on telecommunications (trade, manufacturing, computer systems).

Fixed telecommunications infrastructures were held by governments prior to the start of reform in Europe, with the argument of public service advantages and lowering unit costs of national monopolies. These public advantages and theoretical considerations laid the groundwork for imposing legislative barriers to new company entrance. Furthermore, the telecommunications sector was considered a source of revenue, either to enable governments to develop certain manufacturing businesses via procurement contracts or to utilize a portion of the monopoly earnings to finance government operations (Waverman and Sirel, 1997). However, the reform in the United States (and, in Europe, in the United Kingdom) compelled European policymakers to prioritize telecommunications reform among European policy objectives (Geradin, 2006).

The European perspectives regarding the transformation of the telecommunications sector were expressed in the European Commission's "Green Paper" (CEC, 1987). The document expressed the need to ensure the interoperability of networks, terminals, and services. The EU Commission considered that the introduction of competition was the optimal means to achieve this, and MS cooperation was the vehicle to achieve network interoperability and the development and promotion of new services. The market opening started in 1988 with the First Telecommunications Directive which introduced competition in the terminal equipment sector. The Directive 90/338/EEC introduced the "official" telecommunications market reform in 1990, with the removal of exclusive rights to the provision of telecommunications services in each MS (except voice). The Directive also established a calendar (with 1994 as a limit) for the implementation of further steps and evaluation mechanisms (in particular for the user-end side of the network). Furthermore, the Directive encouraged MS to license telecommunication services with transparent and non-discriminatory processes. As a next step, the EU issued the Guidelines on the application of competition rules (Directive 90/338/EEC), which gave the Commission competence to apply competition rules besides the intervention of national and judicial authorities (Document 91/C233/02). Finally, Directive 96/19/EC fully liberalized the telecommunication markets by lifting all the restrictions on telecommunication voice services.

The proliferation of mobile services has put pressure on interconnection agreements between mobile operators and fixed service providers, as well as between mobile service providers. Melody (2011) suggests that the rapid increment of service provision and investments and the shortage of auctioning spectrum policies for 2G and 3G networks created an oligopoly market structure with a limited number of operators with significant market power. Therefore, part of the EU's efforts were to decrease the operator's market power to exploit call termination and other interconnection fees. Virtual Network Operators also appeared as a solution to promote competition in the retail segment. The EU implemented further reforms that focused on the access and interconnection of communication networks and services (Directive 2002/19/EC), the harmoniza-

tion and authorization rules (Directive 2002/20/EC), and the implementation of a common regulatory framework through open network provisions (Directive 2002/21/EC). The norms regulated interoperability and consumer protection. Later, Directive 2009/136/EC amended the previous Directive and added new consumer protection provisions and universal service requirements for the operators.

As a result, sector investments increased significantly during the 1990s decade. 13 European Member States, in particular, adopted the second generation (2G) standard for mobile voice communications, laying the groundwork for widespread adoption of the Global System for Mobile Communications. Other services, such as optic fiber and mobile internet, also expanded considerably between 1998 and 2010 (Melody, 2011).

Technical challenges to vertical separation

In contrast to the telecommunication and air transport sectors, the benefits of liberalization in energy and rail were questioned because of the difficulties in opening competition in industries where the natural monopoly social costs could hardly be outperformed by an alternative industry arrangement. In other words, these industries were operated by vertically integrated national "champions" that produced / traded goods with physical characteristics (e.g., electricity or gas) and did not allow the implementation of competitive markets (Glachant and Perez, 2011) or heavily controlled the network as in the case of rail industries (Casullo, 2016).

Besides the theoretical arguments, MS considered these industries (i.e., electricity, gas, and transport) as critical elements of their economies and even national security, as in the case of the energy sectors. These national considerations delayed the implementation of the reform, and the legal course is being undertaken (instruments at disposal) by the EU. Other factors that delayed reform in the energy and transport industries were the expected social costs in the form of job losses caused by full liberalization in these sectors (Geradin, 2006).

Energy Industries: Electricity and Gas

Before the reform, the electrical sector was characterized by vertically integrated national (or mixed corporate / public) monopolies serving a defined captive market. Monopoly operations were regulated through direct control in the case of state monopolies or cost-of-service regulation in the case of mix-ownership monopolies (Belgium, Germany, and Switzerland). Furthermore, rather than economic concerns, the operation of interconnected networks at the national and European levels was driven by supply-security concerns Glachant and Perez (2011).

In that context, a few European countries (mostly the United Kingdom) initiated reforms in response to technological changes. At the time, gas-powered electricity generation reduced the size of generation units that might enter mar-

kets, allowing them to compete with large generators [11]. Furthermore, the competition proved viable for lowering consumer prices. However, the sector's physical complexity (i.e., electricity cannot be stored at significant rates; offer and demand must be permanently balanced) conflicted (and still conflicts) with competition because low market prices did not appear capable of incentivizing investments in base-load and peaking plants. Despite this possible conflict, the European Commission increased pressure on MS by introducing competition in the sectors or modules that might sustain it, as pointed out by Newbery (1999).

The underlying goal of EU policymakers was to implement an electricity wholesale market with cross-border exchanges. The rationale behind this ambitious goal was to appropriate the efficiency gains of bilateral exchanges and ultimately serve consumers with adequate quality and value. Therefore, the EU, through the first EU electric Directive adopted in 1996 (Directive 96/92/EC), attempted to introduce competition in the generation and distribution segments. First, the Directive mandated the separation of electricity generation from the transmission segment. Until this Directive, the only nations that did not have vertically integrated electric networks administered by national firms were Norway, Sweden, and the United Kingdom. The Directive also governed the organization of the electricity sector, market structure, and system operation under the principles of competition, security of supply, non-discrimination, and environmental conservation. The unbundling of the electric network was extended to transmission and distribution by the Second Electric Directive (Directive 2003/54/EC) in 2003. The Directive, in particular, required a legal separation of Transmission System Operators (TSOs) and Distribution System Operators (DSOs). The Third Electric Directive 2009/72/EC) gave member states the option of establishing an independent system operator (ISO) or defining ownership separation between generation and transmission. While the first two Directives approximated the implementation of the integrated wholesale market, it was the Third Directive that laid the groundwork for MS interconnection, peak-demand control, and a harmonized regulatory framework. The Clean Energy Package (CEP) Directive (Directive 2019/944/EC) is the most recent electric Directive to be enacted. The regulation modified the definition of network codes and rules to better coordinate power exchange and existing national markets Meeus (2020). The CEP differs from previous directives in that it takes into account the goal of decarbonizing the EU's electric system in addition to the economic justification of previous measures (for example, the Renewable Energy Directive (Directive 2009/28/EC)). It is still uncertain whether the CEP might integrate renewable energies into the grid without generating tensions they create in competitive markets.

Similarly to the electricity industry, the gas sector's organization vertically integrated the production, transmission, and supply components. Long-term contracts delegate service provisions to regulated enterprises, which condition the markets to operate with a small number of firms with considerable market shares. These market characteristics allowed national incumbents to generate rents and reject any reform attempt that challenged the current status quo.

[11] The reform significantly changed the generation structure in the United Kingdom and Wales, while no major changes were reported in France, which relied on substantial nuclear generation capacity (Glachant and Perez, 2011)

It took MS nine years to obtain a minimum threshold of agreements to begin reforming the European gas market, which resulted in the First Gas Directive in 1998 (Arentsen, 2011).

The main argument for introducing competition in the gas market was to allow industrial clients and domestic customers to choose their gas suppliers in an integrated market under the principles of safety and sustainable development. On the one hand, an active cross-border trade would improve system efficiency and reliability (in case of shortages from one of the MS), and on the other hand, the reduced intensity of CO2 from the gas (in comparison to other alternatives such as coal or fuel) offered the MS incentives to adopt natural gas technologies and reduce their CO2 emissions. The First Gas Directive (98/30/EC) opened the market in 1998. The Second Directive (2003/55/EC) aimed to allow third parties (new producers / importers / retailers) to access the pipeline network through the unbundling of national vertically integrated companies. In other words, the gas production / import had to be independent of the transport and retail segments. However, significant delays in the Directive's implementation arose, and the EU launched the Third Directive (2009/73/EC) to increase the requirements on third-party access, set a common regulatory framework, and increase transparency in market operations (Renou-Maissant, 2012). Moreover, the Directives also stressed the importance of the security of supply. In particular, they set the standard rules for the transmission, supply, storage, and distribution of natural gas and other gas sources. The Directives also established the criteria to grant licensees and authorizations for all segments of the industry and the technical details of safe operation in gas transport and injection. Regarding market monitoring, the Directive conferred on MS the mandate to monitor national markets' supply and demand, the market balance, and elaborate plans for future demand and capacity expansion.

Rail transport

Before the rail reform in the early 1990s, the sector experienced a reduction in efficiency and significance among other modes of transport in Europe. The shares of passenger and freight transportation declined from 10 and 20 percent to 6 and 8 percent, respectively. The drop in demand had significant ramifications for governments (which almost operated in the sector through national monopolies) who had to subsidize rail operations, as well as for society and the environment through higher prices and CO2 emissions (an increase in CO2 transport modes) (Holvad, 2017).

The rail reform in Europe aimed to improve the efficiency of a declining sector by separating the industries' different segments first and introducing competition in those segments that could improve efficiency in their operations. According to Knieps (2005), the train operation could be divided into i) tracks and stations, ii) traffic control systems, and iii) transportation of passengers and cargo. Thus, the legislation attempted to support the independent operation of the track network and traffic control (transparent and non-discriminatory access) and introduce competition in the transportation service segment. However, the social characteristics, the multi-product nature, and the inter-competition arrangements with other transport means challenged the envisioned market re-

forms. Social characteristics conflict with the incentive-based market perspective. Rail transport was utilized by governments to bring equal growth across regions, perform public service obligations, and cross-subsidize under social benefit criteria. The previous activities are not compatible with a competitive system. The multi-product and inter-competition arrangements necessitated complex coordination arrangements, which the market may be unable to provide. Rail tracks transported passengers as well as freight (postal, food, chemicals, and raw materials) in both commuting and long-distance travel. Each category had its own demands on the system, which set demands on the tracks and stations that could create congestion (Laperrouza, 2011).

In 1991, the First Rail Directive (91/440/EEC) aimed to create a single European railway market by unbundling the tracks / traffic management from transport services and opening those services to competition. The reform lacked significant progress during the next ten years. To revitalize the reform, four railway packages were adopted by the EU in an attempt to achieve the internal rail market. The first package (Directive 2001/12/EC) supported system unbundling that could take the form of complete separation, holding company, and separation of key powers. Moreover, the First package also conferred on MS the responsibility to develop its own railway infrastructure (considering the Community's needs) and implement safety standards. The Second Package (Directives 2004/49/EC and 2004/51/EC) pushed the sector's liberalization, in particular the liberalization and integration of the freight segment. Second, the package established a common framework for safety improvements in operations and accident investigation procedures. The Third Package [12] (Directive 2007/58/EC) granted access rights for international rail passengers and cabotage agreements, harmonized requirements to rail operators within the EU and set minimum quality standards for the international passenger service. Finally, the Fourth Rail Package focused on the reform that allows the rail sector to compete with other transport modes. As noted by the European Commission, the package had two pillars. The technical pillar (Directive 2016/796/EU) focused on the interoperability of the system within the European Union (international traffic and traffic management), and the market pillar (Directive 2016/2370/EU) focused on granting railway operators the right to operate all types of passenger services, avoiding discriminatory treatment in infrastructure management, and the mandatory tendering of public service contracts.

2.2.3 Progress of regulatory governance reform

Most nations began their road toward economic liberalization in the 1990s. Governments strengthened this movement by creating independent regulators tasked with fostering fair competition between new entrants and incumbents and defending the general welfare (Levi-Faur, 2005). In most nations, utilities had previously been run by public or private entities under the direct supervision of ministries, either through a command-and-control style of government or through contractual links. Independent regulators emerged as a response to the (Stigler, 1971) analysis of the capture of regulators by businesses and to promote

[12]The Third Package began in 2004 with the Commission's intention to revitalize the railway system, as expressed in the "White Paper." (COM(2004) 140)

a model of agency that is immune to undue influence from governments when they attempt to deviate from making decisions in line with the public's best interests (Majone, 1996).

In the European context, where network industries were operated by state-owned, vertically integrated monopolies, market reform required an independent body able to enforce regulation in a transparent and non-discriminatory manner to safeguard competition but also to safeguard the interests of consumers and guarantee the long-run sustainability of the system. Thus, the regulator operates under the tension of private/public competing firms, the government / politicians (representing consumers), and the investors. The European Union chose the "independent regulator agency" (IRA) model as a device to mediate such pressures. The IRA is a bureaucratic institution outside the scope of executive power, with regulatory authority and autonomous decision-making processes (Thatcher, 2002; Alesina and Tabellini, 2008). Single market Directives delegated to IRAs the authority and regulatory powers to steer and monitor the implementation of the single market (in network industries), given three principles: i) introduce and promote competition, ii) build reliable and powerful / secure network systems, and preserve service quality, and iii) carry out regulatory duties in a non-discriminatory manner, mainly when financial compensation or access to the network is at stake. IRAs also follow the principles of environmental sustainability. However, the Directives do not provide IRAS-specific powers to promote environmental sustainability. In contrast to the progressive implementation of market regulation through several Directives and Regulations, the EU mandated the legal implementation of the IRA model to MS using particular Directives (successive Directives updated the list of assigned tasks according to the EU needs and new challenges): for telecommunications, Article 8 of Directive 2002/21/EC, for electricity, Article 35 of Directive 2009/72/EC, for gas, Article 39 of Directive 2009/73/EC and for rail, Article 55 of Directive 2012/34/EU. Beyond the principles, power delegation also relied on three pillars, independent agency decision-making, which includes the resources (human and financial) to perform their work, a defined set of delegated powers, and accountability provisions to limit potential IRA discretionary actions against the public interest (OECD, 2014).

Even if regulators were legally separated from the government, executive and legislative powers could still attempt to influence the IRAs' decisions by overruling them, using ministerial revisions, or appointing or removing the IRAs' decision bodies. European legislation and international agencies proposed measures to limit the influence of the government and the industry on the regulator's decision-making process (OECD, 2014). Generally, the Directives defined precise overruling mechanisms for regulatory decisions to reduce arbitrary ex-post changes in regulatory decisions. Moreover, the Directives encouraged MS to limit the power of ad-hoc committees or ministerial agencies in the agencies' decision-making and allow courts to resolve issues between stakeholders. Regarding potential political interference and private capture, the EU established another set of actions that protected the regulator's governance bodies from arbitrary dismissal. These provisions are particularly helpful when the regulator's and government's preferences are significantly dissimilar. The rules include provisions that fix the term of head / board appointments, set clear head / board

selection criteria, and limit government dismissal powers. In this way, IRA governing bodies are not influenced by the political cycle (Gilardi, 2005). The regulatory governance model also considered rules to limit the private sector's undue influence. Rules limit the participation of head/board members in the industry after their governing period has ended. This period is usually referred to as a "cool-off" period. Finally, the Directives also set rules to secure sufficient financial and human resources to perform their task. An agency without the proper set of means might underperform or choose a non-optimal set of actions (Glachant et al., 2013). The issue could be aggravated when a significant part of the regulator's budget comes from the government or the private sector. Governments could influence the regulator's agenda or efficacy by cutting its financial resources. Similarly, the private sector could lobby for its agenda when the regulator's funds depend on levies or fees paid by the regulated firms.

Besides requesting legal separation, the Directives also defined a precise list of responsibilities with which regulators should comply, which varies according to the sector. Regardless of sector, the list typically includes the traditional economic regulation tools (cost-based regulation, price-setting powers) as well as additional tools that enabled the agency to fulfill its mandates. The European Directives provide agencies with the power to solve disputes between market participants, set technical and safety standards, and generate and provide market information to stakeholders. For instance, the Third Electricity Package delegated to national regulators the responsibility for i) the rules applied to the management and allocation of interconnection capacity, ii) monitoring the level of transparency and competition, and iii) methodology to calculate tariffs (Article 36 of the Directive 2009/72/EC). The Directives also considered arrangements to prevent agencies from deviating from their objectives and to limit agencies' discretionary powers through a set of accountability and transparency rules. Examples of such measures are the imposition of mandatory legislative hearings, reports, the justification of regulatory decisions, and the publication of the methodologies (OECD, 2014).

In addition to implementing the IRA model, European Directives established European institutions that allow regulatory convergence within continental scale markets with no single European regulator (see Glachant (2021) for a reference in the electricity sector). These institutions, formed by national regulators and other sectoral stakeholders, were in charge of enacting new European regulation proposals, elaborating guidelines, determining good regulatory practices, harmonizing methodologies, and sharing common experiences. These forums were mandated by packages and directives in network industries.For instance, the Independent Regulator Group (IRG) was created as a forum to share experiences and create regulatory common knowledge in the telecommunications and rail sectors (Directive 2012/34/EU). The Third Electricity Package created the Agency for the Cooperation of Energy Regulators (ACER) as an independent body with the mission to advise MS about policy implementation and decision-making regarding market integration and harmonization in the electricity and gas sectors.

The previous sections and subsections presented an overview of the sector's pre-reform configuration, the driving forces behind the reform, and the European legislation that is currently governing the reform. However, the im-

plementation status and progress of the reform and its governance model vary significantly across and within sectors. Sectoral implementation differences appear because of the political and technological pressures and challenges, the physical characteristics of the provided services, and the EU instruments at disposal (Geradin, 2006). The European Commission used competition policy (binding decisions) to integrate markets in the telecommunications and aviation industries, whereas directives (which set objectives for MS but did not limit the course of action) govern sector integration in the electricity and gas industries (Glachant, 2021). The differences also remain at a national level, where the political equilibrium, power of veto players, natural endowment, and legal tradition determine the progress of the reform (Gilardi, 2002). Despite the EU efforts to implement the reform and regulatory governance model, the differences persist and are associated by researchers and academics with differences in industry performance.

The empirical analysis of economic regulation in network industries has reached a consensus about the positive effect of market reforms on economic growth (Broughel and Hahn, 2022). Market reforms seem to positively impact investments by incentivizing firm management to maximize stakeholder value (Alesina et al., 2005). Also, the reform is positively associated with factor productivity (Nicoletti and Scarpetta, 2003; Bouis et al., 2016, 2020) and the allocative efficiency of the industries that rely on network inputs (Bourlès et al., 2013; Cette et al., 2017). However, the reform and governance metrics used in the literature might present caveats that limit a better understanding of the reform and are explored in the next section.

2.3 Measurement of the reform

The study of the status and development of reform in a single country or sector may yield valuable insights into the implementation of market reform in network industries. Also, a comparative assessment is beneficial for verifying the state of reform implementation across countries, as well as the probable reasons for the implementation level and progress; more crucially, a comparative evaluation could provide valuable insights about the consequences of the reform on industry performance. The insights from such an analysis might assist policymakers in designing and implementing optimum policies that support the intended policy objectives. The challenge is to establish a framework that allows us to capture and summarize the most meaningful characteristics of market reforms, whether we choose to evaluate a single country or sector or compare the reform across European MS.

The literature focuses on summary indexes and metrics to simplify the comprehension of complex information, establish priorities, plan and implement policies, and assess their success. These measurements also help with information transmission and accountability, as well as the creation of instructive narratives for consumers, the media, and voters (OECD, 2008). In addition, summary indexes can be used to benchmark reform implementation in a specific industry or country and suggest areas for future development. Thus, the methods used to aggregate the data should be carefully chosen. Otherwise, a

poor information aggregation method might lead to incorrect conclusions. Poor or biased indexes, in particular, may:

- Distort public opinion in favor of the desired policy.
- Communicate unclear policy messages or may encourage naive policy conclusions.
- Increase the complexity of determining the best course of action or result in unsuitable policies.

The previous issues highlighted the potential dangers that inadequate or biased metrics could provoke in public and private decision-making. Biases could be introduced to aggregated metrics using arbitrary criteria to summarize and weigh the reform's features. The weighting criteria might confer more importance on particular reform characteristics that support a defined political or ideological view. This issue was salient during the latest wave of criticism directed at the World Bank's "Doing Business" indicators, which began in 2018. The index was criticized for reflecting the World Bank's positive view on deregulation, which is closer to liberal regulatory frameworks (e.g., the United States and the United Kingdom). As a result, the index reflected the distance to an "ideal" regulatory model instead of an accurate reform measure. The index ranked higher countries as being closer to the liberal model and lower countries as having different frameworks. This ranking has implications for countries. For instance, the "Doing Business" ranking significantly impacts the estimation of a country's credit score and, thus, its external funding possibilities. Moreover, similar indexes are used by international institutions and politicians as "naming and shaming" devices to push further policy reforms that favor their political views (Erkkilä, 2020).

The reforms in network industries have been implemented using Directives and Regulations to introduce competition in the segments where it is possible and regulate the "fair" access of firms to the network services. Member States have transposed these rules into their national legislations, however, at significantly different rates. Particular metrics and indicators that use the European Directives and Regulations as reference (a competitive market) are developed to benchmark national / sectoral reform status and progress (OECD, 2008). While the comparison with competitive markets might yield interesting insights into market reforms, the comparison also raises questions about the comparison process: i) Which features or characteristics are relevant in comparing the current reform status with the reference model? ii) Does the metric use one dimension to summarize and describe the reform, or are additional dimensions needed? iii) Are the relevant features or characteristics equally important? The answers to these questions are far from trivial because the criteria used to select important features, estimate their relevance impact, and describe the reform have an impact on the metric / metrics we attempt to construct and the message they convey. The first and second questions address conceptual and theoretical concerns, while the third addresses methodological concerns.

Conceptual/theoretical biases

The literature has addressed the first question by applying the premise that competition gives incentives to firms to minimize costs, restrain prices, and ensure that consumers will satisfy their needs at the least cost. Therefore, entry needs to be encouraged, and regulations that limit that entry need to be removed, following Stigler (1971) perspective on regulatory capture. Indexes of this type consider characteristics related to price liberalization, the removal of entry barriers, and obstacles to competition. Primary and secondary statistics supplied by international organizations like the World Bank, the OECD, and the IMF follow this competition premise. The World Bank and the Fraser Institute market "reform" indicators focus on evaluating entry obstacles: administrative requirements, bureaucracy costs, starting a business hurdles, bribes, license restrictions, tax compliance, and trade barriers. Moreover, the Investment Climate Assessment poll gauges the experts' view of how businesses evaluate the investing environment. Loayza et al. (2010) use the World Bank "Doing Business" indicators to estimate the effect of business regulation on economic growth in a sample of 75 countries between 1990 and 2000. The authors find that entry barriers are negatively associated with economic growth.

However, while the indicators focus on deregulation, they omit additional regulatory aspects that could improve economic performance but do not fit within the selected theoretical or conceptual framework. These omissions could seriously bias the indicators by capturing only one dimension of the reform (e.g., market opening) and not a complete description of market regulations. For instance, Arruñada (2007) discusses the elimination of business registries (as part of reducing entry costs for new firms) creates transaction costs in the long run by preventing judges and administrative authorities from accessing detailed information about business activities. However, the countries that have not eliminated these registries would be penalized by a higher entry barrier score. The previous example highlights the importance of carefully choosing the characteristics of reform and avoiding reflecting political or ideological preferences.

The second issue is whether the reform should be described with a single score or whether numerous features are required. The number of dimensions is crucial, depending on the phenomenon we want to understand. One-dimensional measurements may be effective for evaluating certain program components but not for evaluating the entire reform. A comprehensive legislative review may entail defining relevant dimensions based on our objectives and the message we desire to deliver. An inappropriate or ambiguous selection of dimensions may limit their usefulness and misrepresent the results. In developing regulatory independence measures, selecting the number of elements is critical. Gilardi (2002, 2005) and Bortolotti et al. (2011) employ independence measures to describe sector regulator governance. It is complex to determine whether regulatory independence is associated with superior sector performance or is the overall regulatory governance setup (that includes additional dimensions) that drives their results. Other work (Hanretty et al., 2012; OECD, 2016; Jordana et al., 2018; Casullo et al., 2019) addresses governance structures with additional aspects such as regulator accountability and regulatory action scope (breadth of

delegated powers). The dimensions of market reforms are determined by policy objectives; the World Bank's "Doing Business" indicators focus on the examination of market barriers; therefore, the information is classified according to the type of barrier (e.g., legal, administrative (as in the case of procedures and bribery)). In contrast, the OECD PMR score focuses on the reform's policy aims, such as expanding markets, regulating network access, limiting state influence in regulation, and ultimately running competitive markets. As a result, the survey data is combined into indexes that assess the achievement of such goals.

Methodological biases

The construction of an aggregating index demands the quantification of qualitative reform characteristics and the estimation of the importance of each one of them. The literature (see Broughel and Hahn (2022) for a reference) usually quantifies these characteristics using questionnaires that inquire about a particular characteristic and offer a defined set of possible descriptions (closed-end surveys). A sound aggregation methodology should consider characteristic and response variability to estimate an individual feature's importance. When the variability is estimated from the data, we can distinguish between elements that explain large fractions of the variance and other elements without explanatory power. When the characteristics are quantified, the aggregation of such weights provides robust metrics. In contrast, when weights are set arbitrarily, the indicators might underestimate or overestimate the reform status and progress. Nicoletti and Scarpetta (2003) Conway and Nicoletti (2006) Hanretty et al. (2012) and Jordana et al. (2018), among others, construct aggregated indexes using statistical models that account for the correlations between characteristics (latent factor models like PCA, MCA, and IRT models) [13]. However, weight estimation has other caveats as well. First, the models use stringent distributional assumptions that need to be verified ex-post (this problem is exacerbated when indicators are observed over time because the observations are time-correlated). For instance, PCA assumes that variables are continuous and normally distributed. MCA relaxes both assumptions by allowing the usage of categorical data, but still, a distributional assumption of such variables is required [14]. Second, the models are sensitive to the inclusion of new characteristics in the dataset, which introduces uncertainty in estimating the aggregated indicator. Third, latent factor approaches are also susceptible to units of measure and extreme values, which might yield spurious correlations between variables.

Because of the "estimated weight" method caveats, the literature has relied either on experts' opinions or arbitrary weighting schemes for constructing indexes. Both also approach present issues. When experts' views are used, they raise concerns about political and ideological biases that can drive the metric to

[13] The models assume the existence of a latent factor or dimension that yields the observed characteristic (survey response pattern) configuration. The characteristic weights are estimated from their correlations

[14] The application of MCA demands converting categorical variables into binary response variables. The conversion increases the number of variables in the dataset, and consequently, it artificially increases the data variability. As a result, the extracted latent dimensions decrease their explanatory power.

reflect an institutional quality measure rather than the "true" extent of reform. The problem could be aggravated when the aggregation method is not publicly available or unclear (Erkkilä, 2020). Other researchers and international institutions (e.g., OECD) adopt a more conservative approach to determining the characteristics' weights. They aggregate characteristics by giving them the same importance (Gilardi, 2002, 2005; Koske et al., 2016; Vitale et al., 2020). While the aggregation choice is transparent, it might introduce redundancies in the final metric. It might reflect the number of reform provisions adopted instead of a sound evaluation because it does not consider the association between characteristics.

Besides the potential explained biases, the comparison across sectors and periods could also affect the aggregated index's reform evaluation power. The comparison across sectors is challenging, regardless of the weight estimation method. Many studies compare reforms and regulatory governance arrangements in a single sector. This approach limits the explanatory power of the studies and does not allow for drawing general conclusions about the reform status across sectors. Furthermore, these studies face difficulties in distinguishing the impact of reform and regulatory governance from country-level macroeconomic characteristics (Égert, 2009; Sutherland et al., 2011; Cambini and Rondi, 2012). Besides, cross-section comparisons are useful for studying reform implementation and progress differences; however, cross-sectional comparisons limit the dynamic analysis of market reforms. The methods previously analyzed also present problems when they are used to contrast reforms across sectors and periods [15].

The next two papers introduce NLP methods as aggregating tools that could address the biases and comparability issues exposed in this chapter.

[15]The OECD RIQ questionnaire (survey used to estimate the PMR scores) focuses, at the sector level, on regulation factors such as government ownership, vertical separation, price restrictions, and market structure in the energy, telecommunication, transport, water, and postal industries (Conway and Nicoletti, 2006; Wölfl et al., 2009; Koske et al., 2016; Vitale et al., 2020). The survey was released in 1998 and has since undergone five updates for 1998, 2003, 2008, 2013, and 2018.

Chapter 3

Paper 1: Measuring market regulation in the OECD countries: A cross-country analysis

Abstract: This article explores the application of Natural Language Processing (NLP) algorithms to summarize survey information from the OECD Product Market Regulation and Regulatory Inquiry Questionnaire. Our method extracts key regulatory characteristics from the surveys' text representations and describes regulatory regimes using three dimensions, state ownership, network access, and product characteristic control. This description departs from the traditional view by distinguishing the provisions that support new incumbents' access to the natural monopoly segments of the industry from the incumbent's power to set product and service standards. Moreover, our scores highlight significant correlations between our dimensions and industry outcomes

3.1 Motivation

The European Union has set an ambitious objective of opening state-owned network industries to competition. The reforms began in the early 1990s with the promise of increased investment and operational efficiency. The reform centered on privatizing state-owned enterprises, liberalizing the market, and reducing barriers to entry for new operators. The reform has spread unevenly, with different industries and countries implementing it at varying times, speeds, and scopes. Disparities in reform adoption are caused by differences in national political and cultural traits (Bouis et al., 2020), as well as technological and market conditions at the industry level (Newbery, 1999). Several studies have shown that these disparities have a major impact on industrial performance (Broughel and Hahn, 2022). As a result, precisely monitoring such reforms becomes critical for evaluating potential improvements and designing/implementing future reform initiatives.

Market reforms and regulations in network sectors emerge from applying several qualitative provisions, norms, and restrictions to market participants. A quantitative assessment of such qualitative features is typically based on surveys with closed-ended questions and a set of possible answers that capture a certain attribute. The numerical value assigned to each attribute is determined by the evaluation criteria. In the case of network industries, the most commonly used criteria assign higher points to traits consistent with a competitive market context. Institutions like the Organization for Economic Cooperation and Development (OECD), the World Bank (WB), and the International Monetary Fund (IMF) use methodology to calculate the gap between existing industry setups and an ideal competitive market. Their approaches often involve converting a given distance (extracted from a specific question) into comparable metrics, estimating/imposing the importance/weight of each characteristic, and summing the scores of the characteristics into aggregate indices.

Their approaches, however, have shortcomings. The numerical scores are based on expert views or arbitrary scales, which may reflect a researcher's viewpoint rather than an objective assessment. A second disadvantage is how information is consolidated into summary scores. Researchers do not know the value or weight of any regulatory characteristic a priori. The relevance is assumed or approximated using data variability. Assumptions about the value of each regulatory characteristic may result in measurement errors in the summary scores due to an over- or under-representation of the weight of each characteristic. Another difficulty links the definition of high-order dimensions to various aspects of market reform, such as privatization or entry barriers. A large number of dimensions limits the comparative value of summary scores across industries, whereas broad dimensions limit the insights we may gain from the reform's various elements.

In the empirical literature, market reform metrics have been regularly employed to assess the influence of market regulation on industry output. Scholars have developed a strong consensus on the appraisal of network sector reforms and their effects on industry performance. Liberalization and lower entry barriers are connected with higher levels of investment, superior factor productivity,

and expenditures on innovation (Broughel and Hahn, 2022). Similarly, the reform has transferred rents previously held by state-owned monopolies to downstream enterprises, i.e., firms that use network industry products as inputs. This resource allocation has aided in applying optimal production techniques, resulting in increased efficiency in downstream firms (Cette et al., 2017). However, there is a scarcity of reform assessments on consumer prices or the environmental implications of network industry operations.

In this study, we focus on the weighting problem of current indicators and propose a methodology for summarizing regulatory characteristics of market reforms based on their lexical semantics (words extracted from surveys and questions) using the OECD Regulatory Indicators Questionnaire (OECD RIQ) as regulatory information input from 1998 to 2018. Lexical semantics examines the meanings of word groups and their interactions. We employ semantic linkages to build concepts that identify similar themes across surveys, regions, and industries. The variability in the data is due to varied country/sector responses. After reducing the number of concepts/themes in the survey responses, we use topic modeling to find co-occurrence between these concepts/themes, then uncover latent topics and the value of each concept within them. We avoid the arbitrary weighting of regulatory traits by identifying high-order topics that explain various aspects of market regulation.

Our study showed that concept/topic modeling characterization can describe the regulatory characteristics of a certain country in a specific sector. Our method divides market regulation/reform into three categories: Network access, which assesses how well regulatory requirements set fair conditions and ensure new incumbents' access to the industry's natural monopoly segments. The amount to which restrictions and limitations on company functioning are removed is measured by liberalization. Finally, state ownership includes the government's involvement in the largest incumbent and market concentration. Furthermore, each dimension generates a metric that represents its impact on the reform and is comparable across sectors and time.

Our measures are used to assess the impact of market reform on industry performance. Our measures reveal significant associations that are consistent with existing literature. However, we highlight other relationships that need to be investigated further. Network access and liberalization are connected with lower energy prices and higher energy generation efficiency. Efficiency gains come at the expense of employing carbon-intensive sources. This finding could imply that increasing competition in the energy industry benefits consumers while discouraging the entry of more expensive renewable energy sources. Furthermore, government ownership is strongly linked to superior performance in the transportation industry. This association shows that the industry's structure raises transaction costs between decentralized infrastructure and transport companies, mitigated by vertical integration of the public incumbent.

The remainder of the paper is organized as follows. Section 3.2 provides an overview of market reform metrics and their empirical application. Section 3.3 discusses the text summarization process and describes our data sources. Section 3.4 discusses the estimation results and their implications. Section 3.5 and Section 3.6 provide the discussion and conclusion, respectively.

3.2 Literature review and contribution

3.2.1 Reform metrics and dimensions

European utilities started their liberalization process to attract investments and supply services efficiently (including at lower prices) to consumers. [1] After the successful liberalization experience of the United States' network industries in the 1980s, governments in the EU considered replicating such reform in their network industries. This consideration meant that competition should be introduced in the services supplied over the network, while regulation should guarantee fair access to the core natural monopoly infrastructure.[2] In this manner, services are offered under efficient conditions, while sunk investments are incentivized and not duplicated.

However, as Newbery (1999) points out, implementing such a paradigm is far from uniform. Institutional and cultural characteristics vary the degree, scope, and timing of the reforms. The reforms are subject to political bargaining, economic crisis, social preferences, and technological shocks, which have profoundly impacted the way that countries have opened their network industries to competition and the extent of privatizing their incumbent public monopolies.

The literature that evaluates market reforms in network industries relies on primary and secondary data provided by international institutions such as the World Bank, the OECD, and the IMF. These organizations design surveys and build summary indicators that capture cross-country and cross-sectoral differences in reform adoption. These indicators measure the extent to which regulation restricts market competition and the provisions to correct market failures. The information is gathered through surveys answered by member states or experts involved in the industry. In the case of the OECD, their survey focuses on formal regulatory provisions, while other sources, such as the World Bank, focus on experts' perceptions about barriers to competition (Broughel and Hahn, 2022).

The surveys focus on particular aspects of reforms, which differ according to the policy goal. For instance, the World Bank or the Fraser Institute surveys focus on entry barriers and their classification (legal barriers, barriers to foreign trade). In contrast, the OECD PMR questionnaire focuses on dimensions relevant to the policy objectives of the reform, such as government involvement, vertical separation, price controls, and market structure, among others (Nicoletti et al., 2000; Conway and Nicoletti, 2006). The considered dimensions are crucial to monitoring and evaluating the implications of cross-sectional and dynamic differences between countries and sectors. Aspects should be general enough to capture reform changes between sectors and periods (comparability) and specific enough to provide policymakers with insights about potential reform improvements. No study in our survey uses latent factor techniques to

[1] A priori, both objectives entail a tradeoff between them. If investments are the objective, monopoly franchises should be offered to the investor, while if efficiency is the target, competition is introduced (less costly than regulation), yet it contrasts with the vertically integrated monopoly franchise needed to secure the investments (Newbery, 1999).

[2] In this framework, privatization is not a fundamental component.

uncover aspects/dimensions based on data variability.

We provide a short overview of the current state-of-the-art indicators and dimensions used in the literature to measure market reforms.

OECD Product market regulation

The most comprehensive work on collecting and validating data specifically for network industries (non-manufacturing industries) is done by the OECD (Nicoletti et al., 2000). In 1998, they surveyed the market barriers to competition in the economy-wide and network sectors (see Section 3.3.1 for specific details about the survey structure). We focus our attention on the indicators of network sectors. The questionnaire covers government involvement, monopoly unbundling, and command and control regulation. The indicators aggregate information using a bottom-up approach; information is aggregated into lower-order domains and those scores into higher-order domains until an overview score sums up the barriers to competition. The lower and higher order domains have a sectoral coverage tailored to the structural characteristics of the sectors (Vitale et al., 2020). However, comparability is not always possible. Subsequent updates in the questionnaire are available for five waves, 1998, 2003, 2008, 2013 and 2018 (Conway et al., 2005; Wölfl et al., 2009; Koske et al., 2015; Vitale et al., 2020). The higher-order domains / dimensions are discussed below.

- **Public ownership:** it aggregates information related to the participation of national and local government in the industry and the possible implications of such ownership on the firm's decisions. For instance, substantial state ownership in the incumbent operator deters private firms from entering the market out of fear of preferential treatment (from regulators, for instance). Essentially, the index captures the extent to which the government owns/influences the largest firm in the sector. The questionnaire captures specific information about soft budget constraints and the percentage of state ownership.
- **Entry barriers:** it describes entry regulation and aggregates information about the legal procedures that new market entrants have to comply with or legal limits to their operation. For instance, the component illustrates whether legal provisions limit the number of firms serving a market or whether operators independently choose their routes or service terms.
- **Vertical integration:** it refers to business vertical integration and remedies applied to vertically integrated monopolies. This domain measures the degree of integration between incumbent firms and the natural monopoly segments of the industry. Vertically integrated firms could displace competitors by restricting fair access to specialized assets. Among the questions, we find the negotiation of third-party access to networks and monopoly unbundling. In the case of electricity, the dimensions capture information about the consumer's right to choose suppliers.
- **Price controls:** this category captures information about the ability of governments to fix service or product prices or whether particular methodologies are imposed to estimate those prices.

- **Market structure:** This dimension measures the extent to which one/or several firms concentrate on market operation. Markets with higher concentration might deter the entry of new incumbents. Possibly through abuse of market power or other soft-power tools.

Other measuress

Alternative measures to the OECD Product Market Regulation (PMR) indicators either add information sources to the PMR indexes or rely on different datasets that cover economy-wide barriers to competition, which are also used to proxy network sectors' regulatory environments. A summary is offered below.

A narrative database is introduced in Duval et al. (2018) to track market reforms over time. These new metrics integrate experts' comments and the OECD PMR indicators to correctly represent the timing and scope of major market reforms. The authors define substantial market reform as significant declines in PMR ratings, major reforms deemed necessary by OECD experts, or the publication of several reports highlighting the existence of meaningful reform. Instead of comparing policies across nations or sectors, the goal is to enrich the assessment of the reform's timing and profundity. Bouis et al. (2020) makes use of these indicators to track the delays in the benefits of reforms and their consequences. Similarly, Duval et al. (2021) uses the indicators as the dependent variable to study the impact of the economic crisis on the speed of adoption of new market reforms.

Additional sources describe the market regulation conditions at the economy-wide level and cannot be traced to specific sector characteristics. The questionnaires related to the sources focus on firms' entry and exit barriers. We briefly summarize these data sources based on surveys provided by Nicoletti et al. (2000) and Loayza et al. (2010).

The Economic Freedom Index (Fraser Institute) aggregates data about the size of the government, the legal system and property rights, freedom to trade internationally, and regulation. The index ranges from 1 (for more stringent) to 10 (for less stringent) market regulations. Empirical studies use the regulation component, particularly the data on administrative requirements, bureaucracy costs, starting business burdens, bribes, licensing restrictions, and tax compliance costs. The aggregation of these characteristics has been used in empirical research as a proxy for regulation's restrictiveness on entry and competition (see Gørgens et al. (2005) for an example of the effects of economic regulation on income per capita).

The World Bank provides information about business regulation at the firm, sectoral, and national levels. The Doing Business dataset at the World Bank gathers the most comprehensive information about the time it takes to open a business, the number of procedures, and their costs. Broughel and Hahn (2022) estimates that at least 68% of the studies in their sample use this database to document regulatory barriers. However, recent critics of the Doing Business methodology have obliged researchers to utilize alternative sources such as Enterprise Surveys. However, their coverage is limited.

Finally, the Investment Climate Assessment survey measures firms' perceptions of the investment climate. Time spent with government regulation, time to install a telephone, bribes as a share of annual shares, perceptions about property rights and the legal system, and labor market regulation as an obstacle to economic activity. Individual answers are grouped by industry level. Time comparison could be problematic due to changes in waves of surveys.

3.2.2 Aggregation methods

The construction of summary measures based on qualitative data requires researchers to make decisions that impact the metric and its interpretation. A priori, the importance of each piece of information is unknown and might change over time (in case the metric captures a phenomenon over time). Empirical literature in regulation / reform has relied either on imposing an arbitrary degree of importance (weights) to qualitative characteristics (Gilardi, 2002; Wölfl et al., 2009; Koske et al., 2015; Vitale et al., 2020) or on using data variation to estimate their importance (Nicoletti et al., 2000; Hanretty and Koop, 2012; Jordana et al., 2018).

In the case of imposing weights, these alternatives improve transparency, facilitate the interpretation of the summary indicators, and improve the traceability of the elements aggregated into a domain (Conway et al., 2005; Conway and Nicoletti, 2006). However, potential biases and redundancies are introduced in the summary metrics. One alternative is to assign the same weights to every reform characteristic. The caveat is that fundamental and trivial characteristics of the reform are given the same weight (Koske et al., 2015). Thus, summary indicators are possibly driven by the number of characteristics in the reform / regulatory environment (whether they are essential or not) rather than the current substance of the reform. The problem differs when experts' assessments determine the importance of regulation characteristics because the weights might reflect the experts' judgment on the matter rather than the proper size of the reform (OECD, 2008).

A possible solution to arbitrary weighting is using data variability to estimate the importance of the regulation characteristics. Data variability methods assume that the weights of characteristics are associated with unobservable factors. Different methods estimate unobserved factors and rely on different assumptions depending on the type of data. Kaufmann et al. (2011) estimate governance quality scores (including regulatory quality) by imposing a linear relationship between a latent factor and governance characteristics in a country. Moreover, Nicoletti et al. (2000); Conway et al. (2005); Coco and Russo (2006) apply Principal Component Analysis (PCA) to the OECD PMR indicators dataset. In the first step, data is grouped into domains and sub-domains. The questions that belong to a sub-domain are given a common scale and aggregated to produce a sub-domain score. The PCA is applied to the collection of sub-domain scores. The summary higher-order scores are constructed using the PCA sub-domain loadings.

Even if PCA identifies latent dimensions, the method ignores the categorical component of the data at lower levels. Other studies apply models that

account for the qualitative nature of the information. Other factor analysis models accommodate categorical responses and identify the crucial characteristics within a dimension (Hanretty and Koop, 2012). However, these methods yield similar results compared to arbitrary weighting approaches, Gilardi and Maggetti (2011) find that the association between equally weighted and latent factor indicators is significantly high.

There are other caveats to traditional latent factor models in a panel data setting (when individual units change over time). The survey questions should not vary over time. However, technological, market, and political changes require researchers to update surveys by adding or removing questions. If survey changes are significant, metrics are not comparable between different periods. Significant changes in the OECD RIQ questionnaire have been reported between 2003 and 2008 and between 2013 and 2018 (Conway and Nicoletti, 2006; Vitale et al., 2020). For instance, Vitale et al. (2020) emphasizes that the new OECD PMR indicators (2018) are not comparable with previous waves due to the inclusion of new questions related to entry barriers, vertical integration, and market structure. The OECD has made efforts to preserve comparability in a component of the PMR indicators (reform in network industries) over the long run (1975–2018). However, the effort depends on models with restrictive assumptions. [3]

Another vital aspect of summarization deals with the number of sub-domains / dimensions different studies use to produce their metrics. By dimensions, we mean the number of meaningful higher-order aspects that summarize market regulation. At the economy-wide level, regulation deals with entry and exit, trade, taxes, contract enforcement, labor, and finance (Loayza et al., 2010). Among these dimensions, empirical studies consider entry regulation the most meaningful, while other indicators consider different dimensions in network industries. The OECD PMR indicators use the dimensions in Section 3.2.1 to aggregate information at higher-order levels. Their choice of low- and high-order sub-indicators considers the structural characteristics of industries and policy objectives, i.e., state control, barriers to entry, vertical integration, involvement in business operations, market structure, and price controls (Nicoletti et al., 2000).

A reform overview requires lower-order dimensions to describe different aspects of market regulation. Each network industry faces different technological, market, and political challenges. Any lower-order dimensions definition that could be used across industries should take these differences into account. However, in our surveyed studies, not all reform dimensions are comparable between sectors or traceable over time. For instance, dimensions like *entry* in the OECD PMR indicators do not focus on the same characteristics across industries. Beyond liberalized markets, the *entry* indicator for electricity describes the generators' fair access to transmission lines. In contrast, in air transport,

[3]The OECD estimates Network industries reform scores that vary over time (1975-2018). The OECD applies the splicing method to preserve time series comparability. They fill information gaps in questionnaires and estimate scores for each wave. When questionnaires change, jumps appear in the time series, which are fixed by subtracting the value of the discontinuity in the new series. This technique assumes that new questions added had the same reply in past periods.

entry focuses on cabotage rights and the participation of foreign airlines in the market.

Using latent factor methods, data-generated dimensions could find new dimensions that are general enough to be compared across sectors and over time. Studies that use PCA have attempted to validate pre-defined dimensions Coco and Russo (2006). However, no study has used data-driven approaches to uncover dimensions based on latent characteristics of the data. Only a few studies evaluate whether particular elements of market regulation (regulatory governance) are relevant to a specific dimension. Jordana et al. (2018) identifies relevant features of their governance dimension model using data variability. Based on the results of the estimation, the authors can estimate which features are important or not, even if theory or common practice says otherwise.

3.2.3 Regulation and performance

This section presents a compact overview of the empirical work that links product market regulation and industry performance, focusing on network industries. Different aspects of reform are covered, such as privatization, entry barriers, and monopoly unbundling. The World Bank, the OECD, and the International Monetary Fund assess the reform quantitatively and investigate its implications through a significant body of studies (Broughel and Hahn, 2022). This review presents studies primarily published in academic journals to give the reader an equilibrated viewpoint.

The empirical evaluation of economic regulation in network industries summarizes liberalization using a single dimension that captures the general restrictions on competition. This dimension measures the sector's openness to competition, extent, and timing. Bouis et al. (2020) use the OECD PMR aggregate indicator, along with narrative information about market reforms, to estimate their short-run and long-run effects. The authors identify that market liberalization is positively associated with industry and economy-wide performance (superior capital accumulation and industry-added value). Similarly, Égert (2018) uses the OECD PMR indicators in network industries to evaluate the impact of market regulation on investment. Stringent market regulation is associated with lower investment levels for a sample of 32 OECD countries between 1985 and 2013. Relationships between prices and liberalization are also documented, especially in the electricity sector. da Silva and Cerqueira (2017) document a strong association between market reform (proxied by the date the market was formally liberalized) and lower prices. In other words, countries that liberalized their wholesale markets earlier delivered lower prices.

Other studies measure the effect of competition in network industries on downstream firms that use input from network industries. Literature on the subject argues that anti-competitive regulation in network industries causes downstream industries to transfer rents to their input providers through higher prices or restrictive contracts. Downstream industries accumulate less capital, do not adopt best practices in manufacturing, or reduce their spending on R&D because rents are held in upstream industries. In this way, a reduction in downstream rents leads to lower multi-factor productivity, trade intensity, and

consequently lower economic growth (Bourlès et al., 2013; Fournier et al., 2015; Cette et al., 2017).

Moreover, other studies use the PMR indicators in network industries as a proxy for the economy-wide market regulation measure to evaluate macroeconomic performance. The studies justify this choice because the PMR indicators for network industries are highly correlated with economy-wide PMR indicators and have been available from 1975 to 2018 (Conway and Nicoletti, 2006). For instance, Anderton et al. (2020) uses the NI PMR scores to estimate the effect of anti-competitive regulation on firm entry and exit rates. Following a Schumpeterian argument, competitive markets reduce frictions for firm entry and exit, which leads to the fittest firms' survival, thus improving allocative efficiency.

However, different aspects of market reforms have different implications and mechanisms by which they affect industry performance. Several studies distinguish between privatization and entry barriers to isolate the direct effects of firm ownership and the barriers that limit entry. The distinction helps to verify if all the aspects of market reform have similar or different implications for industry performance. Alesina et al. (2005) uses dimensions of the OECD PMR indicator to estimate the effects of market regulation on investment in the telecommunications, electricity, postal, and transport industries. The study argues that once the intensity of regulation decays, the expected profitability of capital increases. Thus, the capital in the steady state grows. The empirical setup discriminates between the strictness of regulation and privatization to control the influence of firm ownership in the investment stock. By controlling for privatization, the authors were able to capture the previous periods' consistent decrease in investment at state-owned firms.

Similarly, Gal et al. (2016) distinguishes between the overall market regulation indicator (including government ownership) and the entry component alone. The distinction is made to confirm that the source of the regulation's effect on capital, employment, and output comes from entry barriers. Their results suggest a positive and robust association between entry and efficiency. Regarding prices, Gugler et al. (2013) find a robust negative association between government ownership (categorical variable that takes the value of 1 for private ownership and 4 for public ownership) and electricity prices. This finding suggests that government incumbents are concerned about their consumers' prices. [4]

Privatization modifies the incentives of individual actors within the incumbent firm, which also has implications for firm performance. Managers in newly privatized firms are incentivized to maximize stakeholder value and deploy investments in expectation of profitability. Thus, significant privatization leads to the firm's adaptation to the sector's technological conditions. Azmat et al. (2012) finds that privatization is strongly associated with the decline of labor share in a sample of OECD countries. Privatization incentivizes managers to maximize stakeholder value over other social objectives, such as employment protection. Besides, privatization is associated with superior investment and

[4] The authors use government ownership as an instrument for prices in a second-stage regression of investment on prices. The relationship is described as a determinant, and no interpretation is offered.

efficiency in the long run. Regimes in which private incumbents operate can detect profitable investment opportunities and proceed accordingly (Gasmi et al., 2013; Cubbin and Stern, 2006).

Besides, regulators seem to behave differently under a private firm ownership structure. Bortolotti et al. (2011) finds evidence that, under the operation of private firms, regulators observe their operational costs and financial characteristics before setting regulated prices that cover those costs. Private firms anticipate this behavior and finance their operations through more considerable leverage (firm debts as a ratio of the firm's debt plus the firm's market value).

Another set of empirical studies assesses the implications of the reform's other dimensions. Gugler et al. (2013) explores the impact of vertical integration in electricity investments. The authors hypothesize that vertically integrated firms experience lower costs in aligning the long-term interests of generation investors (sunk costs) and the short-term interests of retailers (price-driven) than vertically separated generation, transmission, and distribution networks. They find that vertical separation (two-period lag) is significantly associated with lower investment levels. The regulation of third-party access to the grid shows a similar effect. The evidence in other network industries is scarce; however, the same argument brought up by Gugler et al. (2013) is applied by Howell et al. (2010) in the telecommunications sector because both display similar features and problems related to investments, conflicting parties, and the hold-up problem.

3.3 Data and methodology

3.3.1 Data

This study relies on the information from the OECD Regulatory Indicators Questionnaire (OECD RIQ) (Nicoletti et al., 2000). The questionnaire tracks regulatory reform in the OECD member countries. The first questionnaire was applied in 1998, and the last was in 2018. The survey is administered every five years and focuses on regulations that restrict competition, such as distortions induced by state involvement and entry barriers for domestic and foreign firms. The questions collect information on the regulatory environment at the economy and sector levels, emphasizing network industries (non-manufacturing industries according to the OECD classification). The questionnaire focuses on three main areas: the extent of government influence in the industry, the degree of vertical separation of integrated monopolies or third-party access (TPA), and legal barriers to competition (including the government's ability to regulate prices). A summary of the thematic content is available in the appendix (Table A.4).

The questionnaire varies in content between industries and waves, as shown in Table 3.1. The variation responds to the evaluation of industry-specific regulatory characteristics. In electricity and gas, the survey focuses on vertical integration/separation and third-party access to the grid, compared to the focus on competition and market power remedies in telecommunications. Variation in time responds to the need to keep the questionnaire updated with new tech-

nologies and business paradigms. As shown in Table A.4 (in the appendix), the energy and telecommunication questionnaires experienced the most significant changes. In energy, for instance, the questionnaire records the existence of demand-side incentives to trade electricity or rewards to generators that produce electricity upon request. Meanwhile, the telecommunications survey added questions regarding market power remedies and portability.

The OECD RIQ presents advantages compared to other sources of regulatory provisions in network industries[5]. The surveys focus on an objective evaluation of industry regulation (see Table A.1, Table A.2, Table A.3 in the Appendix section) in contrast to other sources that rely on subjective opinions about the regulatory environment. Moreover, the questionnaire uses closed-ended questions to reduce response discretion and increase cross-country comparability. [6] Similarly, the questionnaire reduces the likelihood of inconsistencies in the responses. The OECD experts validate country answers with external sources, and in case of doubt, member states are asked to re-assess their preliminary responses.

The dataset also presents limitations in evaluating the extent of the reform. First, the questionnaire focuses strictly on competition and do not include questions on environmental or safety regulation that could affect competition (i.e., entry barriers)(Nicoletti et al., 2000). Second, the survey captures only the formal market regulation provisions but not the informal rules or practices in the industry. Third, time comparability requires low variation in the surveys or time series methods [7] to smooth variation in the indicators. The survey has experienced substantial variation between 1998 and 2018, as seen in Table 3.1. Thus, any attempt to construct time-comparable indicators should consider the issue.

This study limits the inclusion of countries and sectors that provide at least 40% of responses in all survey waves. These two conditions yield 600 country and sector observations from 24 countries in five sectors (electricity, gas, telecom, air, and rail transport) between 1998 and 2018. Details about average industry coverage are shown in Table A.5

3.3.2 Methodology

The introduction of competition in network industries depends on their physical and technological characteristics. Previous attempts to evaluate reform in these sectors should be aware of the differences. While particular regulatory aspects or dimensions are common to all sectors (i.e., state involvement in the industry

[5] Alternative surveys, such as the EU survey and the World Bank Doing Business datasets, are used in sectoral studies. In the case of the EU survey, the country coverage is limited, while the WB questionnaire does not reach industry-specific details.

[6] The OECD *RIQ* has two types of questions: continuous (share of state ownership of a firm) and multiple choice (two or more ordered answers).

[7] For instance, the OECD ETCR uses the splicing method to fit indicators based on different questionaries on a single time series. This method assumes that responses to the newly added questions remained fixed for the previous wave. The assumption probably holds when new questions evaluate a technological disruption. However, when new questions describe features that could be measured before, the assumption becomes restrictive.

Table 3.1: OECD RIQ evolution (number of questions)

sector	1998	2003	2008	2013	2018
Electricity	29	31	39	39	53
Gas	28	28	39	39	61
Telecom	24	25	35	35	72
Air transport	14	15	19	19	43
Rail transport	15	18	24	24	25

or price controls), other regulatory aspects differ considerably between sectors. Any quantitative assessment of such dimensions and their metrics should be done with caution.

This study departs from traditional factor analysis techniques (discussed in Section 3.2.2). It proposes a summarization method for categorical data using semantic connections of question words / terms and topic modeling techniques. To this end, data is transformed from categorical to textual in the pre-processing stage. Then, lexical chains are introduced and identified in our dataset (Wei et al., 2015). Finally, topic modeling identifies co-occurring lexical chains and uncovers latent topics (Blei et al., 2003).

Pre-processing

To secure consistency and information availability, only sectors and countries with more than 40% of response rates and answers recorded in the five periods are included in the dataset. This consideration ensures that country and sector responses are representative. Besides, we focus on the formal aspect of market regulation and exclude questions that display the outcomes of reforms. In particular, questions about how many companies are in the market are taken out of our final metrics to avoid problems with endogeneity.

Regarding the questionnaire, we are interested in mapping provisions that regulate markets and access to core natural monopoly segments (i.e., transmission in electricity, rail tracks in rail transport). The OECD RIQ questionnaire evaluates whether or not regulatory provisions are in place. Our dataset contains only positive answers and discards negative ones. However, not all questions hold that dichotomous format (yes or no) and require further transformation. In the case of ordered categorical questions, a new question demands whether a particular category is chosen (or not) and then replaces the previous question. Then, only the positive answer is recorded. In the case of continuous variables, only one question has that format: the percentage of government ownership in the incumbent firm. We assume that having a majority of shares allows the government to influence the firm. Thus, we preserve answers where governments owned more than 50% of the shares and discard them otherwise. [8] As a result, our dataset holds a list of regulatory provisions mapped for a specific country, sector, and period. The first sentence in Figure 3.1 shows the question

[8] Alternative thresholds could qualify state ownership, such as low, medium, or high ownership. However, the use of such thresholds involved additional judgment calls.

If a question's reply is positive,

Original text: Do national governments hold equity stakes in the largest firm in the sector?

it's replaced by:

New text: national (adjective) government (noun) hold (verb) equity (noun) stake (noun) largest (adjective) firm (noun) sector (noun)

Figure 3.1: Example of POS tag and lemmatization in the OECD RIQ

in the survey, and the second sentence shows how we record a yes answer in our database. We will exploit the semantic properties of our dataset to summarize the survey contents.

The textual summarization considers questions (in a given sector, country, and year) as units of analysis and words / terms as the primary input. We aim to represent words / terms in a lower-dimension space by aggregating our words into higher-order categories. The following section introduces lexical chains as a method to uncover these high-order categories. However, first, we need to identify the function of every word in a sentence. To this end, we assign a part of speech (POS) to each word / term and then aggregate similar words into one common root term (lemmatize). In English grammar, POS are clusters of words based on their grammatical properties, such as nouns, verbs, adjectives, prepositions, conjunctions, interjections, articles, and determiners. For instance, tagging lets us distinguish between noun *control* and verb *control*. Besides, POS tagging discriminates between informative and uninformative terms. In our case, we are interested in regulatory information, thus, we use nouns to identify concepts of regulation and verbs / adjectives to qualify the concepts. The rest of the terms are discarded. A lemma is a canonical form of a set of words that are written differently but convey the same meaning. Lemmatization is the algorithmic process of identifying a word's lemma, and it is helpful to reduce the overall number of terms in a document. For instance, the lemma of the word broken is *break*[9], and the count of the word *broken* in a document will be part of the term *break*. In this way, the semantic properties of documents are better represented.

We use the R package *UDPipe* to create the annotated corpus and verify the correctness of POS tagging and lemmatization. Only four POS tagging errors were found in the corpus and corrected accordingly.[10] Part of the errors showed typos and acronyms that were transformed to the full-term version (i.e., TPA to third-party access). After correcting the errors and changes, we rebuilt the annotated corpus. Finally, we remove punctuation and keep nouns, verbs, and adjectives. An example of textual pre-processing is presented in Figure 3.1.

[9]This criterion is usually applied to find lemmas, although, for other words, different rules might apply.

[10]In addition, we found five words with typos. These words were not given a POS tag. We corrected them and reran the procedure.

Lexical chains

Questions and words in the OECD RIQ vary between sectors and new survey waves but describe similar market regulation aspects. Using lexical chains helps to identify shared concepts in our corpus, thus making surveys more comparable over time and sectors. Wei et al. (2015) defines a lexical chain as a sequence of related words that give important clues about the semantic content of the text. In other words, lexical chains are groups of terms connected by semantic relationships. There are four types of relationships; synonymy connects words that convey the same meaning. Hyponyms display terms that belong to a higher-order group. For example, *white* is a hyponym of the higher-order term *color*. Hypernyms are terms that aggregate lower-order terms. For instance, the word *animal* contains the terms cat, dog, or tiger. Meronyms are parts of a word or term. The word *finger* is a meronym to the term *hand*. Finally, holonyms are terms that contain their parts. The word *car* is the holonym of *tire*, *brake*, or *engine*.

In our context, lexical chains reduce our textual information into a smaller number of concepts, accounting for differences in question-wording between sectors. For instance, a higher-order concept of *freedom* relates to *air cabotage* and *vertical separation* in the energy industries. *Freedom* is a meronym of the term *separation* (lack of unity).

Before identifying our concepts (lexical chains), we must determine the meaning / sense a word conveys. Particular words have only one meaning / sense, such as the verb *own* (have possession of), while other words, like the verb *state*, have many meanings: i) express in words; ii) put before; iii) indicate through symbols. To identify the proper meaning of a word, first we need to determine its part of speech (POS) and, second, extract its meaning based on its surrounding words. The creation of the annotated corpus is described in Section 3.3.2. Next, we introduce the word sense / meaning disambiguation algorithm.

The word/sense disambiguation requires evaluating the surrounding words' senses and choosing the one that conveys the highest mutual coherence. The semantic coherence (or similarity) between two senses is estimated based on their semantic proximity. The notion of proximity refers to the number of intermediate senses between a low-order and a high-order sense in a hierarchical classification of words. The distance between two concepts is proportional to the distance of those two senses from a third, higher-order sense that includes them. This higher-order sense is known as a Least Common Subsumer (LCS). If the LCS is close to both senses, their similarity is higher. Wei et al. (2015) uses nouns and their senses to summarize a large text corpus. They use nouns because those terms help identify the contents of texts. We extend the work in Wei et al. (2015) by identifying lexical chains of verbs and adjectives to qualify our concepts (main lexical chains). Therefore, we used two similarity measures in our estimations. For nouns, we choose the Jiang and Conrath (1997) metric for verbs and adjectives, presented in Equation (3.1).

$$\delta_{(C_p,C_q)} = \frac{1}{IC(C_p) + IC(C_q) - 2 * IC(lcs(C_p, C_q))} \tag{3.1}$$

Equation (3.1) uses the concept of information content IC that a word / sense provides. In a hierarchical structure, lower-order terms convey more information and detail about a topic than higher-order terms[11]. When the information content of the LCS between two terms $IC(lcs(C_p, C_q))$ is larger (meaning that the distance between the higher-order sense and the senses p and q is small), the denominator of the expression becomes smaller, thus increasing the similarity between two senses. Compared to Equation (3.2), the main difference is that it uses an external text source and the WordNet lexical database[12] to estimate the IC of each sense.[13].

$$\delta_{(C_p,C_q)} = \frac{2d}{L_p + L_q + 2d} \tag{3.2}$$

In contrast, Wu and Palmer (1994) use Equation (3.2) to estimate the distance between senses (in our case, verbs and adjectives) based solely on distances estimated within the WordNet hierarchical classification. The intuition in Equation (3.2) is straightforward. When the distances between the LCS and the senses p (L_p) and q (L_q) increase, the denominator increases, thus reducing the similarity metric. The expression $2d$ is the distance between a root term and the LCS. In the denominator, the term $2d$ limits the semantic proximity value to one in the case of synonyms ($L_p = 0$, $L_q = 0$).

Once we can discriminate between senses, we apply the maximization algorithm proposed by Fodeh et al. (2009) and Fodeh et al. (2011) to identify the proper sense that a word conveys. The correct sense yields the highest value in Equation (3.3).

$$\hat{s_i} = arg \max_{s_{il} \in S_i} \sum_{t_j \in d} \max_{s_{jm} \in S_j} \delta(s_{il}, s_{jm}) \tag{3.3}$$

[11] In terms of probability, lower-order senses are harder to find; thus, if the sense appears, it provides more information about the hierarchy. The probability of finding a higher-order sense increases monotonically as we move up the hierarchy; thus, it becomes less informative. In the extreme case, if we have a hierarchy with only one top sense, the probability of encountering the sense is 1. Senses like a *boy*, *dog*, and *cat* provide information about the content of a document, while the sense *being* provides less information.

[12] We use the WordNet lexical database to extract the distances between terms. WordNet orders words in a super-subordinate relationship, i.e., a hypernymy/hyponymy relationship.

[13] We choose the metrics based on a benchmarking process. Question by question, we assessed the correct sense based on WordNet senses. Then we compared the results of many measures and picked the one that matched our human assessment. The Jiang and Conrath metric outperformed Wu and Palmer. Jiang and Conrath rely on an external corpus of terms beyond WordNet. Similarly, we evaluated three external corpora and picked the Brown IC corpus, part of Wordnet. Regarding the Wu and Palmer metric, it does not use external sources, just the WordNet ontology.

To determine the best sense, we compare each sense l of the word i to all of its surrounding words j and senses m. First, we calculate the $\delta(s_i l, s_j m)$ similarity distances between the first sense l of a word i and the senses m of a word j.The largest similarity value is preserved, and the rest of the distances with the m senses are discarded. Then, we repeat the same exercise with the rest of the surrounding words j and sum all the preserved distances. After estimating the summation for each sense l of word i, we choose the sense with the highest value. The same procedure is applied to the rest of the words in a document. The result is a corpus represented as a set of senses. A list of words and senses is provided in Table A.6, Table A.7, and Table A.8 in the Appendix section.

After all the terms in the question are disambiguated, we identify the lexical chains following Wei et al. (2015). In a lexical chain, connections between disambiguated senses are determined by the semantic relationships between them. There are different degrees of relationship, which are given by the senses' hierarchical position (as in the WordNet structure). In other words, senses at the same level (synonyms) hold a more robust relationship than higher- or lower-order senses (hypernyms and hyponyms). The hierarchical structure also considers senses as the sum of fragments or parts of a larger sense, as in the case of meronyms and homonyms, respectively. However, these relationships are less significant than those between the first two groups above.

Once we establish the connections between senses, we construct the lexical chains (clusters or senses) using our corpus'[14] list of unique senses. The matching strategy starts with identifying the semantic relationships of each disambiguated sense with the rest of the terms using the WordNet database. The WordNet database identifies a sense's connection to every synonym, hypernym, hyponym, meronym, and holonym. Next, we represent senses' connections as undirected graphs in which senses are nodes, and the relationships are the weighted edges. Graphs are created for nouns, verbs, and adjectives individually. Figure A.3 shows the undirected graph for nouns as an example. A complete list of lexical chains is offered in Table A.9, Table A.10, Table A.11, Table A.12 and Table A.13 in the Appendix section.

The identified lexical chains allow us to reduce the number of features in our documents (cluster similar words / terms within a higher-order concept). Still, we need to assign a representative tag or name to the identified concept. To this end, we estimate the importance of each term in the lexical chain by summing up the number of immediate connections it has with the other disambiguated senses. A list of tags is provided in the appendix.

Finally, our strategy estimates a score to highlight the importance of each lexical chain in our corpus. The score allows us to discriminate between representative and non-representative concepts and preserve those that are more informative. Wei et al. (2015) estimate the concept's importance using Equation (3.4).

[14] We used the package Reticulate in R to import text handling tools from Python. We use the NLTK package and tools to estimate similarity distances. The matching algorithm to construct the lexical chains was implemented in R.

$$S(l_m) = w_l * r_1 + \sum_{k=3}^{5} \sum_{p=1}^{q} w_m * H(c_l, C_m, k) * r_k \tag{3.4}$$

In Equation (3.4), $S(l_m)$ is the concept score for concept m, the term w_m accounts for times a sense (or a synonym of sense i) appears in a document, multiplied by the weight r_1. The term $H(c_i, C_{p,k})$ is equal to 1 if a connection exists between senses c_l and c_m, and 0 otherwise, multiplied by the connection's weights r_k. We preserve the same weights given by Wei et al. (2015), 4 for synonyms, 3 for hyponyms/hypernyms, and 2 for meronyms/holonyms. As a result, we estimate the concepts' importance in sector- and country-level texts. In the following section, we provide details about the data-cleaning process and use the concept representation as input for topic modeling.

Topic modelling

Topic modeling describes textual documents as mixtures over latent topics in the corpus. These topics are defined and labeled according to word co-occurrence and summarize highly dimensional feature spaces. In this section, we expand the usage of topic modeling to the lexical chain (concepts) representation of our corpus. This method has increased significantly in economics, political science, and management recently. In economics, Bandiera et al. (2020) and Brousseau and Gonzalez-Regalado (2022) use topic modeling to detect latent traits in management and regulatory governance fields, respectively.

More specifically, we use the Latent Dirichlet Allocation (LDA) to model market regulatory characteristics (at the rule level) in a country or sector as a mixture of topics (dimensions). Differences in concepts' prevalence in every document identify dimensions and concepts' weights. These weights are comparable across dimensions, sectors, countries, and periods. We briefly explain the LDA model generation process in our context. We follow the notation from Blei et al. (2003). The probability of observing a particular rule/provision depends on each regime's dominant dimension(s), as follows:

1. Draw $\theta \sim \text{Dir}(\alpha)$
2. For each provision w_n:
   (a) Draw a topic (dimension) $z_n \sim \text{Multinomial}(\theta)$
   (b) Draw a concept (descriptor) w_n from $p(w_n|z_n, \beta)$, a multinomial probability conditioned on topic z_n

In the previous generative process, our objects of interest are:

α: Dirichlet prior to the distribution of topics over documents.

β: Dirichlet prior to the distribution of concepts over topics.

θ: topic distribution vector

z_n: *n-th* topic in a provision

w_n the specific concept in a provision

N: the number of descriptors in a given provision

We will use the terms topics and dimensions interchangeably; the same treatment holds for the concepts and descriptors of the terms. The previous process explains the way the n-th descriptor appears in our dataset. At the corpus level, we draw the α parameter, which determines the dimension weights θ and the β parameter that specifies the weight of concepts within a topic. We draw a topic z_n for each concept w_n in the document given *theta*. Finally, given a topic z_n, we draw a concept conditional on z_n and *beta*.

A Dirichlet n-dimensional random variable *theta* can have values in simplex (k-1), implying that $\sum_{n=1}^{k} \theta_n = 1$ .We interpret θ as the influence that a particular dimension (topic) has on the existence of a regulatory rule/provision—different weights of θ capture the observed differences in survey answers across sectors and countries. [15]

For model inference, we are interested in calculating the posterior distribution of our latent dimensions given a provision θ as shown in Equation (4.1). However, this distribution does not support an exact inference (Blei et al., 2003). Following Griffiths and Steyvers (2004), we applied Gibbs sampling to approximate the latent posterior distribution. [16] The estimation uncovers three latent dimensions, as shown in Figure 3.2. The dimensions are interpreted and evaluated in the next section.

This work uses correlation analysis to estimate the *optimal* number of dimensions. We rely on the recommendations in OECD (2008); we check which n-dimensional model highlights consistent associations with the PMR score sub-components. By "consistent associations," we mean that the direction of the association between our indicators and the OECD PMR sub-components is preserved between sectors. For instance, a reliable *network access* dimension should highlight the same positive correlation with the OECD *Vertical Separation* scores, regardless of the evaluated sector. We compared all models between three and six dimensions; the three-dimension model preserved coherent correlations. [17].

[15] The LDA assumes that the number of topics n is fixed and known. To estimate the "optimal" number of topics, we applied the recommendation about the correlation with alternative variables suggested by OECD (2008)

[16] We estimate the topic / term posteriors using the R package Chang (2015). The estimation requires specifying the hyperparameters α and β. Their choice depends on the number of topics (T) and vocabulary size. For α we set a value of 50/T (Griffiths and Steyvers, 2004). We choose to set the value of β at 0.05, which lies at the midpoint of the literature's values.

[17] The Jones (2019b) coherence score (the score discriminates between meaningful and meaningless word/term correlations) suggests a 5-dimension model. However, the correlation analysis presented before yields inconsistent correlations.

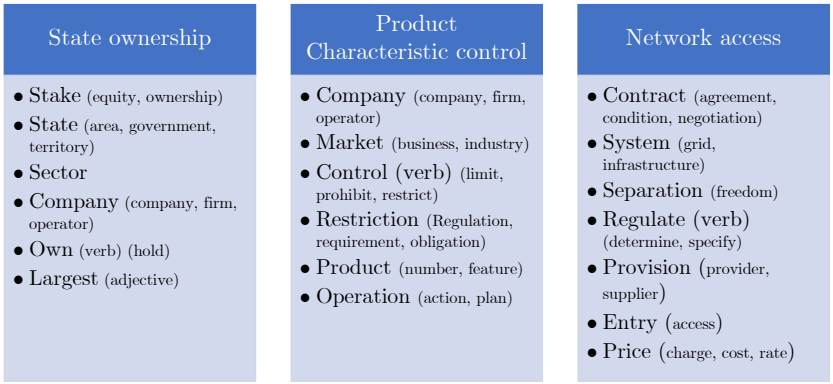


Figure 3.2: Descriptor distribution by dimension

3.4 Results

3.4.1 Three dimensions characterizing market reforms

In Figure 3.2 and Figure A.6, the most frequent concepts/expressions for each dimension are highlighted. These lists help us to understand the concept behind each cluster. We use semantic networks and correlation with the OECD PMR ratings to analyze each dimension.

Both figures highlight three latent regulatory dimensions that characterize market regulation in network industries. [18]

- **State control** refers to the extent to which the government holds substantial ownership of the incumbent firm in the industry. This dimension accounts for the government's influence on the firm's decision-making (50% of ownership or plus).
- **Product characteristic control** refers to incumbent firms' ability to impose product/service conditions and characteristics on their consumers. This dimension reflects the incumbent's power to impose frictions on the market through service quality setting.
- **Network access** tracks the extent to which regulatory provisions grant new incumbents access to fundamental systems, networks, or infrastructure to supply or provide their services.

The correlations between our dimension and the OECD PMR subcomponents (which utilize the same dataset) validate our definitions. The correlations [19] are robust at the national (Table A.14, Table A.15) and sectoral (Table A.16,

[18] Most influential concepts are presented in Figure 3.2. Specific concepts/terms at the industry level, i.e., *transport*, *electricity*, *telecom*, are omitted for interpretation purposes. Our aim is to highlight the comparability of our dimensions across industries. The complete top term list is presented in Figure A.6.

[19] Spearman correlation coefficients are presented in the appendix. Similar estimations are obtained with Pearson correlation coefficients (not reported).

Table A.17) levels. The coefficients at national and sectoral levels hold similar signs and magnitudes of associations, which give us confidence in the coherence of our dimension definitions. We arranged the variables to link high performance in a dimension with a high numerical score. [20]. For clarity, we contrast the indicators' dimensions based on the ownership of the incumbent firm (i.e., state ownership) and a market regulation component. The division helps to distinguish between the influence that the government can exert over an incumbent firm and the market rules and provisions that affect all market participants.

Our *state control* variable is highly associated with the OECD PMR *Public Ownership* indicator. The correlation pattern holds at national (0.89) and sectoral levels (ranges between 0.37-0.78) (Table A.14,Table A.17). These strong associations highlight that both subcomponents capture similar information, that is, the extent to which the government is involved in the incumbent's operations and governance (Vitale et al., 2020).

Regarding market regulation, we contrast the OECD *entry*, *market structure*, and *vertical integration* components with our *product characteristic control* and *network access* dimensions. The results are presented in Table A.15 and Table A.16. In Table A.15, we observe that *Product characteristic control* is negatively and significantly associated with *entry* (-0.51) and *market structure* (-0.41) subcomponents, while the linear association with *vertical integration* is not significant. The negative coefficients suggest that *characteristic control* is associated with high entry barriers and high market concentration, which might reflect the incumbent's power to impose product characteristics in the market that limit entry and, therefore, the number of competitors in the industry. The coefficients of *network access* are associated with the three subcomponents of the OECD PMR. Both *entry* (0.79) and *vertical integration* (0.70) register the highest coefficients while *market structure* (0.66) ranks relatively lower. The *entry* correlation suggests that *network access* is associated with an increase in *entry* due to a reduction of legal barriers (i.e., third-party access regulation, consumer rights to choose their supplier, access to a liberalized market), as well as the extent of the separation between the segments of the vertically integrated monopoly. Similar associations are found when assessing the correlations at the industry level. The coefficient's size and significance vary between industries but preserve the same association direction, as shown in Table A.16.

Our approach coincides with the OECD PMR in identifying a state / government influence dimension. However, our approach also seems useful in disentangling two dimensions of the market reforms: product / service configuration and access to the network. These two dimensions focus on the object of regulation, in contrast to the OECD PMR approach, which highlights the areas of policy intervention (Nicoletti et al., 2000).

In addition to the list of frequent concepts per topic, in the model in Section 3.3.2, we estimate the topic distribution by document, θ_k. Individual topic contributions range from zero (0) (no contribution) to one (1) (full contribution),

[20] In the case of the PMR indicators, they assign scores between 0 and 6, being 0 a fully pro-competitive industry and 6 being a restricted market. The OECD PMR indicators score regulatory domains such as entry, market structure, vertical separation, and state involvement separately for the waves between 1998 and 2013. Only two subcomponents are provided for 2018: state involvement and market regulation level

and they sum up to one (1) ($\sum_{k=1}^{K} \theta_k = 1$). We interpret these distributions as the influence of the considered dimension in a given sector / country. A summary of the dimension scaled scores (θ) is presented in Table A.22

Next, we determine if our dimensions can define various market regulatory regimes. Distributional similarities between dimension scores show their number is inaccurate and should be corrected. Figure A.16 and Figure A.15 show distributional differences by dimension at national and sectoral time averages, respectively. After a visual assessment of the Figure A.16, the long-run distributional properties of each dimension are different in terms of location (different means) and the concentration along the ends of the distribution (shape of tails). On the top panel, the *Product characteristic control* distribution shows a concentration around the mean ($mean = 0.16$), which suggests that countries share similar legal provisions to control product quality in the market. However, the visual inspection seems insufficient to determine distributional differences between *network access* and *state ownership* besides the different mean locations (-0.12 for *network access* and 0.08 for *state ownership*). As a result, we examine distributional differences at industry time-average levels.

Figure A.15 shows the dimension distribution at the sectoral level, and highlights stronger differences across them. In the case of *product characteristic control*, the top panel indicates the presence of a high (right) and a low (left) influence cluster. The observations in the low cluster are concentrated toward its mean, which suggests that regulatory regimes with low *characteristic control* influence tend to converge on a common value. In contrast, sectors and countries that place a high value on *characteristic control* have a variety of arrangements at their disposal. The middle panel shows that *network access* configuration is very heterogeneous among regimes. The bulk of observations are distributed into two groups on the left side of the distribution (bimodal distribution), while the high values of *network access* are scarce on the right side. This distribution highlights that the long-run levels of *network access* influence are weakly / fairly present in the market regulation regimes, at least for a considerable group of sectors/countries. The bottom panel in Figure A.15 presents the distribution of *state ownership* and shows that the dimension influence is more homogeneous across sectors / countries. The values are more concentrated than the mean, with a limited number of extreme values. [21] The previous descriptions highlight significant differences in market regulation configurations, despite the European Union's attempt to liberalize network industries. The configurations might reflect deep political, institutional, national, and sectoral characteristics.

Robustness of interpretation

Beyond the correlation analysis presented in the previous section, we use alternative visual tools to verify our interpretations. First, we check if our dimensions display coherent trends over time (OECD, 2008). In several reports, the OECD

[21] The *characteristic control* score distribution is right-skewed (skewness = 0.59) and has a standard deviation of 1.1. *network access* distribution is right-skewed (skewness = 0.70) and has a standard deviation of 0.82. The *state ownership* score distribution is left-skewed (skewness = -0.17) with a standard deviation of 0.59. The skewness and standard deviation values suggest that different dimensions portray different market regulation characteristics

suggests that pro-competition regulation and privatization have increased over time. The provisions that grant entry, vertical separation, and the removal of legal barriers have increased since 1998 (Nicoletti et al., 2000; Conway and Nicoletti, 2006; Wölfl et al., 2009). In Figure 3.3, the trends in the three panels follow the expected trajectories, according to the correlations in Section 3.4.1. The first panel indicates that *characteristic control* decreases significantly over time for the electricity, gas, telecommunications, and air industries (the decrease is very modest in the rail sector). The decrease is consistent with the increase in competition among firms and the introduction of independent system operators that limit the incumbent firm's ability to impose product standards. The second panel in Figure 3.3 suggests that *network access* has increased over the analysis period. This trend is expected after the introduction of third-party regulation to the network and provisions that support the legal separation of vertically integrated firms (Koske et al., 2015; Vitale et al., 2020). Finally, the third panel shows a decline in *state ownership* between 1998 and 2018. This decline is consistent with previous studies (Azmat et al., 2012) that find a decline in public ownership among the OECD member states.

Besides, we use text analysis tools to verify the connections between concepts /senses found in Section 3.3.2. We assess the joint semantic coherence of our definitions (dimensions) by graphically evaluating the semantic networks (introduced in section Section 3.3.2). The semantic networks highlight the concepts / terms with high centrality and the term connection structure. In Figure A.7, we observe the connection between the concepts of *separation* and *industry/sector*. Moreover, the network connects the senses *contract*, *entry*, *company*, *service*, and *participation*. The links suggest a relationship between legal instruments such as contracts (agreements, conditions, and negotiations) that guarantee new suppliers fair access to the core natural monopoly segments of the industry (vertical separation). Besides, through regulation, new incumbents access the system by paying reasonable costs, charges, and prices. The Figure A.8 depicts three central terms, *company*, *control*, *restriction* and *product*. Those terms seem to refer to the relationships between regulations, restrictions, and requirements that confer control of product or service characteristics on an incumbent firm. *state ownership* captures central terms like *company*, *state*, *stake* and the *own*. The links between these concepts depict the level of state involvement in the incumbent ownership, as shown in Figure A.9.

3.4.2 Cross-Industry and Cross-Country Comparisons

As shown in Figure 3.3, the level and extent of market reform differ considerably between our dimensions and sectors. Overall, there are two groups of sectors that highlight similar trends. The energy and telecommunication sectors started with relative competitive markets, reflected by a relatively higher *network access* and lower *characteristic control* influence. In contrast, the transportation industries seemed to start their market reforms later. According to our measurements, the air industry has undergone significant reform by reducing the influence of incumbent firms on product characteristics and allowing new careers to enter through superior network access. At the dimension level, differences across both groups persist.

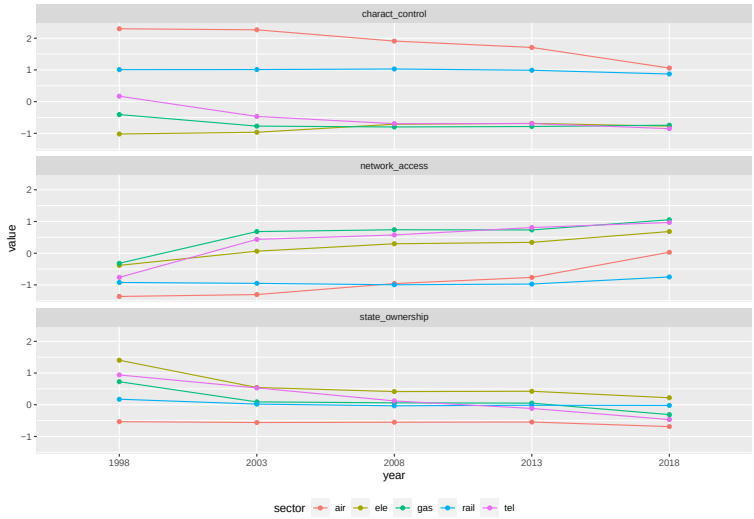


Figure 3.3: Evolution of dimension averages by sector (1998-2018)

The top panel shows that the energy and telecommunications industries started with relatively lower but different levels of *product characteristic control* influence, and the levels have converged to similar lower levels. The transport industries show higher *characteristic control* influence, but their initial levels differ considerably; the air sector's *characteristic control* started with a higher industry average and almost reached the level of the rail industry's influence (which has not varied significantly) in 2018. The two convergence points seem to reflect constraints on product characteristics between utilities and transport services. While the energy and telecommunications industries provide services that must adhere to specific characteristics while remaining competitive, the transportation industries, particularly passenger transportation, must adhere to strict safety requirements throughout any liberalization process. IATA (2007) acknowledges the tensions between safety and the liberalization of the air sector. The document prioritizes security and safety over competition, restricting its expansion with an overarching safety principle.

The middle panel in Figure 3.3 shows that all sectors, except rail, have experienced superior *network access* influence on their market reforms. Energy and telecommunication industries exhibit higher and similar *network access* influence compared to transport industries. The transportation industries—air and rail display heterogeneous behaviors. The rail sector's *network access* influence remained quite stable in the analysis period, while the air sector reinforced the access influence, especially between 2013 and 2018. In contrast to *product characteristic control*, the middle panel suggests that the influence could reach a similar level of convergence, except for rail. The sector's lack of convergence possibly reflects the difficulties and tensions of opening competition in a sector with strong government involvement in the network operation and service provision segments (Casullo, 2016).

On the bottom panel in Figure 3.3, the differences between the govern-

ment influence on the incumbent firm (*state ownership*) start relatively higher in the energy and telecommunication industries, in contrast to the transport industries. However, governments have lost considerable influence on the industry in energy and telecommunications, while the influence in transport has remained quite stable. This pattern suggests that the privatization of utilities has driven the loss of government influence. This pattern suggests that institutional and technological constraints on privatization could be tighter in the transport industries. One potential explanation is that public service obligations are imposed on transport operators and require significant subsidies from the government (especially in the rail industry). State-owned firms might facilitate the coordination and implementation of service provisions under a specific subsidy scheme (Nash, 2008).

Comparison of regulatory governance regimes

To compare regimes across countries, we use score-time averages (1998-2018), *mean*, and growth rates (1998-2018), *growth*. Time averages capture the long-run characteristics of market regulation, while growth rates highlight institutional evolution. We distinguish between the type of reform, either *characteristic control* or *network access*, on the left panel, and the *state ownership* on the right panel of Figure A.1 for mean scores.

Different technological and institutional (formal and informal) provisions are expected to influence the structure of network industries in the long run. The structure of the natural monopoly, the physical characteristics of the product, the speed of technological innovation, and political pressures determine different regulatory configurations between sectors and countries. These differences are evident on the right panel of Figure A.1, which presents the mean differences in market reforms among our OECD country sample. Countries are sorted by the distance between *network access* and *product characteristic control*. The distance helps us observe differences in the prevalence of certain dimensions among countries. The panel suggests that in only four regulatory regimes (Great Britain, Germany, Spain, and Denmark), *network access* is higher than *characteristic control* influence. The second group of countries shows a negative distance (with a prevalence of *characteristic control*) that includes Sweden, the Czech Republic, Estonia, Italy, Ireland, the Netherlands, and Belgium. On the other side of the distribution, three countries (France, Slovenia, and Switzerland) show a significant negative distance.

The previous country clusters are associated with the influence of state ownership, as shown in the right panel of Figure A.1. The distance between *network access* and *product characteristic control* seems to be negatively correlated with the influence of *state ownership*. The first group (high *network access*) is associated with a lower influence of *state ownership*. The same pattern holds for the rest of the groups. The association might highlight the persistent effects of institutions and the technological endowment of each country under state ownership. Influential state incumbents do not face substantial competition; thus, product setting is either imposed by the incumbent or the regulator. In addition, the low, competitive structure does not call for reforms that support the entry of new incumbents. For instance, Nicolli and Vona (2019) finds that

lower incumbent power increases the likelihood of the introduction of legislation that supports the entry of new market participants in electricity generation.

Comparing the evolution of regulatory governance regimes

To evaluate the institutional evolution of market regulation, we assess the relative change in the score between 1998 and 2018. [22]. The results are presented in Figure A.2. We preserved the country order in the first section to contrast the evolution of regimes with their long-run characteristics. The aim is to observe whether the structural characteristics of regulation have an influence on the evolution of the reform. The dashed line in both panels indicates whether the dimension evolution is positive or negative.

The structural characteristics partially explain the extent of the reform evolution, but they are not fully determinant. On the left panel, we observe the differences in the significance of reform evolution. All countries, except for Great Britain, have reinforced the influence of *network access* (green) in their regulatory frameworks. It is not surprising that countries in the first cluster (Great Britain, Germany, Spain, and Denmark) report modest increases in *network access* because they already experienced high levels of access. However, the largest heterogeneity is found in the middle section of the country list (Sweden, Czech Republic, Estonia, Italy, Ireland, the Netherlands, and Belgium, Portugal, Austria, Norway, Slovakia, Iceland, and Hungary). In this cluster, we find the countries that varied the most in our sample (Portugal, Netherlands, and Sweden). The countries in our last cluster (France, Slovenia, and Switzerland) registered positive influence evolution, but they are lower than the previous cluster. The decrease in *characteristic control* (red) is more evenly distributed in contrast to *network access*. The countries of the first cluster have almost no variation in *characteristic control* influence, while the rest of the negative variations seem to be similar, except for Spain, Finland, and Italy, which register a significant decrease in the *control*. Moreover, the right panel of Figure A.2 shows that *state ownership* influence has decreased for almost all the countries in our list, except for Portugal, Hungary, and France. Again, the distance between *network access* and *product characteristic control* does not seem to explain the observed pattern. Our dimensions and scores might be relevant to elicit questions regarding the institutional and sectoral determinants of market reforms.

3.4.3 Reform dimensions and performance

At this exploratory stage, we do not claim to demonstrate causal relationships but rather to identify relevant associations that might explain the potential impact of market regulation on industry performance. We want to give stylized information concerning market reforms and industry performance in output (service coverage, investments, penetration levels), quality (environmental

[22] The regime's evolution is measured in percent change relative to the initial situation by comparing scores between two periods. We define percent change as $PCH = \frac{rawscore_t - rawscore_{t-1}}{rawscore_{t-1}}$

characteristics[23]), and prices.

We divide our analysis into two sections, Section 3.4.3 attempts to detect meaningful associations using cross-industry comparable outcome variables, such as factor productivity and investments. The assessment of these variables demands a statistical analysis that accounts for the time required for a reform to impact sectoral outcomes (Égert and Gal, 2017). Section 3.4.3 studies specific - sectoral variables that do require shorter time spans to reflect the influence of market reforms (i.e., prices). Descriptive statistics of our dependent variables, regulation dimensions, and their information sources are provided in table A.23 for energy, table A.24 for transport and table A.25 for telecommunications in the Appendix section.

Pooled sample correlations

In this section, we show the potential associations of our indicators and factor productivity and investment [24] using the pooled sample (all sectors in our analysis). To estimate significant, stylized effects, our analysis needs to account for the time that institutional reforms require to produce results (Égert and Gal, 2017; Bouis et al., 2020), and the process that state and private firms follow before deploying new investments. These investments in specialized and costly assets usually require careful and detailed planning to reduce uncertainty about firm returns or consumer welfare (Stern, 1997). Moreover, a robust analysis must consider the persistent effects of previous investment decisions on current investment levels. As pointed out by Eberly et al. (2012), the lagged level of investment predicts current levels of investment, in particular at the firm level. To account for all the previous considerations, we use the model in Equation (3.5):

$$y_{ict} = \alpha + \nu y_{ict-1} + \beta x_{ict-1} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict} \tag{3.5}$$

In Equation (3.5), our outcome variable is the investment (the industry gross fixed capital formation as a share of total capital stock) in the sector y_{ict} and the term x_{ict-1} captures the lagged values of our regulatory dimensions. The term y_{ict-1} controls for the persistent effects of investment, and ν stands for its effect. The term α is an intercept, and ϵ_{ict} is an idiosyncratic error term, following the work of Alesina et al. (2005) [25], we also included a battery of sectoral θ_c and country γ_i fixed effects and common time dummies λ_t. Although our model accounts for significant sources of sectoral (technology) and national (institutional, political, and geographical) characteristics, it does not account for macroeconomic shocks on the reform. Reform implementation is politically

[23] Although telecommunication technologies contribute to services that reduce emissions, the sector's main activities do not generate a direct, measurable impact on the environment.

[24] We use data from the OECD Structural Analysis Database (STAN) to estimate our investment and added-value variables for five periods (1998, 2003, 2008, 2013, and 2018)

[25] The authors provide causal estimates of the regulation effect on investment in a 21-country OECD sample between 1978 and 1998. In their study, they use a similar specification (compared to Equation (3.5)) to provide their estimates. We departed from their setup because, in contrast to their dataset, the number of periods in our data would not lead to consistent estimates (T = 5); thus, we use a dynamic OLS model and acknowledge the endogenous problems of our estimates

feasible during periods of economic growth because there are more resources to compensate losers. Meanwhile, bad macroeconomic performance triggers claims for reforms to bring efficiency to inefficient network industries. In addition, our model is limited by the small number of periods (T = 5); thus, we cannot apply alternative dynamic estimation models (i.e., Arellano and Bond (1991)) to deal with endogeneity. Our interest is in estimating the degree of association between our dimensions and performance β.

Table 3.2: OLS estimations: One period lagged independent variables

	Dependent variable:			
	log(investment = GFCF/CAPG)			
	(1)	(2)	(3)	(4)
$network.access_{t-1}$	0.070*			0.066*
	(0.041)			(0.039)
$state.ownership_{t-1}$		−0.060		
		(0.038)		
$charact.control_{t-1}$			−0.058	−0.014
			(0.075)	(0.072)
Lagged investment y_{ict-1}	yes	yes	yes	yes
Country FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Time FE	yes	yes	yes	yes
Observations	281	281	281	281
R^2	0.546	0.544	0.542	0.546
Adjusted R^2	0.495	0.493	0.491	0.493
Residual Std. Error	0.384	0.384	0.385	0.384
F Statistic	10.815***	10.734***	10.659***	10.403***

All reported variables are expressed in logs. The dependent variable is the division of the gross fixed capital formation by the total capital stock measured in current Euro. In model (4), we exclude *state ownership* because of multicollinearity. Robust standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01

We present our results in Table 3.2. Models (1) through (3) test the degree of association between individual dimensions, whereas Model (4) controls the overall effect of our regulatory variables. Only the lagged coefficient of *network access* is associated with higher investment in the current period after controlling for the investment in the previous period. Our associations suggest that the regulation of "fair" access to the network is more relevant to explaining investment levels than the rest of the dimensions. Provisions that support *Network access* seem to increase industry investment levels by improving the entry conditions for new firms in the market. The coefficients of *characteristic control* and *state ownership* show consistent negative estimates but are not significant at conventional levels. These associations support the findings of Alesina et al. (2005); the authors found a significant negative association between all the dimensions of market regulation (government involvement, entry regulation) and investment, but for a different period between 1978 and 1998. While Alesina et al. (2005) offer estimates for "anti-competitive" regulation, our results highlight the potential impact of *network access* regulation on performance. Moreover, our correlations are coherent with other recent studies in network industry investment (Égert, 2018; Papaioannou and Dimelis, 2019; Bouis et al., 2020). While these studies rely on unidimensional indexes to measure market regulation, our study evaluates market reform associations by separating their dimensions.

We also evaluate the influence of market regulation on GDP and industry value added. However, we do not find strong correlations using our econometric specification. Therefore, we do not report the coefficients.

Sector associations: econometric specification

The assessment of sector-specific variables (except investment) allows us to relax the linear model presented in Equation (3.5). At the sector level, we assume that current levels of market reform have a contemporaneous impact on prices, production / service provision levels, input choices, and revenue levels beyond the long-run levels presented in the previous section. Blanchard and Giavazzi (2003) suggest the effects of deregulation (changes in market reform) in the short run decrease entry barriers for firms, and the higher number of firms affect service provision and rent distribution. Given the importance of short- and long-run effects of reforms, we use two linear models to uncover significant associations in our study, as shown in Equation (3.6) and Equation (3.7). This approach allows us not only to uncover significant associations but also to identify whether short- and long-run effects share similar magnitudes and directions.

$$y_{ict} = \alpha + \beta x_{ict} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict} \tag{3.6}$$

$$y_{ict} = \alpha + \beta x_{ict-1} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict} \tag{3.7}$$

Furthermore, in cases where investments have an impact on the outcome variables, such as electricity generation, gas production and transportation, service penetration in telecommunications, and traffic in the air and rail industries, we added a lag dependent variable $y_ict - 1$ (see Section 3.4.3 for the justification).

Sector associations: Energy

As seen in Table 3.3 [26], regimes under significant *state ownership* influence are associated with lower levels of total electricity production (Model (1), column *Coeff*) and lower share of generated solar energy (Model (4), column *Coeff* and column *Coeff lagged*). Besides, the *state ownership* influence is negatively associated with electricity prices for industrial (Model (8), column *Coeff lagged*), residential consumers (Model (10), column *Coeff*), and gas industrial consumers (Model (12), column *Coeff*). These associations could suggest that the historical aspects that have shaped European energy systems, i.e., energy security, natural-resource endowment, technology, and fuel choices (Mez et al., 1997), condition current operational and investment decisions, especially in regimes in which a powerful public-owned firm operates. Powerful state incumbents already specialized in a particular technology, and fuel choice (nuclear, hydro, and coal) might persist in the current system operation and the energy mix, which could marginally reduce the system's performance, delay the adoption of

[26] A detailed report is given in Table A.27.

new technologies (like solar or wind), or affect business practices (Cubbin and Stern, 2006; Gasmi et al., 2013), but with no harm to consumers' prices. These last associations should be interpreted carefully because they do not account for the intervention of regulatory objectives and governance (Newbery, 1994). The significant negative effect on prices is also documented by Florio (2014) for a 15-country OECD sample between 1990 and 2007; however, the authors do not discuss a possible underlying mechanism that drives their results. [27]

Table 3.3: summary of regression estimates for energy variables

Model	Type	Dep Var	Dimension	Coeff	Coeff lagged
1	Perform	total_elec_prod	gov_ownership	-0.09*	-
2		total_elec_prod	network_access	0.08*	-
3		gas_loss	charact_control	0.39	-
4	Quality	share_solar	gov_ownership	-1.10	-1.03
5		share_solar	network_access	1.05	-
6		share_wind	charact_control	2.64	-
7		gas_transport	charact_control	-	-0.92*
8	Prices	elecind_price	gov_ownership	-	-0.25*
9		gashou_price	network_access	0.16	-
10		gashou_price	gov_ownership	-0.16	-
11		gasind_price	network_access	0.13*	-
12		gasind_price	gov_ownership	-0.15*	-

Dependent variables: $total\_elec\_prod$ total electricity produced in MWh, gas_loss gas losses in metric tons, $share\_solar$ share of solar energy relative to the total energy generated, $share\_wind$ share of wind energy relative to the total energy generated, $gas\_transport$ share of gas used in transport industries relative to the total amount of gas disposable, $elecind\_price$ electricity prices for industrial consumers, euro per MWh, $gasind\_price$ gas price paid by industrial consumers in euro per metric tone, $gashou\_price$ gas price paid by household consumers in euro per metric tonne. Column *Coeff* presents the regression estimates of our dimensions, significant at 10% of significance level or below. The column *Coeff lagged* reports the coefficient of the lagged scores of our dimensions ($reg.dimensions_{t-1}$); the coefficient with a significance of 10% or below is reported. An asterisk at the right of the coefficient columns shows that the estimate is robust to the inclusion of the lagged dependent variable (y_{ict-1}). For the complete regression results, see Table A.27. Robust standard errors estimated.

Network access is associated with superior electricity generation (column *Coeff* in model (2)). The dimension increment might be the product of new renewable generation participants; *network access* is associated with a larger solar share in electricity generation (column *Coeff* in model(5)). The coefficient might reflect that "unbiased" entry conditions successfully attract new renewable energy generation power, at least for the period of analysis (Nicolli and Vona, 2019). At this stage, we cannot distinguish between the effect of *network access*, national decarbonization objectives, and the current influence of national and European support schemes). Besides, we observe a strong association between *network access* and gas prices for industrial and residential consumers (column *Coeff* in models (9,11)). The gas tariff setting depends on a myriad of factors, such as demand, international gas prices, alternative energy alternatives, and rent distribution between different segments, among others (Austvik, 1997). Some of the factors also vary with *network access*. This interaction might explain the association between positive coefficients and superior access to the network,

[27] The authors acknowledge that their results reflect the effect on average prices and not about the distributional effects of privatization, in particular, and the liberalization reform distributional effects in general. A distributional analysis might reveal the "true" winners and losers of the reform.

but more research is still needed to disentangle the effect of regulation.

The associations of *characteristic control* with electricity are significant for the share of wind-generated electricity (column *Coeff* in model (6)). This association suggests that in regimes in which generators can impose product / characteristic conditions, renewable generation, which is intermittent (not continuously provided and non-monitoreable), finds lower restrictions to supply electricity to the network. Markets with high levels of renewable (intermittent) generation, particularly wind and solar, drive supply prices down because of their almost zero marginal costs. Price decreases may reduce incentives to invest in the system, reducing the overall amount of electricity generated. However, we do not observe significant correlations between *characteristic control*, produced electricity, or consumer prices. In the case of the gas industry, our correlations suggest that markets with a strong influence of *characteristic control* are linked to more inefficient systems (column *Coeff* in model (3)). The link suggests that substantial *characteristic control* on setting supply/transmission conditions might cause friction with the retail segment of the industry, which is less concentrated compared with the former (less market power) (Austvik, 1997). However, we cannot control for the market power of suppliers and the transmission incumbent. High market power under high *characteristic control* influence might drive our results. In addition, we observe that *characteristic control* is associated with lower usage of gas in the transport industry (column *Coeff lagged* in model (7)). At first glance, *characteristic control* seems to negatively impact the environment by relying their transport industries on CO2-intensive fuels. Yet, we do not observe the share of electric vehicles in the system.

Sector associations: Telecommunications

The regression analysis results are summarized in Table 3.4. [28] Our coefficients suggest a significant association between *state ownership* and lower penetration levels (the number of access paths per 100 inhabitants, column *Coeff* in model (7)). Moreover, our estimates highlight the positive associations between *state ownership* and firm revenues per capita (column *Coeff Lagged* in model (12)) and higher prices for telecom services (models (1) and (4)). According to Boubakri et al. (2009), the association could be explained by the nature of the objectives of the state-owned firm. While private incumbents (management) are motivated by efficiency-driven goals, state-owned incumbents might have different objectives (i.e., universal service provision). In addition, these different objectives could impose a constraint on the pricing scheme of the state incumbent, preventing any benefit to consumers from any efficiency gain. This price friction and high consumer prices could also explain the significantly higher revenues associated with state-owned firms.

Regarding *network access*, the dimension is associated with superior coverage in access paths and subscribers per 100 inhabitants in the column Coeff in specifications (9) and (11). Regarding prices, *network access* shows negative associations with fixed broadband and mobile services (column *Coeff Lagged* in

[28] The results are presented in detail in Table A.28

Table 3.4: Summary of regression estimates for Telecommunication variables

Model	Type	Dep Var	Dimension	Coeff	Coeff Lagged
1	Prices	fixbbpricepc	gov_ownership	0.39	0.96*
2		fixbbpricepc	charact_control	-	-0.75
3		fixbbpricepc	network_access	-	-0.86*
4		mobile_lowpricepc	gov_ownership	0.65	-
5		mobile_lowpricepc	charact_control	-1.66	1.44*
6		mobile_lowpricepc	network_access	-	-0.52*
7	Perform	telaccpath100	gov_ownership	-0.08	-
8		telaccpath100	charact_control	-0.16	-
9		telaccpath100	network_access	0.11	-0.02*
10		telmobsub100	charact_control	-0.32	-
11		telmobsub100	network_access	0.15	-
12		telrevusd_pc	gov_ownership	-	0.21*

The estimates are the product of the model: $y_{ict} = \alpha + \beta x_{ict} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict}$. The terms λ_t and θ_c capture time and fixed effects, respectively. Dependent variables: $fixbbpricepc$ fixed broadband bundle price relative to income per capita in euro, $mobile\_lowpricepc$ mobile data low-priced bundle relative to income per capita in euro, $telaccpath100$ telecommunication access paths for every 100 habitants, $telmobsub100$ mobile subscriptions by 100 habitants, $telrevusd$ operator revenues in US millions. Column *Coeff* presents the regression estimates of our dimensions, significant at 10% of significance level or below. The column *Coeff lagged* reports the coefficient of the dependent variable lagged for one period, significant at 10% of significance level or below. An asterisk at the right of the coefficient columns shows that the estimate is robust enough to include the lagged dependent variable. For the complete regression results, see Table A.28. Robust standard errors estimated

models (3) and (6)) only when the lagged reform scores are added. Both the efficiency and price correlations might indicate that *network access* provisions have encouraged the entry of new efficient incumbents in both technologies (or the threat of entry), which in turn might have improved the industry's overall efficiency and benefited consumers by the reduction of prices (Boylaud and Nicoletti (2000) argue that efficiency gains in mobile and long distance calls might be explained by the entry of efficient incumbents). However, the negative association in column *Coeff Lagged*, model (9) is puzzling. Our pooled-sample results suggest that network access in the previous period (five years before) was associated with higher investment levels (see Section 3.4.3); however, the effect is negative. This association deserves further investigation because it could reveal the undesired effects of market reforms in telecommunications.

The *characteristic control* dimension is negatively associated with coverage in access paths and subscribers per 100 inhabitants in the column Coeff in specifications (8) and (10) within our analysis period. The negative coefficients suggest that regimes under the influence of *characteristic control* might underperform compared to regimes where product characteristics are defined by competition. In a sector characterized by constant technological evolution, lower entry costs (compared to other network industries), and superior competition, incumbents with the ability to set characteristics appear to struggle to keep up with the "optimal" demanded characteristics (Yan, 1999). Besides, the correlations between *characteristic control* and telecommunication prices do not show uniform directions. The dimension is associated with lower mobile service prices, as shown in model (5), column *Coeff* and model (2), column *Coeff lagged*. These associations seem to contradict our previous description of the relationship between *characteristic control* and efficiency, because if an arbitrary product setting increases inefficiency in the industry, prices should reflect the

inefficiencies. When we account for the persistence of prices y_ict-1 in model (5), the sign of the association matches our expectation, but only for the effects of *characteristic control* in the previous period. This pattern deserves further investigation, considering that the price interaction between product substitutes, such as fixed and mobile broadband technologies, might also impact our correlation coefficients.

Sector associations: Transport

The regression results are briefly introduced in Table 3.5 [29]. The *state ownership* dimension is significantly associated with superior air passenger traffic (model (1), column *Coeff*) and freight traffic (model (4), column *Coeff*). This association suggests that industries with significant state incumbents' influence hold higher traffic levels in the air passenger segment. These results oppose the findings of Oum et al. (2008), who find a negative association between different government ownership and efficiency measured by the number of passengers. However, the authors also acknowledge that only using traffic analysis to evaluate airport performance might lead to incomplete conclusions because up to 70% of the operating revenue of airports comes from non-operational sources. Our correlations also show a significant association between *state ownership* and the share of high-speed rails, as shown in model (11), column *Coeff lagged*. This coefficient suggests that low *state ownership* (privatized industry) in the previous period x_{t-1} is associated with higher shares of electric cars in the system. The implications for CO2 and decarbonization objectives are unclear. On the one hand, a lower share of electric cars might imply higher levels of CO2 emissions, but our econometric model does not account for other clean transport modes. It might be possible that decarbonization is not a priority for the industry. Lerida-Navarro et al. (2019) find a negative association between the share of electric cars and system efficiency for 2002–2011.

The associations between *network access* and traffic contrast between the air and rail industries, with contrasting implications for system efficiency and the environment. Model (3), columns *Coeff* and *Coeff lagged* show a negative relationship with air cargo traffic, while model (7), column *Coeff* highlights a positive cargo traffic association with *network access* provisions. In the case of the air industry, our results are surprising because the literature in the field has reached a consensus about the positive effects of liberalization on industry efficiency, either through the introduction of competition and better management or through technological improvements (as summarized by Fu et al. (2010) for the air passenger and cargo industries). However, the analysis periods differ between the most prominent studies and our dataset. One possible explanation is that the entry of new competitors in the cargo sector increases operational constraints at airports (including safety rule enforcement). Regarding rail cargo traffic, our results are aligned with the literature that finds positive effects of vertical separation and third-party access on system efficiency (Cantos et al., 2010) [30]. Also, our coefficients reflect a potential association between *network*

[29] A list with the complete regression results is presented in Table A.29

[30] The literature in the field has not reached a consensus regarding the effects of vertical separation and third-party access on system traffic, operational efficiency, or costs. The

Table 3.5: Summary: Regression estimates for transport variables

Model	Type	Dep Var	Dimension	Coeff	Coeff Lagged
1	Perform	air_freigh_tkgdp	gov_ownership	0.69*	-
2		air_freigh_tkgdp	charact_control	0.53*	0.37
3		air_freigh_tkgdp	network_access	-0.84*	-0.60*
4		air_pass_tkgdp	gov_ownership	0.60*	-
5		air_pass_tkgdp	charact_control	-0.37*	-
6		rail_freigh_tkgdp	charact_control	-0.44	-
7		rail_freigh_tkgdp	network_access	0.59	-
8	Quality	sh_co2_aviation	charact_control	0.27	0.28
9		sh_co2_aviation	network_access	-0.31*	-0.34*
10		sh_electric_rail	network_access	-	0.36*
11		sh_highsp_rail	gov_ownership	-	-1.08*
12		sh_highsp_rail	network_access	-	1.38

The estimates are the product of the model: $y_{ict} = \alpha + \beta x_{ict} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict}$. The terms λ_t and θ_c capture time and fixed effects, respectively. Dependent variables: air_freigh_tkgdp air cargo transported in tons as a fraction of GDP, air_pass_tkgdp air passengers transported as a fraction of GDP, $rail\_freigh\_tkgdp$ rail cargo transported in tons as a fraction of GDP, $sh\_co2\_aviation$ share air transport of CO2 emissions from the total transport industry, $density\_rail\_sqkm$ rail track kilometers per square kilometer, $sh\_electric\_rail$ share of electrified trains relative to the total number of trains, sh_highsp_rail share of high-speed trains relative to the total number of trains. The column Coeff presents the regression estimates of our dimensions, significant at 10% of significance level or below. The column "Coeff lagged" reports the coefficient of the dependent variable lagged for one period, significant at 10% of significance level or below. An asterisk at the right of the coefficient columns shows that the estimate is robust enough to include the lagged dependent variable. This specification follows Alesina et al. (2005) to capture persistence effects. For the complete regression results, see Table A.29. Robust standard errors estimated.

access and positive environmental performance, i.e., lower air CO2 emissions relative to the transport industry (model (9), columns *Coeff* and *Coeff Lagged*) and higher shares of electric cars (model (10), column *Coeff lagged*). The associations might reflect the entry of more fuel-efficient aircraft and the national / technical country rail system.

Finally, we report our results about the associations of *characteristic control*. The coefficients show contrasting associations between air cargo (positive in the model (2), columns *Coeff* and *Coeff lagged*) and passenger traffic (negative in the model (5), column *Coeff*). The air passenger association might reflect the incompatibility between airport operational management (i.e., flight frequencies, safety standards, traffic management) with the current competitive and flexible structure of the air industry (Fu et al., 2010). A similar negative association is observed in the rail freight industry (model (6), column *Coeff*), potentially reflecting the same incompatibility (Lerida-Navarro et al., 2019). However, the air cargo traffic association should follow a similar pattern, but it does not. Air cargo traffic represents a small fraction of the overall air traffic and might be governed by other unobserved determinants (Oum et al., 2008). The implications of *characteristic control* and CO2 emissions are limited; we only find a significant association with a positive share of CO2 emitted by aircraft emissions relative to the transport industry's total emissions. The inefficient time schedules could explain this CO2 intensity and management imposed by the *characteristic control* influence that also utilizes planes inefficiently based on their fuel consumption. To reach more solid conclusions, we must examine

effect on efficiency depends on the intensity of rail network usage. (Mizutani et al., 2015)

the emissions from the transportation industry as a whole, as well as the factors that influence the share of other technologies.

3.5 Discussion

Our methodology suggests three independent dimensions to characterize market reforms:

- the level of state ownership/influence in the industry
- the legal fair treatment given to new/existing firms in the industry (network access)
- the influence of incumbent firms to control product/service characteristics/conditions in the market

These dimensions seem to capture the long-run sectoral and national aspects of the market reform. At the sector level, the telecommunications and energy industries follow a similar reform evolution in two dimensions, *network access* and *product characteristic control*. Market regulation in these industries started with a relatively higher influence of *network access* and a lower influence of *characteristic control*, compared to the transport industries. During the analysis period (1998–2018), all industries reported a reinforcement in *network access* and a reduction in *characteristic control*; The differences between the former group (telecommunications and energy industries) and transport industries have reduced; however, both groups seem to converge at different levels in both dimensions. While the initial differences might reflect the heterogeneity in the initial conditions of the reform and the European strategy and tools used to implement the reform in each industry Geradin (2006) [31]. The convergence levels might reflect the differences in the service standards of each sector. Among transport industries, the air transport sector seems to converge toward a liberalized model at a faster pace compared to the rail transport industry. The air transport industry has introduced access regulation and reduced *characteristic control* in the market faster, even compared to telecommunications and energy industries. These changes coincide with the introduction of new business models in the sector (low-cost airlines and operation of secondary airports), a sustained reduction in airfares (Fu et al., 2010), but the contrast with an increase in airport charges (Wiltshire, 2018).

In contrast with the other two dimensions, *state ownership* does not show significant sectoral differences. All industries started with higher levels of government influence than at the end of the analysis period. The air transport industry already started with a relatively lower *state ownership* influence level at the beginning of the period (Nicoletti et al., 2000; Koske et al., 2016). Our

[31] For instance, Geradin (2006) suggests that the European liberalization process in telecommunication was implemented faster because the European Commission had the sufficient power to coordinate the design and implementation of European Directives with national bodies, in contrast to a relatively evenly distributed coordination power of the European Parliament, the Commission and national authorities in other sectors.

results vary from the OECD PMR index evolution, as shown in Figure A.17 in the appendix section. In their results, rail transport is the sector with the largest state involvement, while telecommunications has the lowest level at the beginning of the period. The differences possibly arise because our scores capture how governments can significantly control the largest incumbent's decisions. Our data coding strategy gives the same weight to firms that control 50.1 or 100 percent of the firm, in contrast to the OECD *ownership* score that shows a continuous measure of government ownership, which is higher in the rail industry.

At the national level, our dimensions and scores also highlight significant patterns in market reforms. Only a small group of country regulatory regimes (four) are driven by access provisions, compared to the incumbent's power to define product characteristics. The rest of the country's regimes are dominated by state-owned incumbents' strong influence and the significant ability of such operators to impose characteristic conditions on the products and services on the market. Regarding regime evolution between 1998 and 2018, European OECD countries seem to have converged toward pro-competition configurations with higher levels of *network access* and lower levels of *characteristic control* and *state ownership*. However, in most of the countries in our sample, the structural characteristics of the regulatory regime do not seem to predict the type of evolution. For instance, regimes with high structural *state ownership* or *characteristic control* influence do not seem to converge at a different pace compared to other configurations. Other unobserved country characteristics might be responsible for such convergence patterns.

Moreover, our dimensions exhibit significant correlations with industry performance. Part of our findings are consistent with previous evidence that market reforms are associated with superior sectoral performance (Broughel and Hahn, 2022). However, our study suggests that strong contrasts exist across industries, which differ from one another. This might partly reflect differences in terms of objectives and industry standards. While market reforms in the telecommunications and energy industries seem to have reconciled system performance, system reliability objectives, and physical system limitations [32], the reforms in the transport industries, which seem to conflict with the strict air and rail safety standards. This conflict seems to even limit the extent to which transport industry reforms can be achieved because further attempts to support liberalization reforms might put safety standards at risk in operations. This effect is particularly evident in the air industry, where future air traffic threatens to congest airport operations and possibly downgrade safety standards (IATA, 2007).

Regarding the index construction methodology, our approach shows several advantages compared to traditional methods. First, our method relies on concept intensity variation and text analysis algorithms to determine the weights of sectoral regulatory characteristics. In particular, the topic modeling approach (Blei et al., 2003) uses word / concept counts and semantic relationships (Wei et al., 2015) as primary inputs to determine latent dimensions (and their influence) in a regulatory regime. While our method relies on the appropriate transformation of categorical data into textual data (the right choice of word / term

[32] However, the current system organization seems to conflict with alternative objectives, such as the decarbonization of European electricity systems (Nicolli and Vona, 2019)

similarity measures), it does not require additional corrections needed to treat categorical data as other methods do require. [33]. The corrections are related to the order of the categories in each question, which implies that an analyst should assign a score to each answer category according to predefined criteria (in the case of the OECD PMR survey, answers should be aligned to pro-competitive criteria). Other corrections treat problems related to the correlation matrices used by latent factor techniques. For instance, MCA requires to account for the artificial variables created (in the case of questions with more than two answers) that threaten to underestimate the influence of the first relevant dimensions [34]. Besides, our estimated latent dimensions (and their influence) reduce the potential issues caused by the redundancies in equally weighted indexes (Casullo et al., 2019; Vitale et al., 2020), which consider that every characteristic in a regulatory regime has the same influence. If highly related features are given the same weight, it could overstate how important one feature is to the final reform score.

Regarding the conceptual aspect of our estimates, our approach allows for comparing market reforms in different network industries, countries, and periods, even if the surveys vary over time. The topic modeling tools and most robust checks allow us to estimate the number of dimensions that are general enough to contrast regulatory regimes across industries and countries. Our algorithm does not require the imposition of an aggregation structure (score-subscore), which might also reduce the dimension comparison power [35]. Moreover, the usage of terms / concepts to summarize survey wording seems to reduce the number of irrelevant terms in our corpus, but more importantly, it allows us to compare aggregated dimensions even if surveys differ between waves [36]. The last feature improves the usage of our estimates in time-dependent analysis.

It is important to acknowledge the potential limitations of our method. Depending on the terminology used in surveys, the complexity of concept identification and dimension interpretation may rise. It is simpler to evaluate the effectiveness of the word / sense disambiguation algorithm [37] in our situation

[33] PCA analysis has been applied in the OECD PMR survey on equally weighted averages of predefined PMR subscores (Nicoletti et al., 2000). Even in the case of PCA, variables need to be normalized to prevent dimension scores from just reflecting the presence of outliers

[34] This correction is needed to deal with the artificial increase in variance needed to recode the dataset into a two-answer question format. In the case of questions with more than two answers, each category is transformed into a new variable with two possible answers. The number of variables increases, and, with it, the variance of the dataset. If the previous issue is not addressed, the influence of the first latent dimension (in particular) could be severely underestimated. This underestimation of the latent dimension scores might require including a significant number of dimensions to capture a relevant dispersion of the data at the expense of reducing the summarizing power of the technique. The OECD compares aggregated indicators in network industries by using the splicing method, in which the time series is preserved by the construction of a time trend and ignoring differences in both wave scores (Koske et al., 2015)

[35] For instance, the OECD PMR places less emphasis on liberalized domestic markets and more emphasis on the entry of international competition in the air transport industry. In contrast, entry into the energy sector emphasizes the availability of transmission infrastructures, the liberalization of wholesale markets, and the freedom of supplier selection for consumers.

[36] These changes are significantly evident in the 1998–2003 and 2013–2018 waves. In the latter case, the OECD acknowledges that the PMR indicators produced with the two surveys are not comparable (Vitale et al., 2020)

[37] We benchmark the performance of the various word/sense disambiguation approaches by

due to the lack of distinct terms overall in our corpus. Our method might not work as well as anticipated if surveys use more intricate or particular vocabulary. However, such surveys use wording specific enough to clarify the extent of the questions and simple enough to reduce ambiguities and misinterpretations among member states (Wölfl et al., 2009). Additionally, more complex word / sense disambiguation methods could be applied, albeit at the sacrifice of interpretation power. The vector estimates supplied by alternative techniques, such as word2vec, are more difficult to interpret than the words / terms and their semantic associations provided by our method.

3.6 Conclusion

This study proposes applying text analysis algorithms to summarize and analyze the OECD PMR. First, our approach uses *lexical chains* to reduce the number of the survey's textual characteristics into a smaller and more meaningful corpus, and second, we apply topic modeling to the summarized text to extract latent dimensions that influence the sectoral regulatory regime in a sample of five network industries, (electricity, gas, telecommunications, air and rail transport) between 1998 and 2018. Our results suggest that three dimensions characterize the network industry regulatory regime, i.e., *state ownership*, *network access*, and *product characteristic control*. While our results corroborate with other studies that highlight the importance of state ownership and its management (privatization) in the regulatory environment, our results differ from the literature in the dimensions proposed to evaluate market reforms. We point out that the regulation of *fair* entry to the network matters as well. We also highlight that the incumbent's control over product/service characteristics is an important feature of market reforms.

Moreover, our resulting dimensions are significantly associated with industry performance. Our econometric analysis shows important associations that require additional investigation.

- *State ownership* is associated with negative performance in energy and telecommunication industries, while the relationship is positive in the air transport industry.
- The associations of *network access* with prices vary among industries (energy and telecommunications).
- The reduction in *product characteristic control* in the electricity sector seems to conflict with the decarbonization of the electricity system.
- Air and rail transport show contrasting associations with our reform dimensions. Even *Product characteristic control* shows different associations between air freight and passenger transport industries.

However, we did not account for unobserved changes in national political priorities and sector characteristics during the course of the investigation. More

comparing the model results with a human-based sense classification.

evaluations are needed to better understand the probable links between sector characteristics and market reforms, as well as between reform progress and industrial success. Such in-depth analyses are required to provide decision-makers with the knowledge they require to establish improved regulatory systems.

Chapter 4

Paper 2: Comparative analysis of regulatory governance regimes in the OECD

Abstract[1]*: Drawing on surveys conducted by the OECD in its member states since the early 2010s, we apply textual analysis to the description of the status of regulatory agencies (RAs) in European countries and sectors with a characterization of their relationships with various stakeholders, and of their duties and the means at their disposal. Four independent dimensions seem to characterize regulatory governance regimes: independence from the government; the level of discretion of the RA; the scope of its market monitoring capabilities; and its ability to ensure transparency of the supply side. Our regulatory governance indicators exhibit significant correlations with industry evolution and performance. However, there is divergence across industries. This might partly reflect differences in terms of "maturity." Younger RAs seem to be characterized by greater informality and access to a more limited set of regulatory tools. However, it is not certain that sectoral regulators are converging toward a common model since they are operating in industries with contrasted economies and different RA agendas. In e-communications, regulatory governance seems critical to performance in terms of quality of service (broadband), while in the electricity industry, the main objective of the RAs seems to be the price of energy, even at the cost of the environmental quality of electricity. In the transportation industries (air and rail), the focus is on the volume / development of traffic and on safety improvements. Compared to previous studies, our results differ on two main grounds. First, we point out that the extent of the RA's formal authority / discretionary power matters (in addition to independence). We also highlight that RAs might promote transparency (in addition to designing markets and setting tariffs). Over the past years in Europe, the most significant developments have concerned these two overlooked dimensions of regulatory governance.*

[1]In collaboration with Eric Brousseau (University Paris-Dauphine (PSL), Governance and Regulation Chair)

4.1 Introduction

Starting in the 1990s, most countries engaged in a path of economic liberalization, translating into the introduction of more competition in utilities and the privatization of key operators in related industries. Governments fortified this movement by establishing independent regulators in charge of promoting fair competition between new entrants and incumbents and of protecting the public interest (Levi-Faur, 2005). For a long time, the model of "independent" regulators was specific to the United States (Balleisen, 2015). In most other countries, utilities had been operated by organizations, public or private, that were directly monitored by ministries, either through a command and control mode of governance or through contractual relationships. As of the 1990s, principles of "good" governance have been advocated by various inter-governmental organizations, including the World Bank, the OECD, and the EU, to promote a model of agency that is immune to undue influence from business (in response to Stigler (1971) analysis of the capture of regulators by businesses) and to undue influence from governments (especially because their sensitivity to electoral cycles may prevent them from making decisions aligned with the long-term public interest) (Majone, 1996). The independence of regulators has also been understood as a significant driver of the internationalization of the related service industries, attracting foreign investments in infrastructure, and supporting the consolidation of transnational operators benefiting from economies of scale and economies of experience. That being said, most countries "imported" the independent regulator model their own way.

Indeed, as pointed out by Balleisen (2015), the United States model of an independent agency is both the result of a specific path of historical evolution and a response to the country's institutional specificity. In particular, in the United States, there were no federal departments of telecommunications, energy, or transportation prior to the development of sectoral agencies. Beyond their specificities in terms of public administration tradition, the countries that adopted the independent regulator model are also characterized by contrasting size, political organization (i.e. federalist vs. centralizing political philosophy), government involvement in the industry, legal tradition, etc. Thus, in practice, independent regulatory structures have been erected on a variety of bases. For instance, in some countries, the regulators are focused on a given industry, while in others, the regulatory agency oversees all network industries. Also, in some countries, agencies are specialized by issue (e.g., competition and market performance vs. safety and other externalities), while in others, each sectoral regulator manages the interreaction of those issues. Of course, the actual mandate, the legal status, and the means available to regulators are also specific to each jurisdiction, being dependent on its institutional specificities and also on the political compromise behind the implementation of this model. As with any institutional arrangement, the equilibrium behind the establishment and the operation of a regulator might evolve. Because regulatory agencies are different in practice and because their characteristics might evolve, it is essential to develop methodologies to compare the organizational specificities of alternative institutional arrangements across both countries / industries and over time. These methodologies are necessary to identify the drivers of alternate institutional designs, to understand the outcomes of these alternatives, and to compare their

performances. More generally, a better understanding of the determinants and outcomes of regulatory-agency characteristics must account for the context of heterogeneous social preferences, national institutional patterns, and intrinsic sector characteristics (i.e., the specificity of market structures and technological choices and the stakeholders' political salience).

Several comparative governance studies have already quantitatively assessed regulatory regime heterogeneity and its association with institutional determinants and outcomes (Gilardi, 2002; Trillas and Montoya, 2013; Guardiancich and Guidi, 2015; Özel and Unan, 2019). However, many of the methodologies used to measure "governance regimes" tend to be idiosyncratic, and their results are hardly comparable across studies (and therefore across time, jurisdictions, and industries). Two standard limits are at play. First, in many studies, the relevant dimensions to characterize the institutional arrangements are assumed ex-ante and measured independently from each other, without checking whether or not these dimensions are actually the most relevant ones for contrasting governance patterns and are mutually independent. Second, these dimensions are usually assessed through a set of measured proxies, which are then aggregated into an index. The methodology relied upon to aggregate the "measures" generally assumes that each one contributes equally and linearly to the predefined indexes, while the relationship between each 'proxy' and the dimension measured is not discussed and analyzed. These methodological biases might compromise the validity of the results and the conclusions drawn.

Our study proposes using text analysis algorithms to circumvent such measurement/characterization shortcomings. We exploit a survey performed by the OECD and aimed at describing in detail a large set of characteristics of Regulatory agencies, namely the "Product Market Regulation - Regulatory Management (PMR-RM)" survey. This survey might be considered as a systematic and standardized textual description of regulatory agencies' statuses in different countries and sectors, together with the characterization of their relationships with various stakeholders (such as the executive and the legislative), and their duties and the tools available to them. Conducted by the OECD among its member states, the survey has the advantage of providing observations based on common descriptors.

Following the methodology initiated by Blei et al. (2003), we then identify co-occurrence patterns in the pooled data (LDA analysis), without making any assumptions about the weight of each descriptor and the number of relevant descriptive dimensions of governance. Four dimensions explain most of the variance and can allow us to compare these regulators not only amongst themselves but also across time. This allows us to characterize what we qualify as "regulatory governance regimes," describing the *de facto* status and the operations performed by "sectoral" regulators in a set of countries. Our results identify four dimensions: independence from the executive; the scope of the agency's discretion (i.e., the degree to which its powers are formally framed); the scope of the instruments relied on to monitor market coordination; and the scope of instruments designed to guarantee transparency and compliance. To a certain extent, the first two dimensions describe the relationship between the regulatory agency and governmental and societal actors, while the last two characterize the levers in the hands of regulators to weigh in on market players' behavior.

We then relate the descriptors of these "regulatory regimes" and their evolution with various descriptors of industry performance (such as the volume of investments, the level of activity, retail and wholesale prices, safety indices, etc.) to explore potential causal links. These "regulatory governance regimes" can also be linked to other institutional, sectoral, or economic structural characteristics to identify patterns and how the industry performances mentioned above might be explained by a combination of these structural patterns, including the "regulatory governance regime."

This exploratory approach is designed to compare regulatory governance across industries and countries to identify potential contrasts and similarities. The objective is also to identify potential stylized facts that merit closer scrutiny to investigate causal relationships between industries' performance and status, the tools available to the regulatory agency, or also the institutional and economic/sectoral determinants of regulatory agencies' features.

4.2 Methodology

4.2.1 The existing literature and our contribution

One of the central issues when comparing alternative institutional or organizational characteristics is that they might differ along multiple characteristics, and reducing these characteristics to the most contrasting ones is a challenge. Several studies have attempted to quantitatively compare regulatory governance regimes—i.e., the institutional and organizational characteristics of sectoral regulators—and to link them to institutional / political determinants and industrial / market outcomes. The methodological heterogeneity of these studies and their potential flaws undermine the validity of their conclusions and the comparability of their results.

First, scores or indices (mostly measuring regulatory independence) diverge in the weights assigned to each governance descriptor (usually captured by survey data). Many studies rely on ad-hoc weighting assumptions, making the results very sensitive to the observation lenses. Some studies even consider only one institutional characteristic, such as regulatory independence, by accounting only for the existence of an independent regulatory agency, e.g., (Bortolotti et al., 2011; Cambini and Rondi, 2017; De Francesco and Castro, 2018). Many studies relying on multi-dimensional descriptors tend to assign equal weight to all elements and sum the presence or absence of this or that characteristic (Gilardi, 2002, 2005; OECD, 2016; Mediano, 2018). This tends to overlook potential redundancies among the observed characteristics and make the results very sensitive to the observation tool and the number of descriptors chosen ex-ante. Characterizations of regulators are then challenging to compare across studies.

Alternative methodologies relax the weighting assumptions and model variation in the information as a function of a latent governance trait, i.e., a significant unobserved governance trait characterizing a regulator and its behavior (Hanretty and Koop, 2012, 2018; Perkins, 2013). For instance, the existence of a

"cooling period" preventing a commissioner or top executives from a regulatory agency from working for the industry immediately after he or she leaves his /her office contributes to strengthening the independence of the regulatory agency vis-à-vis regulated operators. The methodology might also lead to determining whether this "descriptor" is aligned with all the other sources of potentially undue influence (e.g., the executive, legislators, judiciary, activist groups, etc.), or whether independence from the industry is a very specific trait as compared to independence from political or administrative influences. Such a methodology reveals the relevant latent traits and their relationships and might also point out the significant characteristics of a regulatory regime. This is the principle of the LDA methodology we rely upon.

The second main bias in the existing literature lies in its mono-sectoral approach. Partly because of difficulties in standardizing the characterization of regulatory governance regimes but also because it is often assumed that regulation differs in practice from one industry to another, most existing studies rely on a sectoral approach, comparing regulatory governance regimes across countries and not across industries. This constrains our ability to disentangle the influence of the regulatory governance regime from more generic country-level institutional characteristics when studying the impact of public governance on outcome variables such as firm leverage (Cambini and Rondi, 2012), investment to capital ratio (Sutherland et al., 2011), or sectoral added value (Égert, 2009). Sectoral approaches do not allow the identification of potentially similar or divergent regulatory governance patterns by industry or their potential impact on supply-side performance. For instance, Trillas and Montoya (2013) rely on an instrumental variables approach to highlight a strong association between regulatory independence and telecommunications penetration rates in Latin America. Similarly, Edwards and Waverman (2006) suggest that regulatory independence is correlated to lower interconnection rates across the EU telecommunication industry. However, it is unclear whether regulatory independence is related to another institutional pattern in both cases.

The whole purpose of automated textual analysis is to identify contrasts and similarities among text/documents by identifying how words/expressions are related to each other in a given text covering a set of topics, and how different texts are similar or different along with the different topics (whose "weight" and "value" vary across documents). The contributions of words to topics and topics to documents are computed by measuring the frequency and co-occurrence of words in documents and not from any prior hypotheses on how they should be articulated amongst each other. Moreover, the identification of topics in the whole corpus is based on the desire to identify the more contrasting ones and to consider expressions/descriptors that are correlated as contributing to a common topic, hence reducing the number of topics to the most significant vectors of differentiation /characterization of the selected documents. Therefore, the analysis allows every document /description to be characterized by the way it contributes to the various topics identified in the whole corpus of all documents /descriptions. The documents /descriptions can then be compared amongst themselves thanks to a common metric built without any a priori about the most relevant dimension and without biases in aggregating the primary information (i.e., the descriptors in the document) into indexes (i.e., the topics).

For instance, if several descriptors proxy very similar characteristics, they will not increase this characteristic's contribution to the measure of the overall variance within the corpus and the measure of the contrasts among documents. In other words, measurement biases will not impact the results, and a priori presumptions about the "weight" of single descriptors will not matter.

Our "measurement" methodology — based on the Latent Dirichilet Allocation (LDA) method proposed Blei et al. (2003) — allows us to highlight structural patterns and their evolution for each sectoral regulator, allowing comparisons across countries or industries. They permit the exploration of potential causal relationships between governance and performance in the studied industries, namely energy, e-communications, air, and rail transportation. The identified relevant governance traits seem to be possibly linked to industrial and market outputs, although their impact varies across industries. Of course, a detailed and fine-grained analysis would be needed to demonstrate any causal inferences. The suggested relationships are, however, enlightening and suggest appropriate research directions.

4.2.2 Data and Preprocessing

We use the PMR-RM database (Casullo et al., 2019) to describe governance patterns[2]. It draws on a survey to document regulatory agencies' (RA) institutional characteristics, management practices, and formal relationships with governmental and market stakeholders. Since 2013 this survey has been conducted every five years (and therefore in 2013 and 2018) to gather information about economic regulators in transportation (air, rail), utilities (energy, water), e-communications, and infrastructures (roads, ports) in 45 OECD and non-OECD countries.

Our study focuses on four network industries: energy, e-communication, railways, and airports in 23 European OECD countries, for which we benefit from consistent data from the survey in 2013 and 2018 (since additional industries were considered in the second wave) and on industry performance. The covered countries include Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Switzerland, and Sweden. This subset covers 184 regulator-level observations.

We evaluate survey comparability between periods, sectors, and countries. The PMR-RM survey was modified extensively between 2013 and 2018. The number of questions increased from 52 to 76, and the range of possible answers to some of them expanded. Data is not available for all countries and sectors.

The first issue requires identifying the between-period non-overlapping questions and evaluating whether their exclusion affects our analysis. Most non-overlapping questions describe either an informal provision (not part of our analysis) or a regulator's second-rank type of action, e.g., beyond publishing its decision, the agency makes it available online. The remaining questions describe

[2]Both survey waves are accessible through the OECD website: https://www.oecd.org/gov/regulatory-policy/governance-indicators.htm

budgetary agency practices and are excluded from the analysis.[3] Second, since some questions have a richer subset of potential answers in 2018 than in 2013, we adopt a conservative posture and keep the 2013 menu of possible replies. For instance, if in 2013 the choice for performing a given activity was between either the agency or the government, while in 2018 an additional option "cooperation between the two" was added, we keep the reply provided in 2013 to avoid identifying an evolution that did not occur. As a result, our dataset covers 38 questions / descriptors covering the *de jure* aspects of regulatory governance.

Before applying text analysis methods, we convert the survey database into textual data, since the OECD results are in the form of scores. Every question has a unique descriptor. For dichotomous inquiries (yes / no), positive (negative) responses are assigned to a positive (negative) version of a descriptor, while categorical questions use their unique descriptor plus an additional term that characterizes the answer. We converted survey data into a collection of 184 documents (92 for each period). The number of documents' terms is homogeneous, as shown graphically in Figure B.1. Documents with term counts beyond two standard deviations from the descriptor mean (52.8) are removed from the corpus.

The next step is to identify non-useful (non-discriminant) descriptors because they either recur too frequently or too seldom. We remove four descriptors with a frequency below 10 in the corpus, and the term *regulator*, which was extremely common in the documents. As a result, we use a set of 74 unique descriptors.

4.2.3 NLP Methodology

Topic modeling

Topic modeling (probabilistic) describes textual documents in a corpus (collection of documents) as mixtures over latent topics in the corpus. Topics are defined and labeled according to word (term) co-occurrence. Topics summarize highly dimensional feature spaces (words), facilitating document classification. Scholars' affinity for this unsupervised method has increased significantly in economics, political science, and management in recent years. In economics, Bandiera et al. (2020) uses topic modeling to detect latent traits between managers based on their time usage.

We consider that topic modeling has advantages relative to other survey aggregation methods. First, the Latent Dirichlet Allocation (LDA) helps to model a regime rather than standalone dimensions (e.g., independence, accountability). Second, dimensions and descriptors' weights are identified by document (regime) heterogeneity. Third, dimension scores are comparable across dimensions, sectors, countries, and periods.[4]

[3] The way budgetary practices are dealt with is different between 2013 and 2018. However, we were able to verify ex-post that it did not affect our characterization of regulatory regimes too much since budgetary information is aligned with the "independence" dimension.

[4] Different techniques are also available for processing survey information. The "aggregation" methods assign or estimate scores for individual questions and aggregate them according to

Latent Dirichilet Allocation

We use LDA to model regulatory regimes as mixtures of latent dimensions. The probability of observing particular arrangements (descriptors) depends on each regime's dominant dimension(s).

First, we introduce the notation used by Blei et al. (2003):

α: Dirichilet prior on the distribution of topics over documents.

β: Dirichilet prior on the distribution of descriptors over topics.

θ: topic distribution vector

z_n: *n-th* topic in a document

w_n the specific descriptor in a document

N: the number of descriptors in a given document

Next, a governance provision or feature in the network industries may be described as follows:

1. Draw $\theta \sim \text{Dir}(\alpha)$
2. For each provision w_n:
   (a) Draw a topic (dimension) $z_n \sim \text{Multinomial}(\theta)$
   (b) Draw a word (descriptor) w_n from $p(w_n|z_n, \beta)$, a multinomial probability conditioned on topic z_n

We will use the terms *topics* or *dimensions* interchangeably, as we will *words* and *descriptors*. The previous generative process explains the way the n-th descriptor appears in our dataset. At the corpus level, we draw the α parameter, which determines the dimension weights θ and the β parameter that specifies the weight of words within a topic, once. Given θ, we draw a topic z_n for every word w_n in the document. Finally, given topic z_n, we draw a word conditional on the given topic z_n and on β.

A Dirichlet n-dimensional random variable θ can take values that lie in simplex (k–1), which means that $\sum_{n=1}^{k} \theta_n = 1$. In our context, we interpret θ as the influence that a particular dimension (topic) has on the regulatory regime—different weights of θ capture the observed differences in regulatory management across sectors and countries.

The LDA has its disadvantages. The model assumes that the number of topics n is fixed and known. To estimate the "best" number of topics, we follow the Probabilistic Coherence score developed by Jones (2019b). This score calculates a measure of pairwise top-term topic correlation, correcting for meaningless

a defined hierarchical structure. The aggregation methods range from the equally weighted component approach as in Casullo et al. (2019) to factor analysis techniques as in Hanretty and Koop (2012); Jordana et al. (2018).

word correlations. [5] In Figure B.3 we see a plot of the coherence score between 1 and 20 topics. The visualization shows that the highest score is achieved by selecting four topics.

Model inference

We are interested in estimating the posterior distribution of our latent topics given a document θ as shown in Equation (4.1). However, this distribution is not amenable to exact inference (Blei et al., 2003). Following Griffiths and Steyvers (2004), we applied Gibbs sampling to approximate the latent posterior distribution. The algorithm assigns a topic randomly to every word in a document. Next, it draws a topic for one word, holding the previous topic / term distribution fixed. The process is repeated for every word in the corpus until convergence is reached. [6]

$$p(\theta, z \mid w, \alpha, \beta) = \frac{p(\theta, z, w \mid \alpha, \beta)}{p(w \mid \alpha, \beta)} \tag{4.1}$$

Estimation requires specifying the hyperparameters α and β. Their choice depends on the number of topics and vocabulary size. For α we set a value of 10, which is close to Griffiths and Steyvers (2004) value ($50/T = 4$). Higher values of α smooth the topic distribution over documents. In our case, we expect that latent dimensions are balanced in a governance regime, i.e., governance regimes are not defined by only one (resp. a few) dimension(s). We choose to set the value of β at 0.05, which lies at the midpoint of the literature's values. Lower values of β assign a specific word to only one specific topic, i.e., certain words appear only in one topic. The estimation uncovers four latent dimensions, as shown in Figure 4.1. More detailed results are provided in the appendix. They are interpreted and commented on in the next section.

4.3 Results

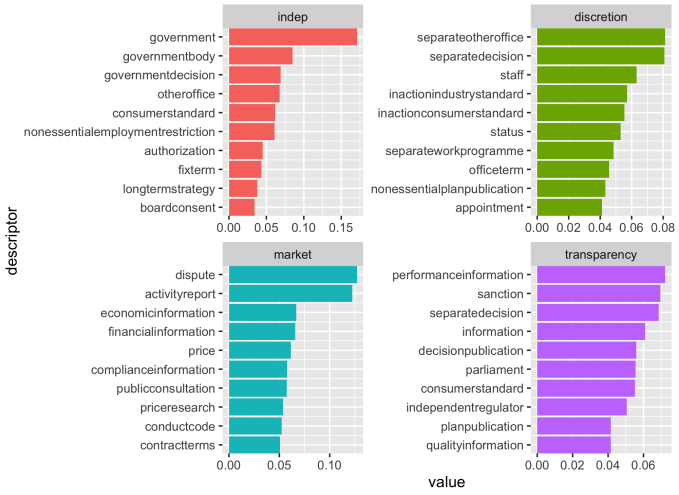
4.3.1 Four Dimensions Characterizing Regulatory Governance Regimes

In Figure 4.1 the most frequent words / expressions contributing to each dimension are highlighted. This type of list helps the analyst interpret the main institutional concepts behind each cluster (e.g., "market monitoring"). We complement our analysis / interpretation of each dimension by considering semantic networks (Figure B.7, Figure B.8, Figure B.9, Figure B.10) and correlation with an MCA analysis based on the scores computed by the OECD.

The four latent dimensions characterizing network industries' governance regimes might be defined as follows:

[5] We estimate the coherence score using the R package Jones (2019a)
[6] We estimate the topic / term posteriors using the R package Chang (2015)

Figure 4.1: Descriptor distribution by dimension



- Independence from the government (*independence*) estimates the extent to which the regulatory agency is protected against the executive's undue influence. The dimension's descriptors portray legal provisions limiting the executive power to dismiss the agency head / board, and review / overturn agency decisions.

- Discretion (*discretion*) is inverse to the number of legal provisions specifying the agency's obligations and proportional to its freedom in managing its resources. It is an inverse measure of the degree of the formalization of the agency decision-making process and established delegation of authority. In that sense, it could also be considered a measure of "informality."

- Scope of market monitoring (*market*), which measures the number of levers a regulator can manipulate to monitor operators' activity on markets (licensing, pricing, conflict arbitration, obligations imposed on market operators, supervision of their economic and financial performance). This dimension reflects the RA's ability to monitor the competitive process, oversee players' behavior, and manage economic incentives.

- Transparency (*transparency*) aggregates measures of the obligation for (public) reporting imposed on the RA and the reporting obligation imposed on market players by the RA. It reflects the regulators' role in reducing information asymmetries; in particular, to ensure compliance and limit behavioral drift. Here, the regulator seems to be considered an ''intermediary" between operators in the industry, public authorities, and users, whose expertise contributes to disclosing unbiased information.

Though independent of each other, the two first dimensions characterize the regulatory agency's degree of independence and autonomy, hence its status, while the last two reflect the channels relied on by the agency to fulfill and, in so doing, reveal its mandate.

The previous definitions are supported by the correlations observed between our scores and the OECD Indicators on the Governance of sector Regulators ($OECD - IGSR$), which use the same underlying $PMR - RM$ dataset.[7] The correlations shown in Table B.4 keep the expected signs and support our dimension definitions. We arranged the variables to link high performance in a dimension with a high numerical score. Regarding governance, the linear association between OECD *independence* and our *autonomy* scores ranges between 0.55 and 0.58, depending on the period. The *discretion* measure is negatively associated with OECD Scope $(-0.47, -0.58)$ and the *accountability* scores $(-0.25, -0.47)$. The negative coefficients suggest that our "discretion" dimension captures a degree of informality in the delegation of power to the RA, which is inversely proportional to its obligation in terms of formal accountability. Therefore, we can expect that regulators benefiting from a high score in terms of discretion would derive their actual authority from their relationship with the other participants in the power system and with the industry stakeholders since this authority is not granted with a broad set of formal levers of power. It might echo deeply embedded institutional characteristics. For instance, in Great Britain, there is a long tradition of "trustees" benefiting from significant *de facto* authority, though its *de jure* scope is nowhere formally established in any detail. On the contrary, in France detailed legal provisions establish the jurisdiction of each decision-maker in the public system. That being said, the level of discretion can also result from a policy choice, either weakening the authority of the RA or, conversely, allowing it to choose the most appropriate levers. The coefficients of *market* are strongly linked to the OECD scores in the matter of scope (and therefore of accountability because of the correlation between the latter; see above), confirming that it captures the RA's ability to influence industry players. Finally, transparency shows significant positive correlations with the three OECD Indicators on the Governance of Sector Regulators. We already observed a correlation between *accountability* and *scope*, and here we notice a positive correlation with *independence*. Our "transparency" indicator seems to capture the idea that an independent and accountable RA combines the ability to gather information from industry players with transparency obligations toward other stakeholders in the regulatory game.

Overall, our methodology seems useful for identifying two dimensions related to the "status" of the RA instead of the executive's sole distancing: independence and discretion. The latter might be either an asset or a weakness given the logic of performance of the institutional framework that translates the RAs discretion into an actual level of authority. Also, compared to the OECD scope score, our methodology disentangles two channels through which regulators operate—in brief: market design and transparency (to ensure compliance). Interestingly, if not surprising, there is a correlation between the RA's mission / status and the tools relied upon. Thus OECD measures of the latter are correlated with measures of the former. Our approach allows us to take into consideration these relationships, and therefore to identify more significant

[7] The OECD Indicators on the Governance of sector Regulators ($OECD - IGSR$) measure (at the sector level) by equally aggregating survey information in three governance dimensions: The degree of the regulator's insulation from undue political and market influence *independence*), the accountability of the regulator vis-a-vis other stakeholders (*accountability*), the range of activities that the regulator performs (*Scope of action*) (OECD, 2016).

vectors of contrasts among regulatory governance regimes. This illustrates the aggregation issue pointed out in Section 4.2.1.

In addition to the list of frequent terms per topic, the model in Section 4.2.3 estimates the topic distribution by document, θ_k. Individual topic contributions range from zero (0) (no contribution) to one (1) (full contribution), and they sum to one (1) ($\sum_{k=1}^{K} \theta_k = 1$). We interpret these distributions as the influence of the considered dimension on the characterization of the governance regime.[8] A summary of the dimension scaled scores (θ) is presented in Table B.1 for 2013 and 2018.

Next, we test whether our dimensions are relevant to characterize alternative governance regimes. Distributional similarities between dimensions' scores would suggest that their number is inaccurate and should be revised. In Figure B.2, each dimension displays different distributional characteristics. The *independence* score distribution is skewed to the left (skewness = −0.46) and is characterized by a lower standard deviation (1.05) compared to the *discretion* distribution (skewness = 0.45, sd = 1.21). Moreover, the *independence* influence seems to impact regimes more evenly. Almost 65% of independence scores lie within one standard deviation from the mean in contrast to the 40% of the *discretion* score. The *market* score distribution is heavily skewed to the left (skewness = −0.78) with a standard deviation of 0.74, while the *transparency* distribution seems more symmetrical (skewness = 0.05) and more dispersed (sd = 0.91). Despite the distribution asymmetries, "market design" capabilities are evenly shared by a large number of regulatory agencies. Close to 80% of this dimension lies within one standard deviation of their means. Overall, this highlights that "independence" and the "market design ability" are insufficient to characterize governance regimes: both discretion and transparency are significantly contrasting among regulatory agencies.

4.3.2 Cross-Industry and Cross-Country Comparisons

At the sector level, as shown in Figure B.4, energy and e-communications show relatively low variation across dimensions, suggesting that regulatory regimes in those sectors are relatively standardized across countries. Moreover, each dimension's mean score is similar (while *discretion* is significantly lower in e-communication). This suggests that both industries tend to be governed by similar institutional arrangements. In contrast, regulatory regimes for transportation industries seem to be characterized by much more heterogeneous arrangements across countries and industries. Overall, *discretion* tends to be high and divergent across regulators in these industries, and they are granted fewer regulatory tools than their counterparts in the e-communication and electricity industries. The differences between railway regulators and airport regulators essentially derive from their independence and their reliance on market design tools (both higher for railway regulators).

[8] Note that the descriptors in the *indep* panel (top left) in Figure 4.1 suggest the existence of a "government proximity" dimension. We defined the "Independence from the government" as government distance to the regulator, ($\theta_{indep} = -\theta_{govdep}$).

Comparison of regulatory governance regimes

We use score time averages (2013–2018), *mean*, and growth rates, *growth*, to compare regimes across sectors and countries. Time averages capture a regulatory governance regime's structural characteristics, while growth rates attempt to capture institutional evolution. These metrics will be used below to explore the correlation between regulatory governance and industry performance.

Regarding structural characteristics, our scores reveal industry differences in regime configurations. We use the ANOVA test to find statistically significant differences between sector *mean* scores. The results are presented graphically in Figure 4.2.[9]

The *governance* panel highlights significant contrasts in governance arrangements across industries—the discretion dimension matters in building these contrasts. When considering network industries, there seems to be an inverse correlation between independence and discretion. More independent regulators benefit from less discretion (e-communication vs. energy), which is consistent with what a rational theory of institutional design would predict. This inverse correlation does not hold for transportation industries: airport regulation is characterized by non-independent RAs with weak statuses, and rail regulators have a high degree of independence and discretion.

This configuration reflects the resistance to the liberalization of the transportation sectors in Europe, which has progressed at a slower pace than in telecommunications and energy. Airports remain under the authority of (National or local) governments. To comply with the European Union's successive "Railway packages," [10] member states created independent RAs but failed to grant them formal authority. Overall, *independence* (red) characterizes regulatory governance in e-communications and energy, while *discretion* (green) is the mark of transportation infrastructure regulators.

The *means /mandate* panel exhibits an association between *market* (cyan) and *transparency* (purple) scores. There is also a clear ranking from e-communications to the airport sector; telecom operators are granted a wide scope of regulatory means to design markets and ensure transparency. Interestingly, the gap between market and transparency scores is higher for energy and railways, suggesting that while regulators in these industries may establish processes and organize markets, they have less leeway to impose transparency, which becomes

[9] We tested the normality and homogeneous variance conditions using the Kruskal-Wallis (column *pnormm* in Table B.7) and Levene tests (see Table B.5), respectively. Except for the discretion dimension for e-communications, we could not reject the null hypothesis that the sector distributions are normal. Regarding the homogeneous variance condition, the Levene test applied to sector-level data did not reject the null hypothesis that distributions hold the same variance. We also tested the mean score significant differences using Tukey's test (see Table B.6).

[10] Between 2001 and 2016, four legislative packages were adopted for purposes of gradually opening up rail transport service markets for competition, making national railway systems interoperable and defining appropriate framework conditions for the development of a single European railway area. These include charging and capacity allocation rules, common provisions on licensing of railway undertakings and train engineer certification, safety requirements, the creation of the European Agency for railways and rail regulatory bodies in each Member State as well as rail passenger rights.

a significant factor of discrimination in sectoral regulatory regimes.

Figure 4.2: ANOVA predicted mean scores by sector

As to international comparisons (country sectors' average scores), Figure B.5 presents national average scores sorted by the distance between the *independence* and *discretion* scores. It highlights a potentially strong influence of national-specific institutional characteristics / political equilibria on RA's statuses. The figure highlights a strong heterogeneity not only in terms of score level but also in terms of hierarchy and gap size between *independence* and *discretion* scores, while the RA's practices seem to be more "parallel" (the country-level scores are relatively close) and overall *market* (cyan) are higher than *transparency* (purple) scores. Interestingly, the scores of regulatory levers seem to be correlated with the gap between independence and discretion rather than with the degree of independence or discretion. Putting it another way, powerful agencies (proxied by the scope of regulatory tools they operate), tend to be either independent from the government (with a precise delegation of authority), or endowed with a lot of discretion (but very closely linked to the executive). Also, it can be noted that the ranking across countries characterized by either a predominance of independence over discretion or by the opposite pattern does not reflect the usual (e.g., World Bank) ranking of countries in terms of public administration performance or market-friendly governance. For instance, we find the United Kingdom at one end of the spectrum and Switzerland and Denmark at the other end. Country size could be one factor playing a role in explaining the stringency of discretion / informality. We already mentioned the role played by political / legal culture. Path dependency in institutional evolution, as well as contrasted preferences in terms of "social contract", are probably the key underlying factor: Establishing an "independent and efficient RA," and the will to do so, are highly dependent on preexisting institutional structures, which are slow to evolve and difficult to reform, and on the socio-political equilibrium. The lower variability of the *scope* scores compared to the *governance* ones suggests that (market and transparency) practices have diffused more evenly across European governance regimes than the institutional model of the "independent" regulator.[11]

[11] We use a Mann-Whitney U test to check whether the observed differences between groups are significant.

Comparing the evolution of regulatory governance regimes

When considering the evolution[12] between two periods (cf. Figure 4.3), average evolution at the sector level highlights relative stability of two indicators (*discretion* and *market*) for all sectors, though there are advances in the matter of *independence* (except for the air-transportation RAs) and transparency (also in all sectors). The relative stability of *discretion* is in line with the idea that this characteristic is intrinsically linked to the general institutional framework / political equilibrium in most countries and is difficult to transform quickly, whereas increasing the RA's formal independence from the executive is easier to implement. The increasing transparency (and the stability in the ability to design markets) might be linked to the fact that the relevant relative performances lag for most agencies, as does the ability to develop the related practices incrementally and, therefore at relatively low political and organizational costs.[13] However, Figure 4.4 highlights that the modest advances in the mean evolution of the *discretion* and *market* scores do hinder an evolution of the distribution of the relevant scores, which is also contrasted across sectors, with an overall tendency to a homogenization around a common norm of lower discretion and higher transparency for e-communications, energy, and railway regulatory governance. This pattern of evolution does not hold for airport regulators that are only becoming more transparent (but whose discretion does not evolve).

International comparisons confirm that, with few exceptions, *independence* and *transparency* scores tend to increase for all countries as shown in Figure B.6. In the case of *independence*, 19 out of 23 countries display reinforcement, and three countries register a non-significant negative evolution (the United Kingdom, Austria, and Denmark). Only Sweden exhibits a regression in the matter of *independence*. *Discretion* shows a divergent pattern. Only 8 out of 23 countries exhibit growth in this field. Changes in Norway, Estonia, Germany, and Denmark are not statistically different from zero. In line with the recommendations pushed forward by the OECD and the European Union, structural reforms have targeted independence, and discretion seems to be a structural characteristic of each country. *Transparency* was reinforced in 22 out of 23 countries in

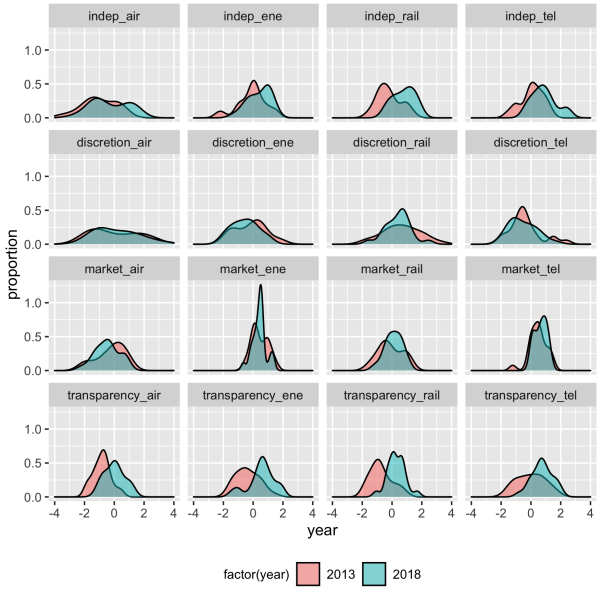
[12] The regime's evolution is measured in percent change relative to the initial situation by comparing scores between the two periods. We define percent change as $PCH = \frac{rawscore_t - rawscore_{t-1}}{rawscore_{t-1}}$

[13] The columns $meandif$ and $pval$ in Table B.7 show the average period difference (2013–2018) and its statistical significance (t-test). The *independence* scores increased between 8 per cent and 18 per cent, while transparency rates range between 20 per cent and 29 per cent, depending on the sector. In contrast, changes due to the *market* and *discretion* influence are modest and statistically insignificant. The *market* score variations are positive for rail (6 per cent), e-communication (4 per cent) and energy (0.06 per cent) and negative for air (–3 per cent). The negative changes in the *discretion* averages suggest a reduction in the agency's discretionary leeway in performing regulatory activities. These variations can be assessed graphically in Figure 4.4. The *evolution* scores do not differ systematically across sectors at the dimension level, as shown graphically in Figure 4.3. We formally check the significance of the differences using Tukey's test, which does not reject the null hypothesis that sector averages are the same (see columns $evoldif$ and $evolpval$ of Table B.6). Note that the rail sector experienced higher regime shift in *independence* (18 per cent), *transparency* (29 per cent), and *market* (6 per cent), i.e., railway regulatory agencies have benefited from legal provisions or changed their practices to favor transparency, more autonomy from the government, and a greater ability to monitor market behavior.

Figure 4.3: ANOVA evolution scores and residuals by sector

our sample[14] (the only exception being Finland), while reinforcement in market design levers is modest (only 12 out of 23 countries show growth).[15] These figures confirm that, over the period, most countries adopted a relatively parallel evolution of their regulatory governance regime. The focus was on guaranteeing more independence to RAs and pushing them to promote transparency (soft-law based / sunshine regulation).

Figure 4.4: Time/sector kernel estimate distributions (Gaussian)



[14] All of the changes are statistically different from zero.

[15] Negative changes are, however, small, and four of them are not statistically different from zero.

4.3.3 Regulatory Governance Regimes and Sectoral Performance

We now explore the potential relationships between our measured regulatory regimes and a set of industry performance measures. At this exploratory stage, we do not claim to demonstrate any causal relationships but rather to identify co-variations that might explain either the potential impact of a regulatory governance regime over industry performance or vice versa, the potential constraints sectoral organizations impose on the characteristics of regulatory governance. To put it another way, our goal is to present stylized facts about the relationships between regulatory governance regimes and industry performance in terms of capacity, quality, and price. Our aim is to explore the revealed impact of the regulatory governance regime, which should be a combination of the mandate of the RA (decided by the legislator and the executive and depending on the socio-political equilibrium and the national strategy) and the policy of the RA (which should be linked to its mandate and to the institutional and political constraints faced). Our scores highlight significant associations with the regulated industries' capacity, prices, and quality of service (with specific variations on this notion across industries: from environmental performance to safety). We test these associations using a linear regression model :

$$y_{ic} = \alpha + \beta x_{ic,m} + \gamma \, controls_{ic} + \epsilon_{ic} \tag{4.2}$$

In Equation (4.2), y_{ic} measures sector c performance (capacity, price, quality, coverage) for country i. The variable $x_{ic,m}$ stands for the dimension structure score for country i in the industry c and β stands for the effect of the dimension structure or change on sector performance. Furthermore, we include a list of general and sector-specific controls ($controls_{ic}$) to account for differences in income, country size, institutional quality, and geographical position. The full list of dependent variables and sector controls are shown in Table B.24 for energy, Table B.25 for e-communications, Table B.26 for the railway, and Table B.27 for air transportation. γ is a vector capturing the effect of each control variable on sector performance and ϵ_{ic} measures unobserved sector-specific heterogeneity. We use 5-year sector averages to capture long-run sector characteristics and reduce data variability in one particular period.

The European Union agenda seems to be an essential driver of governance evolution over time, although national and sectoral constraints influence local rule adoption. For instance, Directive 2009/72/EC defines the governance principles for electricity regulators, including transparency in rule adoption and publication, public consultation, and accountability. Thus, measurement of a change of regime should be less sensitive to national and industry long-run effects (Knill et al., 2012). In this regard, we inspect whether institutional evolution (measured by *growth* scores) drives significant changes in outcomes variables, as shown in Equation (4.3).

$$\Delta y_{ic,t} = \theta + \kappa x_{ic,g} + \mu \, controls_{ic} + \nu_{ic} \tag{4.3}$$

In Equation (4.3) robust correlations are sought by controlling for unob-

served time-invariant heterogeneity. The expression tests whether sector performance time variation $\Delta y_{ic,t} = y_{ic,t} - y_{ic,t-1}$ is linearly correlated to time changes in our dimension scores $x_{ic,g}$. This setup allows inclusion of time invariant controls, in contrast to other approaches such as panel data methods, and the identification of the effects (possibly different) of long-run regimes (β) and their changes (κ).

The vector $controls_{ic}$ measures the income (long-run), institutional quality, and other sector-specific performance determinants (variation), while the vector μ captures their effects on performance. Finally, the term ν_{ic} captures unobserved time-variant heterogeneity. Summary tables report significant coefficients at the 5 per cent level. The regression tables in the following subsections present relevant governance effects on sector performance. Each row represents one regression equation.

We approach the discussion sector by sector, relying on a sector-specific index of performance. In each case, we consider, first, the impact of RA governance measures (i.e. *independence* and *discretion*), and second the impact of RA levers' measures (i.e. *market* (cyan) and *transparency*).

Energy

As seen in Table 4.1, *independence* from the government is associated with greater electricity generation capacity (model 1), including generation from renewables and generation for export, but not including generation from gas. However, increased independence seems to improve the security of the domestic electricity supply at the expense of imports (model 4) and higher CO2 emissions (models 5, 6),[16] even as it favors system efficiency (particularly wind conversion rates, as shown in Table B.9). Overall, this might suggest that more independent regulators favor investments by operators but are less sensitive than governments to decarbonization objectives since their main mandate is to guarantee both security of supply (and of investments) and low prices for users. The level of *discretion* is negatively associated with more ''traditional" electricity production capacities (i.e., gas and hydro; Table B.8) and positively with renewable capabilities (model 3). However, as *discretion* expands, CO2 emitting production capabilities increase (model 8), and renewable generation contracts (model 17). Thus, *discretion* (hence informality) does not seem to be favorable to decarbonization. Also, *discretion* shows significant associations with higher consumer prices and price inflation (models 2, 7). *Discretion* does not benefit the interest of users.

The Table 4.2 seems to confirm our insight that RAs' mandates are not oriented toward the reduction of CO2 emissions, but rather the protection of consumers / users. RAs benefiting from more levers to monitor *markets* and industry operators' remuneration lead operators to invest in domestic generation capabilities, even if they emit CO2 (models 1, 2, 3). A reinforcement of the regulator's arsenal is associated with increasing CO2 emitting capabilities (model 4), while has also a positive impact on renewable capabilities (model

[16] A one per cent increment in the *independence* score is correlated with an almost one per cent increment in CO2 emissions capacity per capita.

Table 4.1: Energy regression OLS estimates for governance dimensions

	class	dimen	category	coef	pval	N
1	mean	indep	elecprod	922.632	0.025	22
2	mean	discretion	price_ind	21.962	0.044	22
3	mean	discretion	renewprod	409.169	0.028	22
4	growth	indep	imports	8.019	0.010	22
5	growth	indep	intcomb	0.269	0.006	19
6	growth	indep	solcap	-0.001	0.040	20
7	growth	discretion	price_hou	3.718	0.002	22
8	growth	discretion	totcomb	6.884	0.029	20

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *dimen* shows the type of institutional variable, *capacity* describes total system variables, *quality* whether energy is produced by CO2 or renewable technologies, or efficiently (relative measure) and *price* consumer retail prices per GWh. **System variables:** *elecprod* total production in GWh, *imports* electricity imports in GWh, $price_hou$ and $price_ind$ electricity consumer prices in USD per GWh. **Renewable:** *renewprod* production of electricity based in renewables and biofuels in GWh, *solcap* solar electricity capacity in MWe. **CO2:** *totomb* electricity capacity based in all combustion technolies in MWe, *intcomb* electricity capacity based in internal combustion machines in MWe. **Controls:** absolute country latitude, rule of law (WB), sector market regulation (OECD), GDPpc growth rate, tax revenue percentage (GDP), change in system capacity in MW. Complete regression tables are found in Table B.8 and Table B.9. Heteroskedasticity − robust standard errors.

5). The co-occurence of the two effects confirms, however, that decarbonization does not rank high in the hierarchy of objectives of the regulators. Low energy prices seem to be the main policy driver. A positive *transparency* variation is correlated with lower electricity prices for industrial consumers (model 6).

Table 4.2: Energy regression OLS estimates for scope dimensions

	class	dimen	category	coef	pval	N
1	mean	market	CO2sh	1.020	0.029	20
2	mean	market	elecprod	1, 054	0.011	22
3	mean	market	exportelec	-414.150	0.010	22
4	growth	market	othcomb	11.930	0.024	18
5	growth	market	solarpv	38.390	0.037	21
6	growth	transparency	price_ind	-3	0.027	22

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *dimen* shows the type of institutional variable, *capacity* describes total system variables, *quality* whether energy is produced by CO2 or renewable technologies or more efficiently (relative measure) and *price* stands for consumer retail prices per GWh. **System dependent variables:** *elecprod* total production in GWh, *exportelec* electricity exports in GWh, $price_ind$ electricity consumer prices in USD per GWh. **Renewable sources:** *solarpv* solar photovoltaic electricity capacity, *CO2sh* CO2 electricity production in GWh, *othcomb* electricity capacity based in internal combustion machines in MWe. **Controls:** absolute value of country latitude, rule of law (WB), market regulation score (OECD), GDP per capita growth rate, tax revenue percentage (GDP), change in system capacity in MW. Complete regression tables are found in Table B.10 and Table B.11. Heteroskedasticity − robust standard errors.

E-communications

The relationship between regulatory governance and performance in e-communications is challenging, given the available performance indicators in this market characterized by the marketing of a diversity of services that are partly substitutable and partly complementary (think, for instance, of voice and digital communications, with the development of voice over Internet phone (VoIP) and videoconferencing; or of fixed and mobile telecommunications). During the period under consideration a central challenge has been the development of broadband Internet access. At the same time, telecommunications operators have stream-

lined their operations by bundling services, in particular providing bundled access to their fixed and mobile digital networks, as well as joint subscriptions to the Internet, cable TV, and telephony. One of the issues is that statistical systems did not keep up with the evolution of technology and the marketing of e-communication services, continuing to differentiate between these services. Overall, it seems that RAs concentrated their efforts on promoting the development of broadband infrastructure, enhancing the overall quality of e-communications services. Pricing of services was not their main concern, at least according to the correlations we observe.

At first blush, discretion seems to have more impact than independence from the government. As shown in Table 4.3, countries with higher *independence* scores exhibit higher development of broadband-based service (VoIP, model 2) at the cost of higher fixed-broadband prices (model 1). However, shoring up the independence of the RA seems to have a positive impact on the high-speed infrastructure (model 6), on (decreasing) fixed-broadband prices (model 7), and on the use of digital services (model 8). Higher scores in *discretion* are associated with higher fixed-broadband coverage (model 4) and lower mobile coverage (model 3), while prices are positively correlated with discretion, in particular for mobile services (model 5). As a matter of evolution, increasing *discretion* has a positive impact on broadband adoption, primarily via mobile (model 9), and triggers a decrease in prices (model 10) and higher coverage.

Table 4.3: E-communications OLS regression estimates for governance dimensions

	class	varia	dimen	category	coef	pval	N
1	mean	price	indep	prixfixbb	0.040	0.020	20
2	mean	capacity	indep	telVoIP	1,227	0.044	19
3	mean	capacity	discretion	accpath	-835.9	0.022	21
4	mean	quality	discretion	fixprate	0.770	0.006	21
5	mean	price	discretion	prixmob	0.730	0.039	20
6	growth	quality	indep	cabsubs	0.030	0.044	19
7	growth	price	indep	ppprice	-0.150	0.049	19
8	growth	capacity	indep	voipsubs	41.860	0.032	17
9	growth	quality	discretion	mobpenrate	0.330	0.032	20
10	growth	price	discretion	ppprice	-0.450	0.005	19

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *dimen* shows the type of institutional variable, *capacity* describes absolute system variables (e.g., total numbers of service subscribers), *quality* describes relative measures (e.g., number of subscribers by 100 habitants) and *price* stands for consumer retail prices in USD for telecom services. **Capacity dependent variables:** $telVoIP$ and $voipsubs$ number of subscribers of VoIP services, $accpath$ number of access paths for telecom services in thousands of access. **Quality:** $fixprate$ penetration rate for fixed broadband internet services, $mobpenrate$ penetration rate for mobile services. **Prices:** $prixfixbb$ and $pprice$ price for 5 Gb fixed internet bundle in PPP USD, $prixfix$ price for 5 Gb fixed internet bundle in USD. **Controls:** Rule of law index (WB), market regulation score (OECD). GDP per capita growth rate average (2013-2018), population density, percentage of the population living in urban areas, and the number of hotel nights spent by tourists in a given country. Complete regression tables are found in Table B.14 and Table B.15. Heteroskedasticity − robust standard errors.

As seen in Table 4.4, scores in terms of reliance on *market* levers do not show a strong association with performance variables, e.g., service coverage or prices. However, the score is negatively associated with mobile termination rates (model 1). Also, reinforced *market* incentives do not seem correlated with any change in industry outcomes between 2013 and 2018. Since the e-communications sector has been liberalized for a while and since the European Union has been promoting convergence of regulatory policies, very similar regulatory policies seem to be involved when the issue is market organization and competition among operators. Nonetheless, policies governing *transparency* seem to have a significant

impact on prices (models 4, 5) and the total number of subscriptions (model 2). Transparency scores are higher in countries with lower fixed penetration rates (model 3), but when transparency increases, it positively impacts subscriptions and penetration rates. Reinforcing transparency highlights a positive correlation with all types of broadband technology subscriptions (model 6). These associations are accompanied by a price increase for fixed-broadband Internet service (model 7), where one per cent increase in *transparency* translates to a five per cent increase in the average price change. Transparency might allow users to identify the variety of potential Internet access solutions / providers, even without a price effect (which is in line with the fact that the market is already significantly competitive).

Overall, with increased transparency being the more significant regulatory governance transformation in the e-communication industry (cf. Figure 4.4), it is not surprising that the evolution of broadband access and use is linked to that governance dimension; which does not negatively impact prices, however. More generally, regulatory governance in e-communications seems to be facing a trade-off between the development of high-speed Internet coverage and the quest for lower prices.

Table 4.4: E-communication regression OLS estimates for scope dimensions

	class	varia	dimen	category	coef	pval	N
1	mean	price	market	mobterm	-0.220	0.036	20
2	mean	capacity	transparency	accpathtot	1,302	0.016	21
3	mean	quality	transparency	fixtotal	-1.320	0	21
4	mean	price	transparency	prixfix	-1.720	0.018	20
5	mean	price	transparency	prixmob	-2.020	0.016	20
6	growth	quality	transparency	accpath	0.220	0.050	20
7	growth	price	transparency	pcprice	0.010	0.023	19

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *dimen* shows the type of institutional variable, *capacity* describes absolute system variables (e.g., total numbers of service subscribers), *quality* describes relative measures (e.g., number of subscribers by 100 habitants) and *price* stands for consumer retail prices in USD for telecom services. **Capacity dependent variables:** *accpathtot* number of access paths for telecom services in thousands, *accpath* number of access paths for telecom services per 100 habitants. **Quality:** *fixtotal* number of subscribers to fixed broadband internet service per 100 habitants. **Prices:** *pcprice* price for 5 Gb fixed internet bundle as a percentage of per capita income, *prixmob* price for 5 Gb mobile internet bundle in PPP USD, *prixfix* price for 5 Gb fixed internet bundle in PPP USD, *prixmob* price for 5 Gb mobile internet bundle in PPP USD, *mobterm* price of termination rates in another network in USD. **Controls:** Rule of law index (WB), market regulation score (OECD). GDP per capita growth rate average (2013-2018), population density, percentage of the population living in urban areas, and the number of hotel nights spent by tourists in a given country. Complete regression tables are found in Table B.13 and Table B.12. Heteroskedasticity − robust standard errors.

Railways

In the case of transportation industries, the multi-product nature of the activity (e.g. local vs. long-distance transportation, passengers vs. freight, etc.) and the marketing methods (e.g. yield management, subscription) make it difficult to use comparable aggregate statistics to assess economic performance. What we have found, however, is that regulatory regimes seem to impact quality, especially safety, rather than retail prices. We also observe an impact on the volume of traffic. It is important to keep in mind that in matters of transportation, competition is largely inter-modal, not only intra-modal; and that users tend to consider mobility in terms of inter-modality, since no single mode of transportation is able to respond to every demand for trips.

When considering railways' regulatory governance, the correlations with structural variables seem inconsistent with those of evolution. As shown in Table 4.5, higher *independence* relates to a high deployment of safety capacity (model 1).[17] An increment of autonomy is associated with a modest increment in derailments (model 5), which account for four per cent of total incidents (European Union Agency for Railways, 2017), while also with a decreased personal incidents rate (model 3) and a positive variation in safety capacity deployment (model 4). These patterns suggest that more independent regulators tend to focus their pressures on operator safety.[18]

Discretion also seems to support safer railway operations. A high *discretion* score negatively correlates with total incidents in rail operations per km (model 2). An increment only impacts (negatively) freight traffic (model 6) and safety capacity deployment (reported in Table B.16).

Table 4.5: Rail Transport OLS regression estimates for governance dimensions

	class	varia	dimen	category	coef	pval	N
1	mean	quality	indep	activecross	0.010	0.013	17
2	mean	quality	discretion	allaccidkm	-0.050	0.045	17
3	growth	quality	indep	accunpeop	−0.001	0.013	19
4	growth	quality	indep	activecrosskm	0.001	0.006	18
5	growth	quality	indep	derail	0.030	0.034	19
6	growth	capacity	discretion	goodskm	-0.060	0.031	19

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes absolute system variables (e.g., length of rail tracks), *quality* describes safety measures (absolute or relative) (e.g., number of rail incidents by km of track). **Quality dependent variables:** *activecross* number of automatic devices to handle crossings in tracks, *allaccidkm* total number of incidents in the rail system per track km, *goodskm* volume of goods transported by rail system in metric tons per km, *accunpeop* number of incidents that ended in the injure of unauthorized persons in rails, *derail* number of yearly derailments countrywide, *activecrosskm* number of automatic devices to handle crossings in tracks per track km.**Controls:** market regulation score (OECD), GDP in PPP USD, total system rail track length, GDP per capita growth rate, rule of law score (WB). Complete regression tables are found in Table B.16 and Table B.17. Heteroskedasticity − robust standard errors.

The scope dimensions show two contrasting patterns; on the one hand, *market* coordination levers seem to favor greater industry output at the expense of safety (see Table 4.6). Reliance on *market* regulatory tools, hence competitive pressure, is associated with more freight traffic (model 2), train delays (model 1), and safety incidents (reported in Table B.18). Growth in the *market* score is only associated with more freight traffic (model 3) and investments in infrastructure (model 4). *Transparency* does not show a significant correlation at the structural level, but its increments are linked to incident reduction (models 5, 6). This result seems to be associated with rail safety assessment as part of the Common Safety Method (Commission Decision 2009/460/EC). Transparency and reporting might allow member states to identify main safety concerns and take further action. This information flow requires active stakeholder engagement and coordination as highlighted by European Union Agency for Railways

[17] High independence is correlated with incidents that involve passengers (Table B.16). However, these events accounted only for three per cent of total incidents involving persons in 2015

[18] In their safety overview, European Union Agency for Railways (2017) highlights that unauthorized person accidents and level-crossing incidents account for almost 85 per cent of all incidents (91 per cent of incidents with casualties). Most of the level-crossing incidents are caused by user misuse (25 per cent of all incidents), and only 53 per cent of level-crossings use automated mechanisms.

(2018). All in all, what seems significant here is that there is a tension between market pressure, which seems to lead to higher volume provided by the operators, and quality both in terms of punctuality and safety. It seems that *transparency* levers are relied on to deal with this necessity to pressure operators on the quality they deliver.

Table 4.6: Rail Transport regression OLS estimates for scope dimensions

	class	varia	dimen	category	coef	pval	N
1	mean	quality	market	delaymin	5,205.950	0.020	16
2	mean	capacity	market	freight	2,330.970	0.045	17
3	growth	capacity	market	goodskm	0.070	0.007	19
4	growth	capacity	market	tracklen	55.280	0.017	19
5	growth	quality	transparency	accicross	-0.100	0.046	19
6	growth	quality	transparency	accidempl	-0.080	0.007	19

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes absolute system variables (e.g., length of rail tracks), *quality* describes safety measures (absolute or relative) (e.g., number of rail incidents by km of track). **Capacity dependent variables:** *freight* volume of goods transported by rail system in metric tons, *tracklen* rail system track length in km. **Quality:** *delaymin* minutes of delay product of rail incidents, *goodskm* volume of goods transported by rail system in metric tons per km, *accicross* number of incidents in road crossings, *accidempl* number of incidents that end in injure of rail employees. **Controls:** market regulation score (OECD), GDP in PPP USD, total system rail track length, GDP per capita growth rate, rule of law score (WB). Complete regression tables are found in Table B.18 and Table B.19. Heteroskedasticity − robust standard errors.

As pointed out above, safety seems to be central in railway regulatory governance, and the associated regime is influenced by this issue, which differs significantly from e-communications and energy regulatory governance. Variations in both *independence* and *discretion* are mostly associated with relevant operational incident reductions. The RA tools show contrasting impacts. While *market* supports high industrial output, increments in *transparency* are associated with safer operation.

Airports

In the case of airports, governance dimensions show similarities with what was observed in the case of railways in their correlations with industry performance. As shown in Table 4.7, *independence* is negatively associated with the number of operating airports (model 1), and with fewer operational incidents (model 2). Reinforcement of the *independence* is related to an additional decrease in operating airports (model 4). Thus a more independent regulator seems to favor safer airports; possibly larger ones.

Our correlations seem aligned with the air transport sector's perspectives. The sector faces a growing unmet demand and few incentives for new capacity deployment (European Organisation for the Safety of Air Navigation, 2013).[19] Therefore, operators and regulators attempt to stabilize costs and efficiency under the pressure of additional traffic.

Discretion is associated with fewer airport operation incidents (model 3). However, reinforced *discretion* is correlated with an increase in total system

[19] A slow economic recovery (2008 crisis), the maturity of the European market, and the prospects for industry growth outside the European Union have raised capital costs. European Organisation for the Safety of Air Navigation (2013) highlights that capacity deployment projections have been re-estimated from a 38 per cent (2008 benchmark) increase in 2030 to a 17 per cent increase in 2035.

incidents, including gate-to-gate operations (model 5), and a growth in the number of operating airports (coefficient not significant and not reported). This seems to confirm the fact that when the regulatory choices lead to operating more airports, smaller, less reliable, airports are operated; explaining the rise in gate-to-gate incidents (European Statistical Office, 2020).

Table 4.7: Air regression OLS estimates for governance dimensions

	class	dimen	category	coef	pval	N
1	mean	indep	airptot	-1.700	0.043	15
2	mean	indep	operincid	-1.160	0.021	15
3	mean	discretion	operincid	-0.930	0.004	15
4	growth	indep	numairpo	-0.170	0	16
5	growth	discretion	totdisrup	3,908.340	0.001	16

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes system variables (e.g., number of operating airports, number of arrivals), *quality* describes safety measures (absolute or relative) (e.g., number of air incidents). **Capacity dependent variables:** *airptot* and *numairpo* number of total airports operating in a country. **Quality:** *operincid* number of incidents related to airline operations, *totdisrup* total number of disruptions of any kind in air operations. **Controls:** product market regulation in air sector, average number of aircrafts in a country airspace (a measure of traffic), GDP per capita growth rate, number of hotel nights spent by tourists in a given country, country GDP in constant USD, air sector national accounts added value in constant USD. Complete regression tables are found in Table B.20 and Table B.21. Heteroskedasticity – robust standard errors.

As in the case of railways, reliance on *market* instruments is positively correlated with the volume of activity and capacity; in our case, proxied by the capacity of the aircraft fleet operating in the country (models 1, 2) in Table 4.8. A one per cent score increase accounts for an eight per cent increment in large-capacity aircraft (150–250 passengers). Increasing *transparency*, in turn, is related to more traffic (as proxied by the number of flight arrivals (model 3), and of operating aircraft (model 5)). While increased traffic is associated with progress in terms of system disruptions (model reported in Table B.23), greater *transparency* reduces airport operational incidents (model 4). It seems that RAs rely on the combination of market incentives and *transparency* requirements, as in the case of railways, to push operators to accommodate growing demand while avoiding downgrades to safety. European Organisation for the Safety of Air Navigation (2013) highlights that airport operators and airlines need to optimize aircraft fleets, locally available runway usage, and improve flight scheduling to deal with the growing unmet demand.

Table 4.8: Air regression OLS estimates for scope dimensions

	class	dimen	category	coef	pval	N
1	mean	market	air150	4.990	0.002	15
2	mean	market	air250	4.480	0.001	15
3	growth	transparency	arrivals	664.390	0.008	14
4	growth	transparency	capacinci	-283.830	0.042	14
5	growth	transparency	numplanes	0.910	0.004	14

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes system variables (e.g., number of operating airports, number of arrivals), *quality* describes safety measures (absolute or relative) (e.g., number of air incidents). **Capacity dependent variables:** *numplanes* number of operating aircrafts registered in a country, *arrivals* number of year arrivals in all airports countrywide, *air*150 number of aircrafts with capacity below or equal to 150 passengers, *air*250 number of aircrafts with capacity from 150 to 250 passengers.**Quality:** *capacinci* number of incidents related to airport land operations. **Controls:** product market regulation in air sector, average number of aircrafts in a country airspace (a measure of traffic), GDP per capita growth rate, number of hotel nights spent by tourists in a given country, country GDP in constant USD, air sector national accounts added value in constant USD. Complete regression tables are found in Table B.22 and Table B.23. Heteroskedasticity – robust standard errors.

In sum, greater independence of RAs seems to favor the development of larger airports, with a positive impact on safety. Reliance on market levers has a positive impact on traffic, while the latter's development might translate into a higher number of incidents. To control for that effect, RAs favor increased transparency, which seems to be a successful strategy. As said, a more in-depth investigation would be needed to test causality.

4.4 Discussion and conclusion

Our methodology suggests four independent dimensions to characterize governance regimes:

- independence from the government
- the regulatory agency's level of discretion (which might also be interpreted in terms of the informality of its powers)
- the scope of the regulator's market monitoring capabilities
- the RA's ability and obligation to impose transparency between the supply side and the other stakeholders of the regulatory game, in particular public authorities and users.

These dimensions seem to capture long-run sectoral and national aspects of regulatory governance. At the sector level, energy and e-communications exhibit similar regulatory governance logic, driven by the RA's high independence and low discretion. The latter benefits from strong capabilities to frame operators' behavior on the market and have increased their role as guarantors of transparency over the past years. The regulatory governance regime differs in the transportation industries. While rail RAs tend to be as independent as their counterparts in the e-communications and electricity industries, they benefit from a less formal status and less clear delegation of authority. This is even more true of RAs responsible for airports, which remain in the governmental sphere.

Across countries, institutional arrangements governing RAs' statuses tend to differ considerably, and differences seem to persist. At the same time, there is a common trend toward developing the role of RAs as agents of transparency, which accompanies their ability to monitor markets and the economics of operators.

Moreover, our governance and scope dimensions (both their structure and evolution) exhibit significant correlations with industry performance. However, strong contrasts exist across industries, suggesting that the actual role of regulators differs from one industry to the other. This might partly reflect differences in terms of "maturity" since, in Europe, the implementation of independent sectoral regulatory agencies started with the liberalization of the telecommunication markets in the 1990s, followed by energy ten years later, and by railways and airports mostly as of the 2010s. Younger RAs seem characterized by more

informality and access to a smaller set of regulatory tools. However, it is not a given that sectoral regulators converge toward a common model since they operate in industries with highly contrasted economies. In the e-communications sector, regulatory governance seems critical to performance in terms of quality (broadband) of service. In contrast, in the electricity industry, the RAs' main concern seems to be energy prices, even at the cost of electricity's environmental quality. In the transportation industries, the focus is on the volume / development of traffic and improved safety.

While our results partly corroborate previous studies that have attempted to establish a link between regulatory governance and performance, they differ on two grounds. First, while independence from the government has already been identified as a significant dimension, we point out that the degree of discretion / formalization of the RA's powers also matters. We also highlight that RAs play a role beyond designing markets and setting tariffs: promoting transparency. Moreover, in the past years in Europe, the most significant developments in regulatory frameworks have involved these two overlooked dimensions of regulatory governance regimes: discretion / formalism and transparency. Our exploratory study calls for more in-depth analyses of these dimensions and consequences for sectoral performances.

The drivers of the potential causal relationships identified in this study require further investigation. We have not accounted for other features that impact performance, such as national political priorities, and unobserved sector characteristics that also influence operators' economic incentives and decisions. Further research is needed to better understand the potential links between sector characteristics and governance regimes and between developments in governance and industrial performances. Such detailed analyses are necessary to provide policymakers with relevant knowledge to design superior regulatory institutions.

Chapter 5

Paper 3: Impact of Regulatory Governance Regimes on Renewable Energies: An empirical analysis of European National Regulatory Agencies from 2013 to 2018

Abstract[1]*: We analyze the impact of National Regulatory Agencies (NRAs) governance on achieving environmental objectives. On the one hand, during the liberalization reforms, European governments delegated regulatory powers to NRAs to maintain fair competition in the electric market, provide investment incentives, reduce consumer bills, and increase the efficiency of electric networks. On the other hand, decarbonization has acquired widespread political support in recent years. In the last ten years, we have observed an increase in the share of renewable energy in most European countries, which creates tensions with some of the liberalization's objectives. We hypothesize that independent NRAs align with the liberalization mandates at the expense of reducing the adoption pace of renewable energies. We use a panel data analysis to assess the influence of NRAs governance on renewable-energy shares in 24 EU countries for 2013-2018. We uncover a negative, significant and robust relationship between NRA independence – which measures the distance between the NRA and the government – and the share of renewable energy generation from total energy consumption.*

[1]In collaboration with Eric Brousseau (University Paris-Dauphine (PSL), Governance and Regulation Chair) and Diego Cebreros (Université Paris-Saclay, CentraleSupélec, Laboratoire de Génie Industriel)

5.1 Introduction

In Europe, National Regulatory Agencies (NRAs) in the electric sector were designed to become key actors in implementing the liberalization reforms performed during the 1990s. The liberalization had as its primary objective the restructuring of the electric industry, typically controlled by vertically integrated monopolies, through regulatory reforms to develop a competitive market that would attract new investments (Joskow, 2008). European countries engaged with the liberalization process because competition promised to increase sector performance, redistribute the gains derived from efficiency to European citizens through lower prices, and encourage the integration of EU markets by reducing the exchange barriers between countries.

In 1996, the European Parliament defined a common regulatory regime [2] for the electric sector in all member states through a series of Energy directives. In 2003, new Energy directives formalized the role of regulators in National Regulatory Agencies and defined a standard governance regime. The regime was designed to ensure NRA would not deviate from the liberalization reforms and to protect them from the influence of politicians with short-term interests or private actors trying to abuse their market power. The NRAs were given technical capabilities and resources to improve their regulatory practices and enforcement power to act as fair market referees. The ultimate goal was to improve the sector's efficiency.

The liberalization reform and NRA governance regime were a remedy to introduce efficiency in a centralized vertical integrated electricity industry with considerable hydroelectric power and thermic generation able to produce electricity at any moment (Pollitt, 2019). However, European member states have increased their support for renewable electricity generation due to the ambitious decarbonization targets in current European legislation (Second renewable electricity directive in 2009/28/EC). The most relevant are those resulting from the Paris Agreement and the European Climate Law that target the complete decarbonization of the electric sector for 2050. These commitments introduce additional tension to competitive markets that need to be addressed.

Given the above, we consider it relevant to propose a research question: What is the impact of NRA's governance regimes on the share of renewable energies? Most empirical research focuses on the effects of market reform on decarbonization objectives (Steiner, 2003; Asane-Otoo, 2016; da Silva and Cerqueira, 2017; Nicolli and Vona, 2019), while the impact of regulatory governance has received less attention in the literature. This article focuses on NRAs, their governance, mandates, and potential tensions in integrating renewable energies in competitive markets. The growth of renewable energies relied primarily on feed-in tariffs, and the investment costs of renewable energies were still significantly higher than other thermic sources.

When the first targets of Renewable energies were set, most of the large-scale technologies for renewable energy production were not mature enough to attract investment; hence, they required subsidies like feed-in tariffs for their

[2] The institutional structure and responsibilities for carrying out regulatory actions (May 2007:9). Section III gives more details of the concept.

implementation. The subsidy of renewable energies threatened the objectives of liberalization and the mandates of NRAs. On the one hand, the competition was threatened by subsidizing renewables over thermic technologies. On the other hand, renewable energies have a production function that disrupts the current market design.

Under a marginalistic market design of wholesale electric markets [3], the extensive participation of renewable energy units (with zero marginal costs) reduces wholesale prices. Lower prices give fewer incentives to investors for current and future investments. In addition, more renewable units, which rely on varying weather conditions, increase the supply uncertainty and, consequently, the cost of balancing supply and demand (especially during peak hours) and the risk of system failure. Ultimately, the balancing costs and subsidies are paid by consumers via higher bills.

We perform an empirical analysis using panel data to measure the impact of regulatory governance on electric tariffs and renewable energy growth in EU member states. We rely on text-analysis-based metrics based on OECD regulatory governance surveys and its characteristics (Brousseau and Gonzalez-Regalado, 2022). This method uses data variability to identify the relevant features of a governance regime and the participants' weights assigned to each dimension. Our results show that between 2013 and 2018, independence is negatively correlated with changes in the share of renewable energy sources (RES) in total energy consumption.

Our contribution is two-fold. First, previous work (Alesina et al., 2005; Égert, 2018; Anderton et al., 2020) focuses on the effects of the reforms (policy output) on economic performance (investments, factor productivity, and labor markets). We contribute to the empirical literature on the effects of liberalization in utilities by separating the effects of regulation in regulatory and governance regimes. Second, we contribute to the literature on empirical determinants of renewable energy generations by discussing the role of NRA's governance regimes in the trade-offs between economic and environmental objectives.

This study has eight sections. In the second section, we display an overview of the history of EU regulation, considering the implementation of liberalization reform, the standard mandates for EU NRAs, and the climate change commitments. Then, in the third section, we review the academic literature that has treated related research questions and define regulatory governance concepts. The fourth section presents our analytical framework and develops our hypotheses. Later, in the fifth section, we explain the data used and our empirical strategy. Section six presents our results, and section seven discusses them in detail. Finally, in section eight, we offer our conclusions.

[3] Wholesale electricity prices are set by the marginal cost of the last generation unit included in the market.

5.2 Historical review of the EU reforms in the electric sector

5.2.1 Liberalization reform in the EU

Joskow (2008) defines liberalization as restructuring a sector through regulatory reforms to develop a competitive market. The objective of liberalization for the electric industry is to ensure that prices reflect *the efficient economic cost of supplying electricity and service quality attributes that reflect consumer valuations.*

For the European Union (EU), the main objectives of the liberalization were threefold: First, to facilitate the integration of the electric systems in the EU. Second, give incentives to investors for developing transmission lines for exchanging electricity amongst countries which would contribute to better system reliability by taking advantage of different industrial policies and natural resources. And third, redistribute the surplus of efficiency gains directly to customers through lower electricity tariffs.

Three transformative actions were set in place to achieve the reform objectives. First, the privatization and vertical separation of formerly state-owned national monopolies, which in many cases controlled the totality of electric assets within a country. Second, the creation and design of specialized wholesale electric markets for electricity and power based on competition and efficiency principles. And third, the development of a common regulatory framework to guarantee the functioning of the markets and the integration of European electric systems.

We present an overview of the legal instruments introduced by the European Parliament to implement the liberalization of the electric sector. There are four legal instruments: Treaties, Directives, Regulations, and Common market rules -such as network codes and guidelines- (Meeus, 2020). The most relevant instruments enacted have been Directives and Regulations. Directives have been used to set common goals for all EU countries within a defined time frame without constraining the legal acts required to implement at a national level. While, Regulations have been used less, as they are harder to implement across member states because they are immediately applicable to all member states overruling national legislation.

The first EU electric directive issued in 1996 (96/92/EC) set the target of unbundling electric production from the transmission segment. Until this Directive, Norway, Sweden, and the United Kingdom were the only countries without vertically integrated electric systems managed by national companies. The second electric directive (2003/54/EC) extended the unbundling of the electric network to transmission and distribution. In particular, the Directive required a legal separation of Transmission System Operators (TSOs) from Distribution System Operators (DSOs). Besides, it mandated the creation of independent NRAs [4] in all member states to guarantee non-discriminatory access to the network. The third electric Directive (2009/72/EC) gave a choice to member states

[4] Art. 23 of this Directive defines the tasks of NRA's

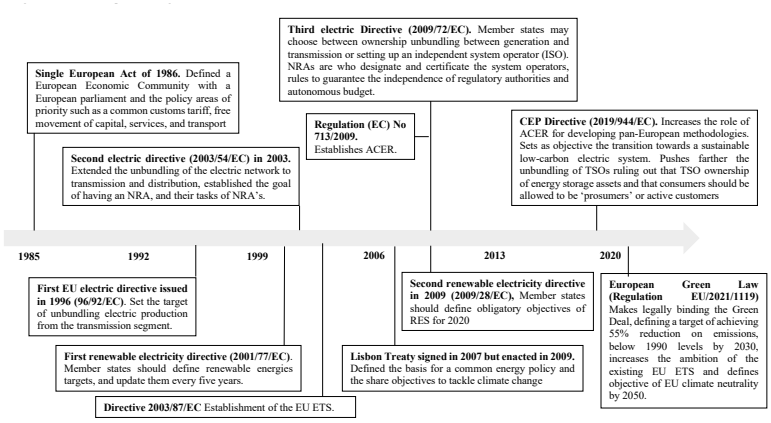


Figure 5.1: Timeline of implemented legislation in the EU for the electric sector

between defining ownership unbundling between generation and transmission or setting up an independent system operator (ISO). The directive also (Art. 35) laid out the rules to guarantee the independence of regulatory authorities and an autonomous budget.

From the beginning of the liberalization reforms, the unbundling of vertically integrated monopolies seemed insufficient to attract investments in the EU. The rationale was that investors required stronger guarantees of fair competition from incumbents and that short-term political interests would not risk the return on new investments. Hence, even if some countries already had delegated regulatory tasks to independent bodies since the beginning of the '90s (Glachant, 2012), the second (2003/54/EC) and third (2009/72/EC) packages triggered the diffusion of NRAs in Europe as the institutions responsible for overseeing the design of competitive markets and promoting good regulatory practices.

The last electric Directive approved until today is the Clean Energy Package (CEP) [5]. The directive changed the definition of network codes and guidelines to coordinate electricity exchange and the existing national markets (Meeus, 2020). An essential difference between the CEP and previous directives is that it accounts explicitly for the objective of decarbonizing the EU electric system beyond the economic rationale of prior instruments.

[5]For reference, see the Directive 2019/944/EC

5.2.2 European NRA governance regime

The NRA model proposed by the Second and Third Electricity Directives delegated the exercise of regulatory powers to NRAs based on principles of competition, security, and environmental sustainability. Following these principles, member states commissioned a set of responsibilities and tools to carry their mandates to NRAs and give them independence. Regulators should decide on matters such as interconnection capacity and tariff setting. Table 5.1 summarizes the principles and provisions that member states should follow when establishing NRAs.

Table 5.1: Summary of legal instruments for EU NRAs in Europe

Actors	Legal origins Principles and tools	Delegation
Member States	Competition - ME shall ensure electricity markets are operated following the competition, security, and environmentally sustainable principles. (Article 3 Directive 2003/42/EC; Article 3 Directive 2009/72/EC).	Delegation - ME shall designate a single national regulatory authority at the national level. (Article 35 Directive 2009/72/EC)
	Non-Discrimination – If financial compensation (other forms) and exclusive rights that ME grants for fulfilling the obligations shall be done in a non-discriminatory and transparent way (Article 3 Directive 2003/42/EC).	Independence - Member states shall guarantee the independence of the regulatory authority and shall ensure that it exercises its powers impartially and transparently. Member states shall ensure that regulatory authority can take autonomous decisions independently from any political body and has separate annual budget allocations (Article 35 Directive 2009/72/EC)
	ME shall ensure the implementation of a system of third-party access to the transmission and distribution systems based on published tariffs. (Article 24 Directive 2003/42/EC)	
	Monitoring - ME shall ensure the monitoring of the security of supply. Where ME consider it appropriate, governments may delegate this task to the regulatory authorities (Article 4 Directive 2003/42/EC)	
NRAs	Responsibilities - Regulatory authorities shall ensure non-discrimination, effective competition, and efficient market monitoring. (Article 36 Directive 2009/72/EC)	Independence - Regulatory authorities shall be wholly independent of the interests of the electricity industry (Article 35 Directive 2009/72/EC)
	They should be responsible for: (a) rules on the management and allocation of interconnection capacity, (b) the level of transparency and competition, (c) methodology to calculate tariffs, and (d) help achieve in the most cost-effective way the development of secure, reliable and efficient production of electricity (Article 36 Directive 2009/72/EC).	Accountability - Regulatory authorities shall submit formal decisions to the relevant body in the Member State regarding the methodologies to calculate tariffs. Member states may approve or reject the propositions of regulators (Article 36 Directive 2009/72/EC).
		Authority – Regulators shall have the authority to require transmission and distribution system operators, to modify the terms and conditions, tariffs, and rules, to ensure that they are non-discrimination. Regulators may also act as dispute settlement authority between parties (Article 36 Directive 2009/72/EC).

However, the transposition of the Energy Directives to national legislation has been uneven across EU member states. While all member states in our sample have already set up an independent NRA, budgetary autonomy, head/board length term, dismissal conditions, industry ties, and agency staff remain disparate. This issue is highlighted by the OECD (2016) and Casullo et al. (2019). Although, evidence shows that these differences are diminishing over time and that member states are gradually implementing the 2^{nd} and 3^{rd}

Energy Directives (Brousseau and Gonzalez-Regalado, 2022).

5.2.3 Decarbonization of the electricity sector in the EU

Directives to promote renewable energies were initiated in 2001 under the Kyoto Protocol, which agreed on a binding target for the EU to reduce their emission levels by 5% to respect their 1990s for 2012. The first renewable electricity directive (2001/77/EC) ruled that member states should define renewable energy targets, update them every five years, and encourage them to use national economic mechanisms until the EU defines a common framework. Its update in 2009 (2009/28/EC) enforces that member states should define obligatory objectives of RES for 2020, and its last version in 2018 (2018/2001/EU) set a binding target for collectively ensuring that the share of energy from RES is at least 32% in 2030.

European Green Law (Regulation EU/2021/1119) is the most recent commitment from the EU to climate change targets. It legally binds the Green Deal, defining a target of achieving a 55% reduction in emissions below 1990 levels by 2030, increasing the ambition of the existing EU ETS, and the ambitious objective of EU climate neutrality by 2050.

Figure 5.2 presents the evolution in the share of renewable energy as a percentage of total energy consumed in 27 EU member states. Since 2004, the share of renewable energies has almost been duplicated. The growth of renewable energies relies substantially on subsidies, which reflect the political commitment to decarbonization targets. Governments either support the reduction in the investment costs in renewable energies, mainly for solar and wind units, or guarantee positive and stable revenue streams through support mechanisms such as feed-in-tariffs / premiums, quotas, and other instruments.

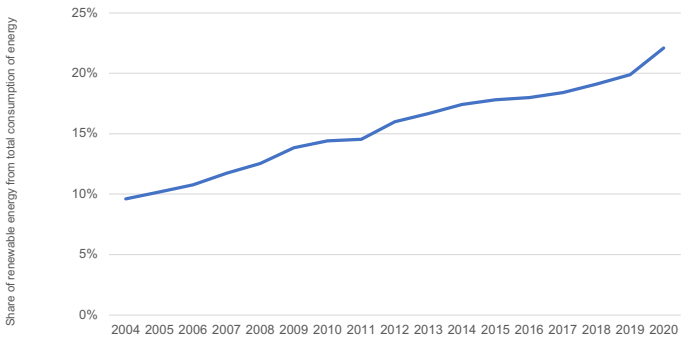


Figure 5.2: Growth in the share of renewable energy as a share of gross energy consumption

The support instrument used the most was feed-in tariffs which in 2019 represented a subsidy of €53 billion (EC, 2021). Because feed-in tariffs have

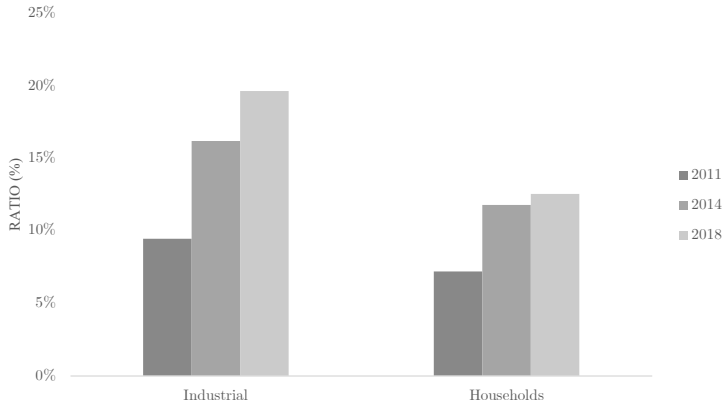


Figure 5.3: Ratio between the tariffs paid to support renewable energies and the electricity tariff by type of consumer. (Authors, based on Eurostat and CEER)

supported renewable energies, and renewable energies reduce the price in wholesale electric markets, the subsidies from feed-in tariffs have become more expensive over time (Henriot and Glachant, 2013; MacLean et al., 2015; Council of European Energy Regulators, 2021). Between 2015 and 2019, EU subsidies for renewable energies increased by €6 billion, which meant a rise of 8% of the period. Figure 5.3 shows that the ratio between the total support given to renewable energies divided by the gross MWh consumed; and the costs of generation and supply (network costs) is increasing for non-households and households [6].

5.3 Literature Review

5.3.1 Independent regulatory regimes

Before the electricity reform started in Europe, national ministries were responsible for implementing regulation, i.e., policymaking, enforcement, monitoring, and sanctioning misbehavior. Scott (2005) calls these capacities "regulatory powers" and the designation of these powers to an entity as the "regulatory regime." Scott (2005) defines a "regulatory regime" as the institutional and procedural components required to control a social or economic sector. These components include objectives, procedures, standards, monitoring methods, and re-alignment provisions to prevent departures from goals.

Interestingly, European member states did not develop the regulatory system's governance (or "governance regime"); rather, it was adopted from the United States. Because the executive was not mandated to regulate utilities or

[6] For 2011, the share was calculated using the renewable energy support of 2010 and the generation and supply costs of 2011. All ratios were calculated by the authors. The data used in the numerator is the weighted average of the surveyed countries as calculated by the Council of European Energy Regulators (CEER) in their 2011, 2014, and 2018 Renewable Energy

create competitive markets, the federal government in the United Statesestablished regulatory agencies. Federal governments found it convenient to delegate regulatory powers to independent agencies to overcome information asymmetries (Glachant et al., 2013), policy commitment issues (Gilardi, 2002, 2005; Gilardi and Maggetti, 2011), settle disputes, and address industry performance. The EU and national governments implemented the model to attract new investments, improve system reliability, and transfer rents from vertically integrated national monopolies to consumers by introducing competition in the generation and transmission segments.

Independence became the model of governance for the EU "regulatory regime." Governments allowed NRAs to pursue their mandate and have budget autonomy[7]. This limits short-term political opportunism and discriminatory treatment, which reduces investor risk [8].

5.3.2 Dimensions of governance regimes

The assessment of governance regimes has focused primarily on studying the impact of independence and its diffusion as a governance regime (Thatcher and Sweet, 2002; Levi-Faur, 2005). In line with the empirical literature on the independence of central banks, Gilardi (2002, 2005) used independence as the prominent dimension to compare governance regimes in economic and social sectors. The author proposed that the appointment length of head or the board and provisions for their dismissal, budgetary autonomy, internal resource management, and delegated tasks are the most salient features of independence, thus the governance regime.

However, recent studies suggest that even if independence is a fundamental dimension, more than one dimension is needed to study the impact of governance regimes accurately [9]. For example, Transparency is another relevant dimension analyzed in the literature. Hanretty et al. (2012) discuss the role of accountability in regulatory decision-making, suggesting that superior agency transparency and decision justification improve agency performance. Moreover, Pollitt (2019) discusses the role of Transparency as part of the regulatory process. The author argues that transparency has increased substantially in the electricity sector since the beginning of the sector reform. The decision-making process is more open to public scrutiny and includes stakeholders' interests. However, these features are complex to measure because regulators differ in objectives and face different institutional constraints.

Besides independence and Transparency, OECD (2016) stresses Regulatory Tools' importance in regulators' performance. A broader set of policy tools such as deploying ex-ante regulation, setting network access conditions, settling

[7]The *independent regulator model* also considers arrangements to limit the influence of the industry in the regulator's decisions (OECD, 2016)

[8]Investment in utilities requires the deployment of high-cost specialized capital. Under the presence of investor risk (political instability), firms might not deploy optimal capital levels (underinvestment) or even not invest at all (hold-up problem).

[9]Gilardi (2002) operationalizes the independence dimension by constructing a weighted index that summarizes survey information about the agencies' head/boar appointment process, budget and organizational autonomy, and the scope of regulatory powers.

disputes, and having strong acquiring information powers allows regulators to solve complex and unexpected problems (Jamasb and Pollitt, 2005).

Jordana et al. (2018) and Brousseau and Gonzalez-Regalado (2022) used factor analysis and text mining algorithms, respectively, and suggested additional dimensions that could discriminate governance regimes. Jordana and co-authors describe a four-dimension model (Political independence, Managerial Autonomy, Regulatory Responsibilities, and Public Accountability). Meanwhile, Brousseau and Gonzalez-Regalado define four dimensions to compare governance regimes, (i.) Independence from the government, (ii.) Discretion of regulator, (iii.) Scope of market monitoring, and (iv.) Transparency.

5.3.3 Governance regimes and sector performance

Several studies have tested the link between various governance dimensions and industry performance. Most of this literature highlights the role of independence as a commitment device used by the government to signal policy credibility to investors.

Independence is associated with higher electricity generation per capita, especially in developing countries. In some circumstances, the effect of independence is conditional on privatizing utilities. Cubbin and Stern (2006) use the presence of a regulatory law and an independent regulator (with external funding) as proxies for independence. They show that the three features are associated with superior electricity generation per capita. Zhang et al. (2008) use a similar approach and add the fix-term appointment of the head or the board of the regulatory agency as an additional independence feature. Their results indicate independent regulators are associated with a higher generation per capital only in the presence of private incumbents. This claim supports previous work by Zhang et al. (2005), who show that privatization is effective only when an independent regulator is established before the reform.

Other factors, such as investment and firm leverage, have also been evaluated. Égert (2009) used a cross-section of 13 countries and six utility sectors in 2008 to show that incentive price regulation (including the electricity sector) fosters investment conditional on the existence of an independent regulator. Moreover, Cambini and Rondi (2017) highlight the impact of establishing an independent regulator (IRA) on the investment capital ratio of 80 utilities in 15 EU countries (37 firms belong to the energy sector in distribution and transmission). After controlling for political and institutional context, they found that between 1994 and 2004, IRAs enhanced policy credibility and increased investment from the private sector.

Other governance dimensions in the empirical literature, i.e., transparency and breadth of delegated powers, have less coverage, and their effects on industry performance haven't been explored empirically. Current studies connect transparency / accountability to the ability of regulators to produce better work. Hanretty et al. (2012) examine the correlation between accountability (another term for Transparency) and perceived regulatory quality (self-administered survey to the NRA staff in three utility sectors). They find a positive but non-

significant link. Similarly,Hanretty and Koop (2018), using an ordered probit regression, did not find any correlation between accountability and regulatory quality (proxied by scores from the Global Competition Review) for 30 OECD competition authorities in 2005-2014.

5.3.4 Governance regimes, liberalization reform, and renewable energy

To our knowledge, no study in the literature studies the relationship between governance regimes and the share of renewable energy. Hence, we will review the empirical evidence from the impact of the liberalization reform in renewable energy. These studies suggest that the liberalization reform has reduced the emission of pollutants. However, the effects might be mainly driven by the entry of efficient gas generators (replacing coal generators) and not by new renewable units (Pollitt, 2019).

For example, Asane-Otoo (2016) finds that industry vertical separation and privatization lead to lower pollutant emissions, but surprisingly, removing entry barriers (proxied by the OECD PMR entry index) did not influence the entry of new renewable generators. In contrast, Nicolli and Vona (2019) suggest that liberalization allowed the access of new generation units, which decreases the incumbent power to lobby against renewable support policy. Their empirical evidence shows that an extended market reform (OECD PMR index) positively correlates with public support for renewable energy.

Additional studies assess the determinants of renewable energy, including the impact of national-level institutions. Their argument assumes that better institutions improve the government's capacity to attain its goals. For instance, Baldwin et al. (2017) find a positive relationship between state capacity (government ability to carry out their goals – proxied by the ratio between taxes and GDP) and renewable electricity. However, the study acknowledges that the renewable support mechanism is the most influential determinant. Similar results are provided by Cadoret and Padovano (2016) using government quality (proxied by control of corruption).

5.4 Analytical Framework

5.4.1 Tensions between liberalization and renewable electricity generation

The current organization of the wholesale market is designed to reward generators based on cost efficiency [10]. Given an electricity demand level, the price paid to generators is set by the marginal cost of the last generation unit participating in the market. This market design follows a centralized electric approach sys-

[10]The current technological and institutional paradigm was designed in the context of centralized thermic systems. Thermic generators burn fuel to produce energy; thus, even at low prices, their marginal costs are positive.

tem based on thermic units and large hydroelectric plants with positive marginal costs and the ability to dispatch electricity at any moment.

However, renewable energies have almost zero marginal costs and are non-monitorable (depending on weather conditions and cannot be stored). Both characteristics generate tensions in the system and increase uncertainty about investors and their returns. On the one hand, the inclusion of zero marginal costs units in the queue line impedes generation units from recovering their costs, either by reducing the wholesale market price (the marginal cost of the last participation unit is lower) or decreasing the loading factor of thermic plants (Blazquez et al., 2018). On the other hand, intermittency increases uncertainty in investments (often R&D investments) and regulatory needs to balance energy supply at every level of demand (especially during peaks). Balancing requires network and storage investments, congestion management, and capacity mechanisms to keep the system running.

Both issues contrast with the objective of transferring rents to consumers and incentivizing investments. Additional renewable generation units decrease the wholesale market prices, but consumers (particularly households) tend to pay more for the electricity they consume because of additional system balancing costs and subsidies. Empirical studies show a significant correlation between the share of renewables in the energy mix and higher prices in the OECD countries (Moreno et al., 2012; da Silva and Cerqueira, 2017). Moreover, low wholesale prices and sunk investments (needed to cope with intermittency) increase return risk and uncertainty for investors (thermic generator, transmission), thus potentially reducing system investment.

5.4.2 Governance dimensions and indicators

We follow the definitions brought by Brousseau and Gonzalez-Regalado (2022) to measure the independence and delegation of regulatory power to NRAs. These definitions allow us to distinguish between the delegation/formalization of the regulator and its Scope of actions. The dimensions are:

1. Independence from the government estimates the insulation level between the regulatory agency and the executive's undue influence [11]. The objectives of independence are to support political stability; the dimension signals that market and competition rules will be respected (Gilardi and Maggetti, 2011).

2. Discretion describes the agency level of "informality.". The dimension portrays an agency's freedom to manage its internal decision-making process and resources.

3. Scope of market monitoring describes the extent to which the regulator can monitor/coordinate the competitive process, supervise the industry behavior, and manage economic incentives.

[11] Gilardi and Maggetti (2011) use a similar definition, in which describe independence as the institution that separates the government bureaucracy from the elected politicians

4. Transparency reflects the regulators' role in reducing information asymmetries between operators in the industry, public authorities, and users [12]; in particular, to ensure compliance and limit behavioral drift.

The first two dimensions portray the institutional characteristics of the regime, while the second two describe the levers at the regulator's disposal to monitor and enforce market performance.

5.4.3 Hypotheses

Delegation: Independence / formality

More independent regulators / formal regulators credibly commit to the liberalization objectives/mandates. This commitment becomes an important signal for investors (generators, system operators) because competition, system, and market stability prevail in the NRA decisions (Glachant, 2012), even at the expense of designing markets with lower participation of renewable generators. Thus, we expect that:

- H1: More independence is associated with a lower share of renewable energy in the grid.
- H2: More discretion is associated with a larger share of renewable energy in the grid.

Levers: Scope of market monitoring and transparency

Regulators with more legal levers are better equipped to fulfill the liberalization mandates. Regulators that count on levers to steer market operations or levers that support higher compliance among firms are expected to achieve their objectives. Thus, we expect that:

- H3: More market scope monitoring is associated with a lower share of renewable energy in the grid.
- H4: More transparency is associated with a lower share of renewable energy.

5.5 Data and methodology

5.5.1 Data

Because of data availability, our econometric analysis relies on 24 countries: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Germany, Denmark, Es-

[12] The dimension aggregates measures of the obligation for (public) reporting imposed on the RA and the reporting obligation imposed on the market players by the RA.

tonia, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Luxemburg, Lithuania, Latvia, the Netherlands, Poland, Portugal, Sweden, Slovenia, and Slovakia. We analyze the European electric systems for the period 2013-2018. The Appendix C.1 gives a detailed summary of the data used and statistical characteristics, in particular Table C.1.

The share of electricity produced from renewable sources was extracted from the Statistical Office of the European Union (EUROSTAT) database. The share, in the numerator, includes hydropower, wind, solar, biomass, bioliquids, biogases, tide, wave, and ocean gross production. The denominator is the country's gross energy consumption in MWh [13]. However, hydroelectric generation has been contested as a green-friendly energy source because of its social and environmental costs. Thus, we created a second variable that captures solar and wind generation.

To capture de NRAs' governance regime, i.e., independence, transparency (accountability), and Scope of action, we use the indicators described in Brousseau and Gonzalez-Regalado (2022). The scores range between 0 (no dimension influence) [14] to 1 (whole dimension influence). The authors propose a dynamic indicator to compare governance regimes across time. The metrics considers two periods, 2013 and 2018.

Their metrics offer several advantages. First, they are derived from surveys on network sector governance regimes (electricity, gas, telecommunication, rail, and air transport) performed by the OECD. The OECD (2016) provides the most comprehensive dataset about regulatory governance to date for both periods. Second, the characteristics and number of dimensions were defined using text-analysis algorithms [15] (word co-occurrence) to uncover latent dimensions using the data variability and without any predefined assumption of the regime configuration. Third, their metrics allow for developing comparisons over time. Mainly the model will enable us to assess whether changes in the governance dimensions have implications for industrial output. Finally, the metrics summarize scores based on the data variation and not in a predefined weighting scheme.

Second, we control liberalization effects with two variables. A constructed *market access* variable captures how electricity systems grant legal access to generation and retail markets. The metric relies on the OECD PMR (Vitale et al., 2020) survey data as input. It depends on textual analysis to identify the co-occurrence of similar terms (details of the variable construction in Annex 2). For robustness, we use the OECD PMR index (Vitale et al., 2020). The OECD PMR index aggregates information on entry barriers, market structure, integration, and price controls. The data is available as a time series from 1975

[13] European Environmental agencies use this metric to track country decarbonatization target performance

[14] The OECD estimates governance scores with the same survey (Casullo et al., 2019). However, the scores are not comparable between periods because of a significant change in their questionnaire.

[15] Brousseau and Gonzalez-Regalado (2022) use a coding scheme to transform survey categorical responses into textual documents. Using topic modeling, textual sources are analyzed and uncover co-occurring groups of terms named topics. Based on these groups and their terms' semantic meaning dimensions are identified and defined.

to 2018.

Additionally, our dataset contains other controls. The electric system's technical characteristics, consumption, production, and capacity come from EUROSTAT (2018) and IEA (2018). The GDP and population data from Penn World Tables version 10 (Feenstra et al., 2015). The institutional quality information is extracted from various sources. The Freedom House Political Rights Score (Freedom House, 2018) accounts for government freedom to carry out its mandates. Other institutional characteristics are captured by the rule of law indicators from IHS-Market and the Corruption Perception (CPI) Index from Transparency International (2018). The green social preferences are extracted from the Comparative Political Data Set (Armingeon et al., 2021) and measured by the number of seats that green parties hold in the legislative. The incumbent lobbying power is measured by the share of the most prominent incumbent in the electricity sector (Vitale et al., 2020). Finally, the measure of learning effects was captured by the number of patents by millions of habitants and extracted from the Agency (2018) database.

Besides our list of controls, we construct three additional variables—the first accounts for the lobbying capacity of the dominant non-renewable energy mix structure. We followed Pfeiffer and Mulder (2013) and estimated the Hirschman-Herfindahl (HH) index for non-renewable sources [16]. The shares are extracted from EUROSTAT (2018). The second variable captures the government support for renewable generation. It tracks the number of years that a policy (or group of policies) has provided incentives or direct subsidies to renewable energy generation [17]. More promotion of green energy calls for more firms in the generation segment (larger firms, too) (Nicolli and Vona, 2019). The third index accounts for the importance of subsidies in policies that support renewables (percentage of policies granting subsidies as a share of total renewable support policies, i.e., loans, regulations, and framework laws, among others). We use the IEA (2018) Policy Database to identify the policies, type, status, and duration period.

To measure efficiency, we use end-use consumer year-averaged prices (for industrial and household customers, excluded VAT). The data comes from IEA (2018) *Energy Prices and Taxes Statistics database*.

5.5.2 Evolution of renewable shares, liberalization, and governance regimes

The shares of renewable energies have grown for our sample countries between 2013 and 2018. Figure 5.4 shows that disparities between countries remain over time despite the growth. This heterogeneity reflects differences in geographical location, country energy resources, and institutional and economic long-run conditions (Bourcet, 2020). As discussed in the following subsection, a fixed-effects model could account for these long-run differences.

[16] The variable is estimated as follows: $lobbying_{it} = 1 - \sum_{i=1}^{N} shareNR_i^2$

[17] We selected current active policies relevant to electricity generation at the national level. Policies that support consumers were not included in the indicator. If a policy is active since 1976, in 2013, it was active for 37 years, while in 2018, it was active for 42 years.

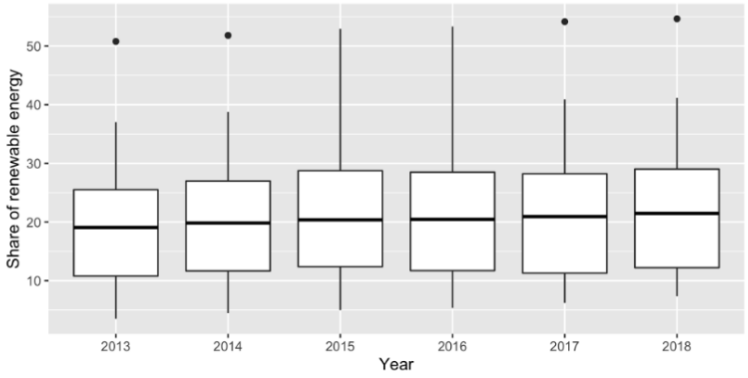


Figure 5.4: Distribution in the growth of renewable energies

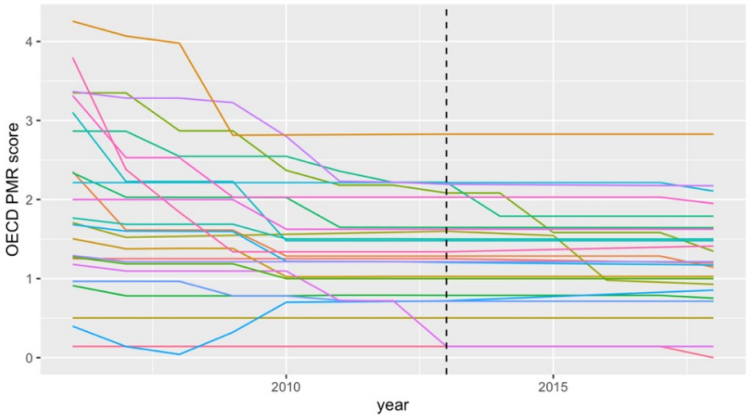


Figure 5.5: Evolution of entry barriers in the European Electricity markets

The market reform, measured by the OECD PMR index, shows a strong convergence until 2013. Since the early '90s, countries have liberalized their markets at uneven paces, as Figure 5.5 highlights. Each line represents the PMR index for a given country, showing that after 2013, only a few countries have liberalized their markets further, while the rest have followed a steady trajectory.

In contrast, governance regimes experience changes between 2013 and 2018. Figure 5.6 shows that NRAs are more independent (red) from the government and were granted higher levels of formality (reduced discretion in purple). However, regulators are still far from converging to a similar independence level. The variance of the score remains quite significant. In contrast, the transparency (green) and scope of market monitoring (blue) tasks increased their homogeneity and their average levels in the same period (only in the case of transparency).

A more liberalized sector might push for more regulatory delegation; thus, the effects of governance are simply the effects of the reform itself. However, governance evolutions with stable market reform trajectories allow us to distin-

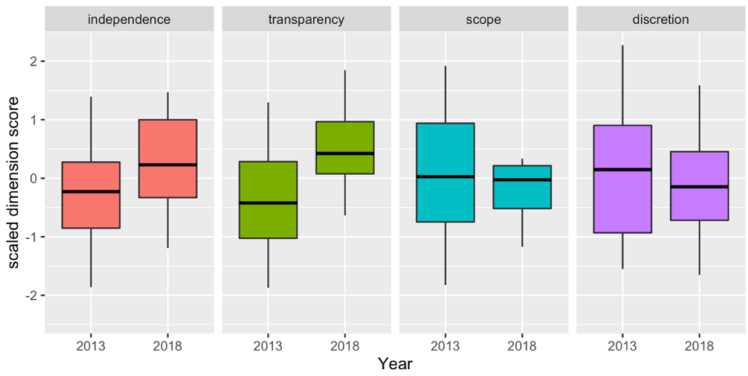


Figure 5.6: Evolution of the IRA dimensions in Europe between 2013 and 2018 (Brousseau and Gonzalez, 2022)

guish the impact of governance from the overall effect of liberalization in our analysis period. This distinction partially solves potential upward biases in our estimates. The detail of the econometric model will be discussed in the next section.

5.5.3 Econometric model

We use an econometric investigation to uncover the effects of governance and regulatory regimes on the share of renewable energies. We use a two-way fixed effects (FE) model to control the unobserved country and time effects [18].

$$\ln(dependent\_variable_{i,t,}) = \alpha + \beta_1 * govern\_regime_{i,t} + \beta_2 * regulatory\_regime_{i,t} + \beta_3 * controls_{i,t} + \mu_{i,t} \quad (5.1)$$

In Equation (5.1), stands for our outcome variables, i.e., electricity price and share of renewable energy produced. We are interested in estimating the effects of governance regimes on the Independence and scope of action $govern\_regime_{i,t}$, captured by the term β_1. However, governance regimes are strongly associated with electricity market reforms and other unobserved country differences.

Figure 5.6 shows that governance regimes evolved significantly between periods while market regulation remained stable (Figure 5.5). However, The

[18] We checked for significant individual and time effects by testing if, jointly, all individual and time intercepts are different from zero in an OLS regression. Our results suggest that the fixed-effects model should be selected. Our specification also assumes a constant effect of independence over countries and time. However, we tested whether the overrepresentation of negative heterogeneous treatment effects might artificially negatively bias our average estimates. We follow de Chaisemartin and D'Haultfœuille (2020) test to test if the effect direction comes from a true prior or is the result of overrepresentation. Our model is not driven by the issues presented on de Chaisemartin and D'Haultfœuille (2020).

$regulatory\_regime_{i,t}$ term accounts for current changes in market reforms, which might impact our dependent variables, while β_2 stands for reforms' effects.

Moreover, the error term structure $\mu_{i,t} = \delta_i + \nu_t + \gamma_{i,t}$ controls for unobserved electricity and renewable sector characteristics. The δ_i term captures time-invariant system characteristics (long-run level of market reform, the lasting aspects of geography, institutions, and local preferences). The ν_t captures unobserved specific time shocks that could affect our dependent variables, and $\gamma_{i,t}$ term is an idiosyncratic individual error term.

In addition, we added a set of covariates $controls_{i,t}$ to account for other determinants of the energy mix, such as changes in demand (primary energy demand, income, energy security) and supply factors (changes in the generation mix structure, innovation, and specialization effects), and institutional quality measures (government effectiveness). The vector β_3 highlights the effects of every control on our dependent variables.

5.6 Results

5.6.1 Effect of governance regimes on renewable energy growth between 2013 and 2018

Table 5.2 shows the parameter estimates for the effects of the governance regime on the share of renewable energies. Models (1) to (4) test the individual effect of each dimension, while model (5) tests the overall regime effect.

Models (1) and (5) show a negative relationship between *independence* and the share of renewable energy shares after controlling for the rest of the dimensions. This significance confirms $H1$, which indicates that independent regulators are associated with a lower share of renewable electricity produced. At this point, we cannot disentangle the independence granted to the regulator and its mandates (objectives), but we add a set of controls to account for other potential factors that might influence the share of renewables and the governance regime.

Moreover, the effect of *discretion* is negative, which conflicts with *H2*, but is not statistically significant. Thus, we reject *H2*. *Transparency* has the expected negative impact on renewable energy shares in model (2); however, after controlling for the effects of the rest of the dimensions in model (5), the coefficient almost drops to zero. We reject *H3*. The lack of *transparency* significance coincides with the results of Koop and Hanretty (2018), where no strong associations are found between transparency and organizational performance. Finally, the *Scope of the market monitoring* index shows a positive but non-significant coefficient in models (4) and (5). The positive effect might indicate that regulators use market steering tools to design markets that support additional renewable units after controlling for independence, yet we reject *H4*.

Table 5.2: Fixed Effects: Impact of governance on renewable energy shares

	(1)	(2)	(3)	(4)	(5)
Independence	-0.817**				-0.968*
	(0.334)				(0.531)
Discretion		-0.203			
		(0.317)			
Transparency			-0.371		0.098
			(0.496)		(0.504)
Market				0.167	0.53
				(0.682)	(0.683)
mkt access	1.456**	2.306**	1.725*	2.091**	1.452**
	(0.616)	(0.864)	(0.902)	(0.787)	(0.583)
FH pol rights	0.038***	0.041***	0.039***	0.040***	0.039***
	(0.006)	(0.008)	(0.008)	(0.008)	(0.006)
1-IHH gen	1.039***	1.328***	1.148***	1.297***	1.084***
	(0.312)	(0.351)	(0.358)	(0.371)	(0.312)
GDP	2.049**	1.739*	2.133**	1.887**	1.978**
	(0.861)	(0.843)	(0.977)	(0.910)	(0.852)
incomePC	-2.136**	-1.926**	-2.271**	-2.067**	-2.051**
	(0.921)	(0.918)	(1.029)	(0.971)	(0.934)
trade balance	0.107	0.095	0.101	0.094	0.104
	(0.105)	(0.118)	(0.113)	(0.115)	(0.113)
years ren. laws	0.262***	0.319***	0.274***	0.309***	0.255***
	(0.058)	(0.085)	(0.092)	(0.087)	(0.073)
patenthundred	0.134**	0.125*	0.125*	0.123*	0.127**
	(0.056)	(0.067)	(0.067)	(0.070)	(0.053)
Individual effects	yes	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes
adj. $R\hat{2}$	0.87	0.842	0.846	0.841	0.868
AIC	-141.4	-132.3	-133.5	-131.8	-139.5
Observations	48	48	48	48	48
F-statistic	33.137	18.331	23.049	24.334	36.048

Controls: *mkt access*: a measure of market reform implementation related to granting new incumbents access to the natural monopoly segment of the industry (i.e., the network). *FH pol rights*: Freedom House political rights score. The metric captures the extent to which political institutions are stable. *1-IHH gen*: inverse incumbent lobbying power of non-renewable generators in the industry. Higher metrics show that no traditional incumbent firm has significant generation participation; therefore, their lobbying power is low.*GDP*: Gross domestic product measure in PPP USD of 2010. The measure proxies the electricity demand in a country. The correlation with primary electricity demand is above 0.98. *incomePC*: *Income per capita*: the variable measures average income in PPP USD 2010 per person. *trade balance*: measures the net electricity trade (exports - imports) as a proxy of electricity security. *years ren. laws*: measures the political support for renewables by legislation. The metric sums the number of years that different laws are set in place in logs. *patenthundred*: captures the effects of specialization in renewables. The measure is constructed as the ratio of patents and the number of people in a country. Discretion is excluded in model (5) due to multicollinearity with the other gov. dimensions. Heteroskedasticity robust standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Confounding factors and additional controls

We assess confounding factors that affect the share of renewable electricity and the governance regime across models in Table 5.2. First, we control for the effect of liberalization, which influences the speed and extent of the IRA model adoption (Gilardi, 2005), and fosters renewable energies by removing entry barriers (Nicolli and Vona, 2019). The impact of market liberalization (*mkt access*) is positive and significant. Second, we assess the security of supply (*trade balance*). Countries with energy deficits (more imports than exports) could set up independent regulators to foster investments and call for more renewable generation units to enter the grid and compete, thus improving their electricity deficit situation (Pollitt, 2019). We found that countries with positive trade balances (trade balance) are associated with larger renewable shares, yet the coefficients in all models are not significant. Finally, we controlled for the institutional environment and used political capture, as a proxy, following Baldwin et al. (2017). According to the authors, political capture threatens new investments by increasing the risk of expropriation. If political capture becomes large enough to hold up new investments, politicians set up independent regulatory agencies to attract new investments (Gilardi, 2005). In our specification, we use political rights (*FH pol rights*) as an inverse proxy (horizontal distribution of power) and find that it is positively and significantly associated with larger renewable shares. In the robustness check section, we used alternative indicators to control for other institutional characteristics, such as protection from expropriation and government quality. The results of the alternative measures are very similar among institutional characteristics.

In addition, we checked whether the power of the incumbent firm in the market could influence delegation negatively as a means to decrease competition in the market, and the energy mix, by concentrating power on the incumbent to choose a profitable technology. Table C.2 (Appendix C), model (2) shows a negative relationship between the share of the largest generator and the share of renewable energy [19].

In Table 5.2, we also control for policies supporting renewable generation (*years ren. laws*) [20], and the coefficient is positive and significant. Similarly, we consider lobbying pressures to preserve the current technology (*1-IHH gen*). Lower domination of a non-renewable source is positively correlated with our dependent variable. Innovation/specialization effects (*patenthundred*) are also positively correlated with a larger share of renewables. Moreover, we included demand factors controls such as electricity consumption and income. Regarding electricity demand (*GDP* [21]), we find a positive and significant effect. However, more prosperous countries (*income PC*) show a significant negative coefficient.

[19] Share of the largest incumbent in generation was not included in the main specification for two reasons. The sample size drops by excluding 3 countries and the coefficient size does not significantly change from the one in Table 5.2, model (1)

[20] We use a second variable to control for policy support. We estimated the share of policies that support subsidies from all the policies implemented in national legislation. Results in Table C.3 show no significant correlation between the variable and the share of renewable energy.

[21] We measure electricity consumption by using GDP instead of primary electricity consumption because of their high correlation (Pearson correlation coefficient = 0.98) and because of data availability.

5.6.2 Robustness check

Outliers

Figure 5.7 shows the negative relationship between independence and the renewable share of electricity generation. On the vertical axis, we observe the change in the share of renewable energy (logs) from each country, while on the horizontal axis, we see the change in the independence score (logs). The figure highlights the presence of potential outlier observations that might drive our regression estimations [22].

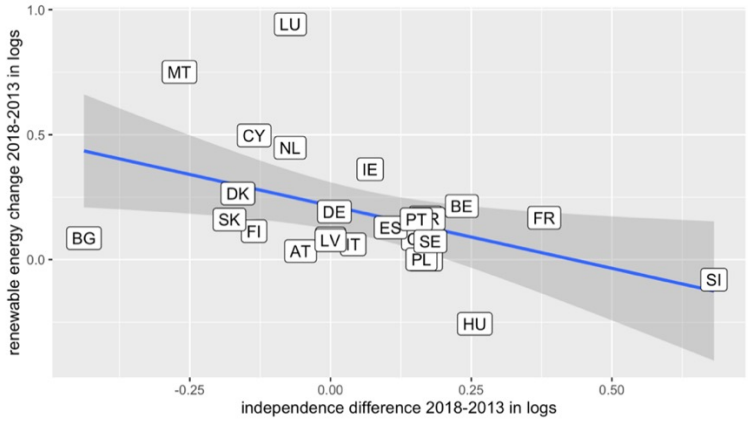


Figure 5.7: Correlation between renewable energy share and independence

Consequently, we use the model (1) in Table 5.2 to re-estimate a new set of coefficients after excluding one country at a time. The results are presented in Figure 5.8. The y-axis displays the independence coefficient size, while the x-axis shows the excluded country. The solid line shows the coefficient confidence interval (90%). The estimates do not vary considerably between models, and none include 0 in their confidence intervals. Thus, outliers do not seem to drive our results.

Institutional channels

The institutional environment and its measures might impact our results as well. Different aspects of national institutions could add uncertainty to our estimations. Table 5.3 shows the estimation results with other institutional variables used in the literature on renewable share determinants (surveyed by Bourcet (2020)) to check potential issues. Model (1) displays the coefficients of our baseline model. In model (2), we add the variable *Green Party* to capture environmental preferences beyond government policies. The coefficient remains

[22] In addition to the leave-one country out regression, we test the potential effects of outliers graphically after a logarithmic transformation. Our analysis identified Slovenia (SI) as a potential outlier. Even after excluding Slovenia in the regression analysis, our estimates remained robust.

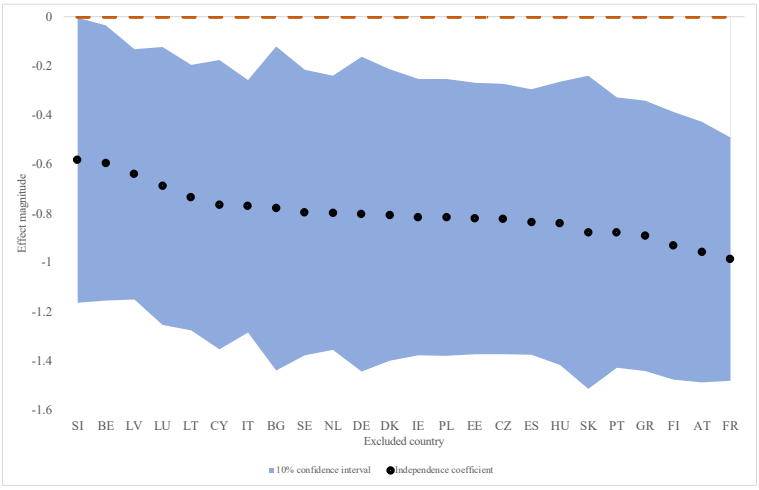


Figure 5.8: Effects of independence on renew. energy excl. one country

robust (at a 10% level) and suggests that countries where green parties have more delegates, are associated with larger renewable preference shares.

We did not include this variable in our main specification because it reduces estimation accuracy more than improving the model fitting, as pointed out by the Akaike Information Criterion (AIC) [23]. In model (3), we use the OECD PMR index to track changes in the market reform as an alternative to our *mk-taccess* variable. The independence coefficient varies slightly, but it becomes less significant [24]. Although, the reform coefficient shows the expected negative sign (lower values of the PMR highlight a more profound reform). In model (4), we use Transparency International Corruption Perception Index (CPI) as a proxy for government effectiveness. Lower corruption levels are translated into better functioning services offered by the government. The independence coefficient slightly varies compared to model (1), yet the CPI coefficient is not statistically significant. In model (5), we use a measure of the "Rule of Law" by the IHS-Market, which captures how investments are protected from expropriation. The independence coefficient changes in magnitude, but the effects' direction and statistical significance remain. However, the IHS-Market coefficient becomes negative and non-significant. All the previous results conclude that our model is robust to changes in institutional measures.

Overlapping sample

Finally, we measured the share of renewables using the overlapping sample (22 countries from the price regression analysis presented in the discussion section

[23] In Table 5.2, a lower value of AIC indicates a robust model. Model 1 has an AIC of -141.5, and model 2, -136.6

[24] We did not include the OECD PMR in our main specification because not all countries had a score. Missing country data was obtained by imputation. We decided to keep the variable as a robustness check.

Table 5.3: Fixed Effects: Additional institutional covariates

	(1) Base	(2) Green	(3) OECD.PMR	(4) Corr.Index	(5) IHS.RL
Independence	-0.817**	-0.860*	-0.736*	-0.898**	-1.309*
	(0.334)	(0.423)	(0.383)	(0.363)	(0.649)
green		0.019**			
		(0.007)			
FH political rights	0.038***	0.034***	0.036***		
	(0.006)	(0.005)	(0.005)		
OECD PMR			-0.021*		
			(0.012)		
Corruption Index				0.012	
				(0.007)	
Rule Law					-0.693
					(0.480)
Individual effects	yes	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes
adj. R^2	0.87	0.855	0.862	0.837	0.833
AIC	-141.475	-136.557	-138.922	-130.82	-129.556
Observations	48	48	48	48	48
F-statistic	33.137	43.161	100.244	11.964	16.269

is estimated varying the institutional quality measure. Model (1) shows the coefficients of the equation in $Model(1)$ - Table 5.2. *green*: number of shares of the green party in the legislative per person. *FH political rights*: Freedom house political right score. *OECD.PMR*: score of market reforms calculated by the OECD between 0 (fully liberalized) and 6 (vertically integrated - state-owned industry). *Corruption Index*: Transparency international corruption index where higher scores stand for more transparent and efficient government. *Rule of Law*: IHS rule of law score. It represents the protection to private investments in a country. Heteroskedasticity robust standard errors in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01.

(Section 5.7) [25]) and the generation of solar and wind sources as a share of total electricity production [26]. In Table C.4 (Appendix C), models (1) and (2) remain negative and significant at a 10% percent level. These parameter estimates suggest that the effect of the governance regime is present across different samples and renewable energy measures.

5.7 Discussion of Results

5.7.1 Contextualizing the results

The discussion aims to put our analytical framework and results in context with current and future EU climate change targets. We suggest an ongoing tension between government support for renewable energy growth and the NRA mandate of stable markets to frame our discussion.

The effect of independence on achieving current renewable energy targets will depend on the trade-off of increasing the share of renewable energies. Our results suggest that, for 2020 targets, the trade-offs in most countries have not been significant enough to impede governments from achieving their climate goals, as for 2020, the EU achieved its objective. According to the European Environmental Agency (2020), 22 Member States reached their 2020 targets, Belgium, Romania, and Slovenia remain close to meeting the target (< 1 %), and France and Poland were the countries furthest away from their 2020 target (over two percent below, European Environmental Agency (2020)).

The central argument of our work relies on the assumption that regulators are mandated to implement competition, reduce rents from previously state-owned utilities to consumers and improve investments, ultimately, reliability. Thus, we test if governance regimes are associated with superior sector performance in the analysis period. Results in Table C.5 (Appendix C) show that regimes with exceptional independence and transparency are correlated with lower final prices for consumers (yet the independence coefficient is not significant at conventional levels). Although the analysis of prices is not exhaustive, the association seems intuitive. More *independent* and *transparent* NRAs (more information traffic from the industry to the legislative, in the form of accountability) stick to one of their crucial mandates - to serve their consumers at lower prices.

5.7.2 Implications of the results and future research

Our findings suggest independent regulators commit to their competition and efficiency mandates, which slows down the entrance of green electricity producers beyond efficient levels. This effect implies that some of the positive impacts of market liberalization in green electricity generation, such as reducing entry

[25] The price analysis includes Great Britain and Switzerland and excludes Bulgaria and Cyprus. Data availability drives this decision.
[26] This measure is less sensitive to changes in electricity consumption patterns.

barriers to clean producers (Nicolli and Vona, 2019), might be offset by the current governance regime.

Evidence shows that NRAs are converging to the independent regulator model in Europe (Brousseau and Gonzalez-Regalado, 2022; Casullo et al., 2019). Our results show that *independence* negatively correlates with the share of renewable energy. Future climate change targets will become more stringent as an unprecedented transformation in the energy system is necessary to meet the 32% renewable energy target set for 2030 and full decarbonization for 2050. We expect that if NRAs do not account for environmental concerns in their mandates, the effect of the governance regime will become more significant over time. Under this hypothesis, a question that seems obvious is: What is the role of the governance regimes and liberalized markets in reducing the trade-offs to achieve climate change objectives?

According to Bartle and Vass (2007), the expertise and specialized knowledge of NRAs position them to have the role of facilitators in the integration of renewable energies. They identified three areas that ease the conflict. First, regulators may coordinate actions with other institutional actors to increase the exchange of information between actors and become a mediator in planning the paradigm change. For example, NRAs' experience may detect situations in which market reforms and policies account for externalities. Second, NRAs may take an advisory role in policy elaboration. This collaboration might detect policy conflicts and redundancies and assess trade-offs. Finally, the information disclosure with stakeholders should be augmented beyond the economic Scope of the NRAs' operation.

The previous solutions have, of course, some caveats. First, substantial coordination threatens potential investments because it makes it difficult for investors to observe if governments are credibly committed to system stability. Second, if regulators are required to develop additional tools, they may require increased resources and lose part of their specialization benefits. Third, if the extent of their role increases, NRA's accountability provisions should account for their new environmental roles. Agency performance analysis becomes fuzzy with a set of partly conflicting responsibilities. In addition, for all cases proposed by Bartle and Vass (2007), NRAs will require increasing their transparency and measuring their performance through adapted performance indicators. Future empirical research on the tensions between liberalization and environmental performance is still missing in the academic literature.

5.8 Conclusions

This paper assessed the impact of four dimensions (*independence*, *discretion*, *transparency*, and *scope of Market Monitoring*) of the governance regime on European NRAs in the share of renewable energies. We focus our analysis on the period between 2013 and 2018. Results show that NRA's *independence* is negatively correlated with variation in the share of renewable energies. In addition, we found that *transparency* is negatively correlated with electricity tariffs for industrial users.

The findings suggest that independent regulators did not deviate from their original mandate with consequences for the rate of renewable energy growth due to the impact of renewable energies on competition, efficiency, and market stability.

The main paper's contribution provides quantitative evidence that between 2013 and 2018, NRAs governance regimes decreased the adoption of renewable energy in the electric sector. Finally, we discussed our results, contrasting them with the literature. We found many arguments supporting that future climate targets will become harder to achieve. They are open questions regarding the impact of changing the NRA mandate to align them with renewable energy growth.

Chapter 6

Conclusions

Market changes in network industries have transformed their structure and performance during the previous 35 years. These disruptive acts opened markets where competition was possible, regulated access to the core network, and partially privatized national incumbents in the energy, gas, telecommunications, air, and rail industries. While the influence of such changes has been linked to economic growth and other efficiency metrics, the investigation of alternative aspects of market reform and its implications for prices, service quality, and sustainability has largely gone unexplored. This thesis helps to improve understanding of the various components of network industry changes, how they are measured, and how the reforms affect new challenges that the EU is facing and will face in the next years.

This chapter is divided into four sections. Section 6.1 examines whether we answered the research questions raised in the introduction chapter (Chapter 1). Section 6.2 provides policy advice, such as reconciling liberalization with other societal goals that do not align with the reform's objectives. Section 6.3 examines the limitations of our work, and Section 6.4 identifies further areas where our work could be expanded.

6.1 Answers to research questions

Following the presentation of our studies, we assess whether they answer the research questions stated in the introductory chapter. The first study investigates if *alternative dimensions* describe market reforms in network industries and whether the progression of these aspects has resulted in a single regulatory paradigm across nations and industries. Our research demonstrates that the NLP coding approach (lexical chains (Wei et al., 2015)) and topic modeling (Blei et al., 2003) can summarize and identify important components of market reforms, such as *state ownership*, *network access*, and *product characteristic control*. Furthermore, the overall score for each feature demonstrates that market reforms progress unevenly across industries and countries. At the industry level, the reform has reduced incumbents' power to regulate product attributes

while expanding network access provisions in energy, gas, and telecommunications. The transportation industries appear to follow a common regulatory pattern that restricts aspects of deregulation that are incompatible with passenger safety. Countries do not appear to have agreed on a single regulatory model at the national level. In particular, network access influences just a limited number of countries when compared to the incumbent's ability to control product attributes. The third and fourth questions inquire whether our alternative reform aspects have an impact on industrial performance and whether the effects are consistent across industries. The first analysis discovers that network access regulation is connected with higher levels of investment and service coverage across industries. These findings back up previous findings in the literature (Broughel and Hahn, 2022). However, our findings show that *network access* provisions are incompatible with environmental goals (especially in the energy industry), whereas *product characteristic control* is related to higher shares of renewable energy produced. Our findings suggest that, in contrast to renewable energies, deregulation has prioritized monitorable energy sources such as hydro and CO2-based electricity.

The following questions focus on the "independent regulator model" implementation in the energy, telecommunications, air, and rail industries. The first question is whether alternative dimensions reflect regulatory governance arrangements and whether they indicate convergence toward a unique governance model across sectors and countries. According to the findings of the second study, our coding approach and topic modeling establish four aspects that describe the governance regime in the European network industries: *independence from the government*, *discretion*, *transparency*, and *market monitoring scope*. The first two dimensions describe the regulator's autonomy, while the last two show the regulator's accessible channels for carrying out its mandates. Regulatory governance systems converge across sectors and countries toward more independent and transparent frameworks. Almost every country in our study showed progress in both dimensions. Compared to the energy and telecommunications sectors, the transportation sector shows substantial differences. To carry out their objectives, transportation regulators have fewer *transparency* levers and a large variety of *market monitoring tools*. The transportation sector, on the other hand, has a different distribution of *independence* and *discretion*. Rail regulators have high *independence* and *discretion*, whereas air regulators have high *discretion* and limited *independence*. The third and fourth questions inquire whether the alternative dimensions are related to industry performance and whether the linkages are consistent across industries. Governance and scope dimensions (structure and evolution) are related to industrial performance. The significant differences between sectors demonstrate that regulators' objectives differ by industry. This could be attributed to differences in "maturity" as in Europe, autonomous sectoral regulatory bodies began with the deregulation of telecommunications markets in the 1990s, followed by energy ten years later, and then railways and airports in the 2010s. Younger RAs appear more informal and have fewer controlling tools. Because sectoral regulators operate in industries with disparate economies, convergence toward a single model is unlikely. Regulatory control over e-communications seems crucial to service quality (broadband). RAs in the electricity sector typically emphasize energy costs over environmental quality. Regulators in the transportation industry prioritize safer

operations over traffic.

The last set of questions is concerned with regulatory governance and the performance of the European Union's electrical industry. The first and second questions inquire about the most important governance dimensions that influence electricity performance (and the fuels used to generate it), as well as the directions of the effects, while the third and fourth inquire about the potential impacts of governance regimes on decarbonization and market prices. According to the third study, *independence from the government* is the only meaningful component that influences the share of renewable electricity generation from 2013 to 2018. After adjusting for a wide range of renewable generation factors, *independence* is found to be negatively linked with renewable generation. According to our findings, more independent regulators are following the EU mandate to promote competition, system efficiency, and reliability. Higher-independence regimes appear to attract electricity generators who are compatible with the current market paradigm (merit order model). Our research finds no substantial association between consumer independence and electricity prices.

6.2 Policy implications of the results

In this section, we look at the policy implications of our findings. Our findings are based on an examination of a specific dataset (the OECD RIQ questionnaire), which was gathered for market reform between 1998 and 2018 and for regulatory regime aspects between 2013 and 2018. Moreover, this thesis emphasizes exploratory work rather than specific causal study. Consequently, the breadth of policy implications is limited and applies to our European country sample. Additional limitations of this study are described in the Section 6.3.

The first and second studies assessed the state and development of market reforms in 24 OECD European countries. The findings show considerable disparities in adopting reforms and governance models across industries. The disparities show that European aims and technology variations restrict the degree to which change may be achieved in a sector. For example, in the transportation sector, liberalization, reform, and implementation are only practicable if they do not clash with safety (IATA, 2007). When deciding to make new national and European laws and put them into effect, policymakers must look at the policy goals and find a balance between them while keeping these sectoral factors in mind.

The third study looked at the impact of regulatory governance on energy renewable shares in 24 OECD European countries from 2013 to 2018. According to our findings, independent regulators appear to support the implementation of markets based on a marginalist merit system, which rewards plants with the flexibility to dispatch power at any time, such as hydroelectric and CO2 sources. Such markets are incompatible with renewable energy sources such as wind and solar. This incompatibility raises concerns about system reliability, consumer pricing, and decarbonization goals. Part of the benefits of liberalization has been passed on to renewable energy producers through operational subsidies paid by users. Furthermore, increasing renewable energy shares necessitates

greater management from system operators to maintain system stability. As a result, authorities must be conscious of the tensions between liberalization, electricity price, and decarbonization goals. If renewable energy shares begin to grow, the tension between *independence* (which appears to benefit consumers and market efficiency) and renewable energy sources may become significant [1]. Furthermore, policymakers should consider assessing current governance structures and national and European goals for electrical networks.

6.3 Limitations of the research

We recognize that this dissertation study may be constrained by many factors. These restrictions are described in this section. We have no reason to suppose that any of these constraints should cast doubt on our conclusions, but we cannot rule out the possibility. The difficulty of restricted datasets and endogeneity are two potential constraints of the investigations discussed in this thesis.

6.3.1 Data limitations

The first constraint is the number of study periods available. Our dataset on market regulation is available for five years (1998, 2003, 2008, 2013, and 2018). The number of observations is limited by the interval between surveys. To overcome this limitation, we compared our measurements to other reform indexes and institutional quality variables accessible yearly. Furthermore, we compared the trends we observed with previous studies and determined that the number of observations would have no effect on our estimates. Another concern is the quality of the data. Every five years, the OECD RIQ study covers regulatory and governance frameworks. The surveys are completed by national MS bureaucrats assigned to ministries or departments by their respective governments. This system has two possible flaws: i) the respondent may submit responses based on his or her own (contextual) understanding of the survey, and ii) the provided answers may reflect a national perspective on the reform rather than a "fair" assessment of the country's circumstances. In this regard, the OECD RIQ survey assists MS when they supply the needed information, and second, the OECD has an ex-post validation methodology in which national responses are compared to other official sources (Vitale et al., 2020). As a result, we are confident that the OECD data is consistent with the current reforms and does not jeopardize dimension identification.

In terms of the relationships between regulation/governance and industrial performance, our dataset lacks two key aspects. First, we ignore the informal structures that underpin market regulation and governance. The issue is less pressing for market changes that necessitate a set of explicit norms to promote competition and guide market exchange (Glachant, 2021). However, informal or *de facto* behaviors are especially significant in regulatory governance frame-

[1] The tension is believed to increase under the assumption that the main problems for renewable electricity generation are not solved. If renewable electricity could be stored, the tensions with the current market design would decrease

works. Regarding independence, we are concerned with how well regulators are insulated from undue external influence. The legal independence provisions may indicate the level of protection, but independence *in practice* is determined by the regulator's ability to apply its powers based on its own judgment (Maggetti, 2007). Both types of independence are associated positively, indicating that our formal measure represents certain features of independence *in practice*. However, other country features explain de facto independence as well (Koop and Hanretty, 2018) (the lifecycle of agencies, veto players, and European networks of agencies). By including institutional quality indicators and a battery of fixed effects, our econometric models seek to adjust for these aspects. Second, we cannot observe or measure the regulators' actual mandates, which govern the agency's day-to-day operations. This missing component prevents us from distinguishing between the effect of our governance regime dimensions and the underlying mandates or aims that the regulator seeks to achieve. The distinction is especially important in determining whether sector regulators operate under the principles of European Directives or their national agendas. Further research should be conducted on the subject.

Our third study's dataset does not account for the overall amount of subsidies that each government must spend to encourage renewable energy. This variable appears unrelated to *independence*, although it may cause an omitted variable bias in our estimates. To control for the variable, we employed a variety of policy support metrics from the literature to determine whether the missing variable is a problem. Our checks indicate that the policy variable we created—the total of the years that renewable support programs are in effect—captures the political support for renewable power. Other candidate variables did not yield significant results, e.g., the number of policies that support the generation of renewable energy and the public expenditures as a fraction of total expenditures.

6.3.2 Endogeneity

Our three studies attempt to find strong associations between the estimated dimensions of regulation and governance and industry performance that could be explored in the future. Even if we do not attempt to demonstrate causal results, our work has limitations that need to be acknowledged. Parts of our results are supported by previous studies, particularly those that assess the effects of reforms on macroeconomic outcomes. This support makes us confident that our econometric methods capture relevant correlations. The first study uses a dynamic OLS with fixed individual and time effects. Our approach controls for time-invariant, unobserved characteristics such as institutional, geographical, and legal tradition differences. However, we do not control for time-varying unobserved factors such as changes in national policy priorities, macroeconomic cycle information, and other changes that might impact both the progress of the reform and the industry performance variable. The second study uses a linear regression approach that measures the degree of association between average and growth rates of governance dimensions and outcome variables. We use a wide set of industry-specific controls based on the literature, but similarly to the first study, we do not control for the status and progress of regulatory objectives,

technological improvements, or industry specialization effects.

The third study looks at the relationship between regulatory independence and the percentage of renewable energy in 24 OECD European nations. After controlling for many literature-derived factors of renewable energy performance, there is concern that the variables measuring institutional efficiency influence our regulatory and governance scores, just as our scores influence our assessments of institutional quality. While such a possibility cannot be ruled out, we employ additional metrics of institutional efficiency (property rights protection, corruption prevention) to test the sensitivity of our estimations to various features of institutional efficiency. Furthermore, reverse causality can cast doubt on our estimates. Perhaps the amount of renewable electricity represents renewable generators' lobbying power, which could influence regulatory and governance reforms in their favor. The best way to investigate this issue is to use an IV approach; however, despite our best efforts, our dataset lacks a variable related to the governance variable and not the unobserved factors that explain the share. In any case, we are confident in our projections because Pollitt (2019) already highlights the contradictions between the liberalized market model for electricity and decarbonization goals.

6.4 Future research implications

Finally, we address probable future directions for this study. There are methodological and empirical extensions. The first two studies used NLP methods to code and summarize survey data. Human verification of the coding process was essential despite the different methodologies used. The verification was possible due to the small number of words / concepts in the survey. However, if surveys have a large or complicated vocabulary, evaluating them may become more challenging. When there are a lot of terms, other strategies for coding the survey data can be explored.

Our first analysis focuses on two specific relationships. According to the literature, state-owned enterprises are under insufficient pressure to adopt better organizational and technological methods, resulting in low performance compared to private firms. Our findings in energy and telecommunications support those found in the literature. However, this is not the case for the air sector, highlighting the link between state ownership and greater air traffic. The second correlation connects *network access* to telecommunications and energy pricing. Increased competition, as facilitated by *network access*, should result in lower prices due to improved allocative efficiency, as seen in the energy market. The positive correlation in telecommunications raises the question of whether it exists because of unobserved variability or because the sector rewards investors at the expense of consumers. Finally, *product characteristic control* correlations with transport traffic measures yield contrasting results in air passenger and freight traffic segments. More research is required to determine the reason for such association disagreement. The results could contribute to the understanding of reforms and their effects on different sectors.

The second study reveals differences in regulatory priorities. Energy and

telecommunications regulators appear to favor market efficiency, whereas transportation regulators appear to prioritize safety. However, our econometric model does not consider variables that indicate the status and development of national policy objectives. As a result, extensions related to analyzing such characteristics may help us better comprehend the connections between governance regimes and their objectives.

Finally, the final analysis finds a link between regulatory independence and the percentage of renewable electricity generated. There are two approaches to expanding the study. The first step is to identify viable instruments for our independence metric. Because of the data's characteristics, this seems to be the most practical strategy for dealing with endogeneity issues. According to a regulatory governance diffusion argument (Levi-Faur, 2005), reform in other industries, such as rail or air transportation, could be a good choice for an instrumental variable. Other formal independence determinants could also be used as instruments. Such national-level traits, however, may be related to industry performance. Furthermore, the study has the potential to spark a debate about the contradictions that exist between market liberalization, efficiency, and environmental goals. The pertinent considerations are i) if frictions exist at all levels of renewable energy shares and ii) whether such conflicts demand a transformation in the current governance model. The European Union's decarbonization targets for 2020 and 2021 have been met. However, the average renewable European share is between 9 and 10%. (depending on the calculation method). This average indicates that the tensions between market design, reliability, and renewable energies have not jeopardized the market or the MS's environmental goals yet. An extension to this study could evaluate the negative association between independence and renewable energies in countries with high renewable generation. This extension could allow testing whether tensions between governance, market design, and renewable energies are exacerbated. Concerning the second question, Bartle and Vass (2007) analyze alternative strategies for adapting the current "independent regulator model" to the challenges of decarbonization. A potential extension could consider gathering recent data to test whether regimes converge to the "independent regulator model" or whether a new paradigm is emerging.

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Appendix A

Appendices of Paper 1

A.1 Summary statistics

Figure A.1: National averages of indicators by dimension

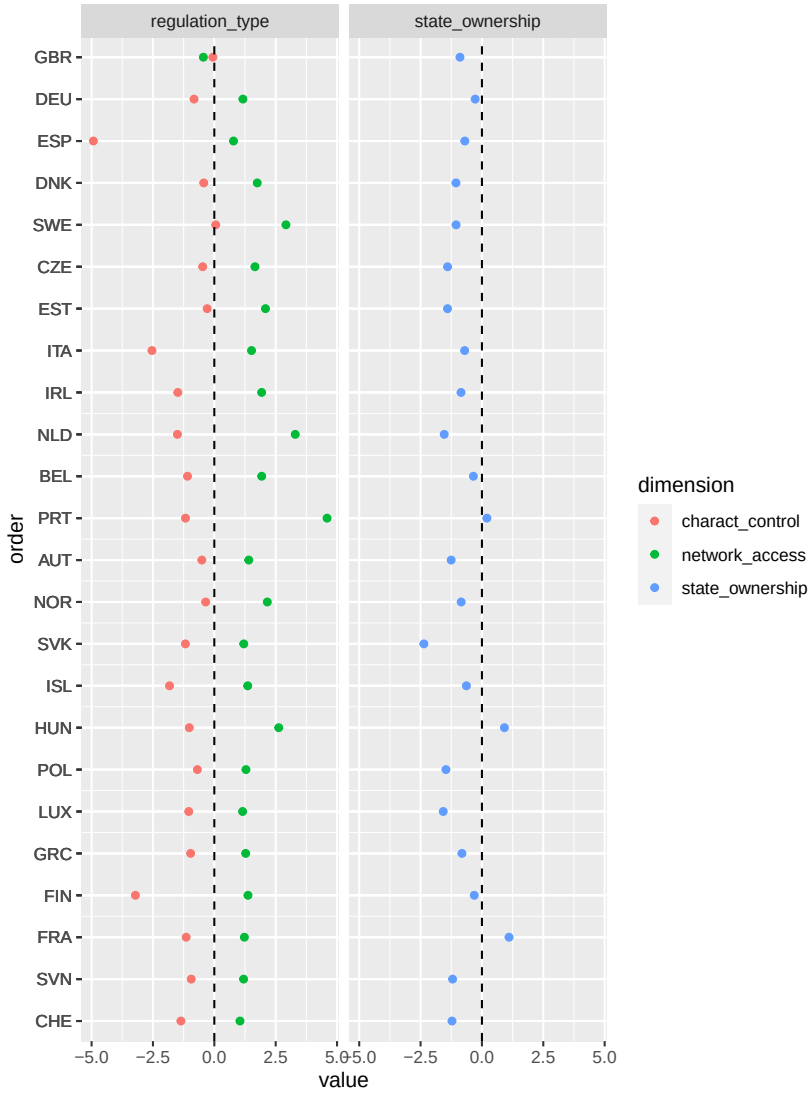


Figure A.2: National growth rates of indicators by dimension

A.2 PMR survey questions

Table A.1: Representative questions from the PMR Energy surveys

Industry	Question	Answers			
Electricity	How are the terms and conditions of third party access (TPA) to the electricity transmission grid determined?	regulated TPA	negotiated TPA	no TPA	
	Is there a liberalised wholesale market for electricity (a wholesale pool)?	yes		no	
	What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier ?	no minimum consumption threshold		consumption threshold / no consumer choice	
	What is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector?	% of shares owned by government smaller than 50%		% of shares owned by government smaller than / equal to 50%	
	What is the degree of vertical separation between a certain segment of the electricity sector and other segments of the industry?	ownership separation	legal separation	accounting separation	no separation
Gas	How are the terms and conditions of third party access (TPA) to the gas transmission grid determined?	regulated TPA	negotiated TPA	no TPA	
	Do national, state or provincial laws or other regulations restrict the number of competitors allowed to operate a business in at least some markets in the sector?	no		yes	
	What percentage of shares in the largest firm in the gas sector are owned by government?	% of shares owned by government smaller than 50%		% of shares owned by government smaller than / equal to 50%	
	What is the degree of vertical separation between a certain segment of the gas sector and other segments of the industry?	ownership separation	legal separation	accounting separation	no separation

Table A.2: Representative questions from the PMR Telecom surveys

Industry	Question	Answers	
Telecom	Is free entry permitted in at least one market in the sector (i.e. can anyone enter the market, provided they meet licensing criteria)?	no	yes
	Do laws or regulations restrict, in at least one market in the sector, the number of competitors allowed to operate a business (e.g. by establishing a legal monopoly or duopoly, or a limited number of franchises or licenses)?	no	yes
	Is unbundling of the local loop required?	no	yes
	Is mobile phone interconnection mandated?	no	yes
	What is the percentage of shares owned, either directly or indirectly, by the government in the largest firm?	% of shares owned by government smaller than 50%	% of shares owned by government smaller than / equal to 50%

Table A.3: Representative questions from the PMR Transport surveys

Industry	Question	Answers	
Air	Does your country have an open skies agreement with the United States?	no	yes
	Is your country participating in a regional agreement?	no	yes
	Is the domestic aviation market in your country fully liberalised? That is, there are no restrictions on the number of (domestic) airlines that are allowed to operate on domestic routes?	no	yes
	What percentage of shares in the largest carrier (domestic and international traffic combined) are owned by national, state or provincial authorities?	% of shares owned by government smaller than 50%	% of shares owned by government smaller than / equal to 50%
Rail	What are the legal conditions of entry into the passenger/freight transport market?	free entry (upon paying access fees)	entry franchised to single / several firms
	What percentage of shares in the largest firm in operation of infrastructure sector is owned by government?	% of shares owned by government smaller than 50%	% of shares owned by government smaller than / equal to 50%
	What percentage of shares in the largest firm in the passenger/freight transport sector is owned by government?	% of shares owned by government smaller than 50%	% of shares owned by government smaller than / equal to 50%
	What is the degree of separation between the operation of infrastructure and the provision of railway services (the actual transport of passengers or freight)?	ownership separation / legal separation	accounting separation / no separation

Sector	Questionnaire	Updates	
		2003-2008	2013-2018
Electricity	1. Information about generation, transmission, distribution, supply and imports 2. Government holdings equity in firms / special voting rights 3. Vertical separation of the industry 4. Third-party access 5. Wholesale markets / prices regulation, consumer discrimination	1. Government control / direction of incumbent firm(s) 2. Legal constraints for selling firm equity	1. Questions for the electricity exports 2. Legal restrictions for number of competing firms in transmission, distribution and export 3. Price benchmarks, consumer billing 4. Demand response 5. TPA for distribution networks
Gas	1. Information about production, transmission, distribution, supply and imports 2. Government holdings equity in firms / special voting rights 3. Vertical separation of the industry 4. Third-party access 5. Wholesale markets / prices regulation, consumer discrimination	1. Government control / direction of incumbent firm(s) 2. Legal constraints for selling firm equity	1. Questions for gas exports and storage 2. Legal restriction for number of competing firms in transmission, distribution, storage 3. Nature of vertical separation 4. TPA for distribution networks 5. Price benchmark, consumer billing
Telecom	1. Information about fixed-line, internet services and mobile services 2. Government holdings equity in firms / special voting rights 3. Legal restrictions to the number of competitors / free entry 4. Regulated prices / rates 5. Service obligations	1. Government control of a firm in the sector 2. Legal constraints for selling state firm stakes 3. Regulator access to information	1. Questions for mobile networks 2. Market power existence and remedies for fixed and mobile (price regulation, service access and transparency) 3. Portability, data-caps, zero-rating services
Air transport	1. Information about domestic and foreign air traffic, freight, airports 2. Goverment controls air-traffic control 3. Legal restrictions to the number of competitors / liberalized market 4. Regional agreements / open skies agreements with the US 5. Service obligations 6. Regulated prices / rates	1. Government control a firm in the airline services and airports 2. Government holds special voting rights 3. Cabotage within open skies agreements	1. Questions about airport operations, air-traffic control activities, 2. Domestic market freedoms (flight schedules, air-craft capacity) 3. Open-skies agreements, breath and additional freedoms)
Rail transport	1. Information about passenger, freight transport, operation of rail infrastructure 2. Government holdings equity in firms / government control of incumbent 3. Legal restrictions to the number of competitors 4. Legal entry barriers / service obligations	1. Legal constraints for selling of state firm stakes 2. Government holds special voting rights	1. Legal provisions that support competition

Table A.4: Subjects covered by the OECD Regulatory Indicators Questionnaire and further updates

Table A.5: RIQ response rate (in percentage points)

sector	**1998**	**2003**	**2008**	**2013**	**2018**
Electricity	65.82	68.79	95.66	99.00	98.56
Gas	50.98	53.02	93.95	97.71	98.93
Telecom	75.74	78.00	89.38	99.07	98.49
Air transport	74.58	85.49	93.66	95.65	98.94
Rail transport	76.86	92.32	96.47	98.82	99.04

A.3 Word-Sense disambiguation

Table A.6: Word-Sense disambiguation - algorithm choice nouns

Noun	WN sense	Noun	WN sense	Noun	WN sense
state	3	operation	1	trading	1
government	1	railroad	1	hub	2
equity	2	infrastructure	1	voice	1
stake	1	provision	3	video	4
firm	1	railway	1	data	1
sector	2	area	1	group	1
electricity	2	right	1	power	1
generation	6	country	1	call	1
transmission	3	sky	1	origination	1
distribution	4	agreement	1	question	1
supply	3	aviation	4	reference	3
percentage	2	restriction	2	offer	2
share	1	airline	2	termination	2
law	2	carrier	5	subset	1
regulation	6	route	1	portability	1
market	1	requirement	1	form	2
number	1	obligation	1	product	1
business	2	customer	1	practice	1
monopoly	1	liability	1	use	1
franchise	1	loss	1	billing	1
license	1	company	1	spectrum	2
nature	1	way	1	zero	1
separation	1	constraint	3	rating	3
segment	1	sale	5	feature	1
industry	1	voting	1	plan	1
term	3	cabotage	1	cap	7
condition	7	territory	1	rail	2
party	1	regulator	2	competition	1
access	2	information	2	provider	1
grid	2	cost	1	manager	1
wholesale	1	structure	3	system	2
pool	3	ability	1	equivalence	1
consumer	1	activity	1	discrimination	1
supplier	1	import	1	airport	1
minimum	1	accounting	3	control	1
consumption	3	type	1	transportation	1
threshold	1	benchmark	1	subject	1
order	1	objective	1	availability	1
year	1	standard	1	slot	3
gas	6	ownership	1	frequency	1
production	5	negotiation	1	flight	1
telecommunication	1	action	1	size	1
line	15	operator	2	aircraft	1
network	1	category	1	representative	1
service	1	bill	2	enforcement	1
internet	1	ministry	1	freedom	1
entry	5	body	2	supervision	1
criterion	1	demand	2	level	1
retail	1	response	1	charge	3
rate	2	consent	1	revenue	1
loop	7	capacity	1	export	1
price	2	reward	1	side	1
interconnection	2	mechanism	2	public	1
air	9	place	3	contract	1
transport	1	sort	1	measure	1
passenger	1	tender	3	procedure	1
freight	1	auction	2	margin	4
traffic	1	user	2	squeeze	3

Table A.7: Word-Sense disambiguation - algorithm choice verbs

Verb	WordNet sense
allocate	1
allow	1
approve	2
base	1
charge	3
choose	1
combine	6
compete	1
control	1
cover	6
determine	5
do	1
enter	2
establish	2
exceed	1
exit	1
franchise	1
guarantee	2
have	1
hold	4
include	1
indicate	2
integrate	3
introduce	1
lease	4
liberalise	1
license	1
limit	1
list	1
make	4
mandate	2
meet	4
need	1
negotiate	1
offer	6
operate	1
own	1
participate	2
permit	1
prohibit	1
provide	2
publish	2
put	1
regulate	2
require	3
restrict	2
sell	1
send	3
separate	1
serve	1
specify	3
update	2
use	1
wish	2

Table A.8: Word-Sense disambiguation - algorithm choice adjectives

Verb	WordNet sense
able	1
actual	1
administrative	1
annual	2
appropriate	1
bilateral	1
busy	1
clear	3
commercial	1
common	2
constitutional	2
domestic	1
downstream	1
efficient	1
exclusive	1
foreign	2
free	1
geographic	1
golden	6
independent	2
individual	1
industrial	1
international	2
large	1
legal	1
legislative	1
limited	2
local	1
many	1
medium	1
mobile	3
municipal	1
national	1
necessary	1
open	1
operational	1
particular	2
possible	1
provincial	1
public	1
regional	1
regulatory	1
relevant	1
residential	1
secondary	3
separate	1
several	1
significant	2
single	1
small	1
special	1
subject	3
substantial	1
technical	2
third	1
timely	2
universal	2
vertical	2

A.4 Lexical Chains

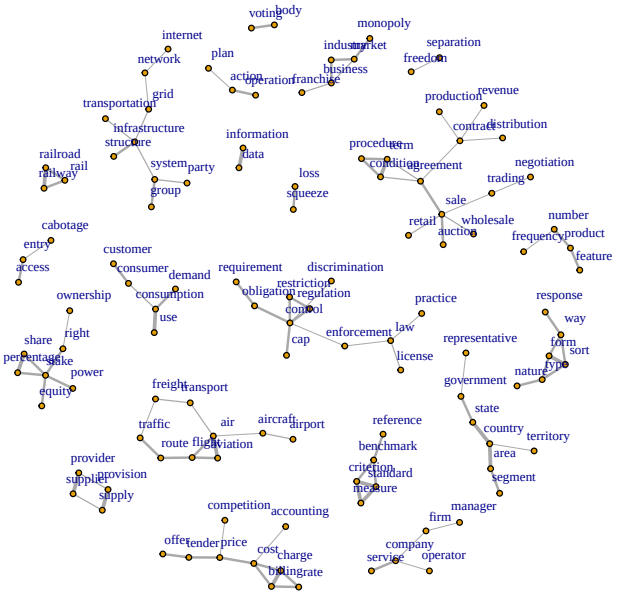


Figure A.3: Lexical Chains undirected graph for nouns

Table A.9: Lexical Chains and Semantic Relationships for nouns I

Main term	Secondary Term	Relationship	Chain (Main term)
area	country	3	1
country	state	3	1
area	segment	2	1
government	state	2	1
country	territory	1	1
government	representative	1	1
condition	term	3	2
auction	sale	2	2
condition	procedure	2	2
procedure	term	2	2
sale	agreement	2	2
condition	agreement	1	2
sale	wholesale	1	2
sale	retail	1	2
term	agreement	1	2
contract	distribution	1	2
contract	production	1	2
contract	revenue	1	2
contract	agreement	1	2
negotiation	trading	1	2
sale	trading	1	2
group	system	2	3
infrastructure	structure	2	3
grid	infrastructure	1	3
infrastructure	system	1	3
infrastructure	transportation	1	3
party	system	1	3
grid	network	1	3
internet	network	1	3
criterion	measure	3	4
criterion	standard	3	4
measure	standard	3	4
benchmark	criterion	2	4
benchmark	reference	2	4
benchmark	standard	2	4
percentage	share	3	5
equity	stake	2	5
percentage	stake	2	5
power	stake	2	5
share	stake	2	5
stake	right	2	5
ownership	right	1	5
cap	control	2	6
control	obligation	2	6
control	regulation	2	6
control	restriction	2	6
obligation	requirement	2	6
regulation	restriction	2	6
law	license	1	6
control	discrimination	1	6
control	enforcement	1	6
enforcement	law	1	6
law	practice	1	6

Table A.10: Lexical Chains and Semantic Relationships for nouns II

Main term	Secondary Term	Relationship	Chain (Main term)
form	sort	3	7
form	type	2	7
form	way	2	7
nature	type	2	7
response	way	2	7
sort	type	2	7
sort	way	2	7
air	aviation	3	8
air	flight	2	8
aviation	flight	2	8
flight	route	2	8
route	traffic	2	8
air	transport	1	8
aircraft	airport	1	8
freight	transport	1	8
air	aircraft	1	8
freight	traffic	1	8
billing	charge	3	9
billing	cost	2	9
billing	rate	2	9
charge	cost	2	9
charge	rate	2	9
cost	price	2	9
offer	tender	2	9
price	tender	2	9
accounting	cost	1	9
competition	price	1	9
business	industry	2	10
industry	market	2	10
market	monopoly	2	10
business	market	1	10
business	franchise	1	10
railroad	railway	3	11
rail	railroad	2	11
rail	railway	2	11
access	entry	2	12
cabotage	entry	1	12
provider	supplier	3	13
provision	supply	3	13
provider	provision	1	13
supplier	supply	1	13
consumption	use	3	14
consumer	customer	2	14
consumption	demand	2	14
consumer	consumption	1	14
feature	product	2	15
number	product	2	15
frequency	number	1	15
action	operation	2	16
action	plan	1	16
data	information	3	17
loss	squeeze	2	18
body	voting	2	19
company	service	2	20
company	firm	1	20
company	operator	1	20
firm	manager	1	20
freedom	separation	1	21

Table A.11: Lexical chains for nouns

Cluster	Terms	Number of terms
1	area, country, government, representative, segment, state, territory	7
2	auction, condition, contract, distribution, negotiation, procedure, production, revenue, sale, term, trading, agreement, wholesale, retail	14
3	grid, group, infrastructure, internet, network, party, structure, system, transportation	9
4	benchmark, criterion, measure, reference, standard	5
5	equity, ownership, percentage, power, share, stake, right	7
6	cap, control, discrimination, enforcement, law, obligation, practice, regulation, requirement, restriction, license	11
7	form, nature, response, sort, type, way	6
8	air, aircraft, airport, aviation, flight, freight, route, traffic, transport	9
9	accounting, billing, charge, competition, cost, offer, price, rate, tender	9
10	business, industry, market, monopoly, franchise	5
11	rail, railroad, railway	3
12	access, cabotage, entry	3
13	provider, provision, supplier, supply	4
14	consumer, consumption, customer, demand, use	5
15	feature, frequency, number, product	4
16	action, operation, plan	3
17	data, information	2
18	loss, squeeze	2
19	body, voting	2
20	company, firm, manager, operator, service	5
21	freedom, separation	2

Table A.12: Lexical Chains and Semantic Relationships for verbs

Main term	**Secondary Term**	**Relationship**	**Chain (Main term)**
charge	require	2	1
limit	control	2	2
limit	restrict	3	2
control	restrict	2	2
restrict	prohibit	1	2
choose	specify	2	3
choose	determine	2	3
determine	regulate	2	3
base	establish	3	4
cover	include	2	5
franchise	license	2	6
negotiate	sell	2	7
hold	own	3	8
enter	participate	3	9
allow	permit	3	10
meet	provide	2	11
provide	serve	2	11
put	use	2	12
require	need	3	13
need	lease	3	13

Table A.13: Lexical Chains and Semantic Relationships for adjectives

Main term	**Secondary Term**	**Relationship**	**Chain (Main term)**
clear	free	1	1
clear	open	3	1
free	independent	1	1
foreign	international	1	2
common	medium	1	3
domestic	municipal	1	4
domestic	national	1	4
national	public	1	4
individual	separate	1	5
individual	single	3	5
separate	single	1	5
particular	special	3	6
significant	substantial	3	7
commercial	technical	1	8

A.5 Metrics from Topic modelling

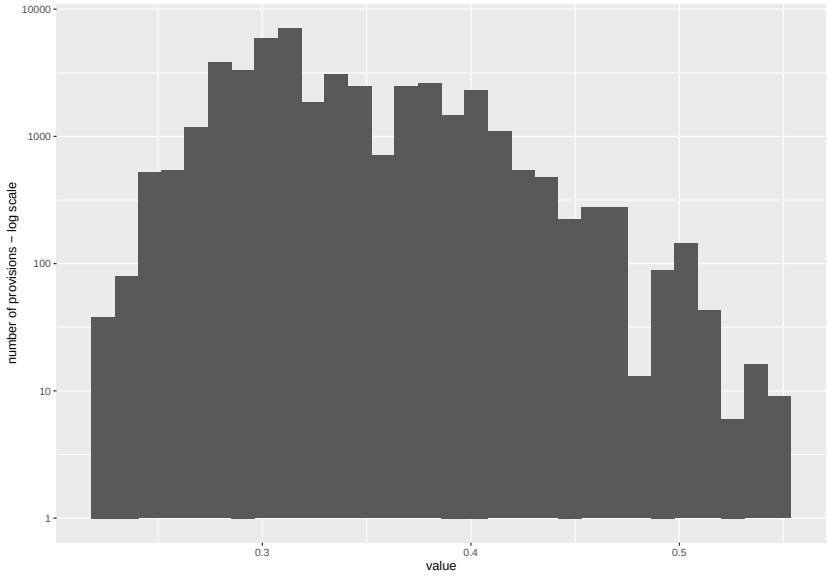


Figure A.4: Indicator (all) distribution of questions (provisions)

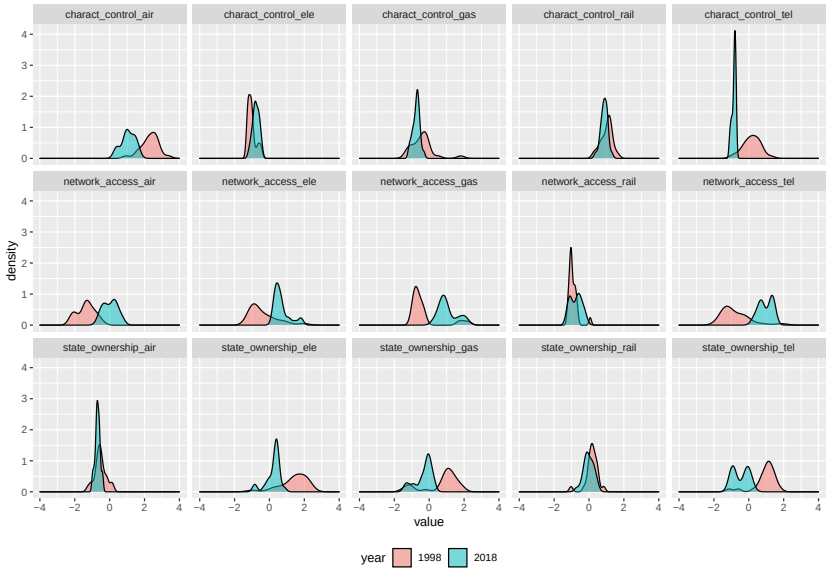


Figure A.5: Estimated densities (Gaussian Kernell) at sector level - evolutions

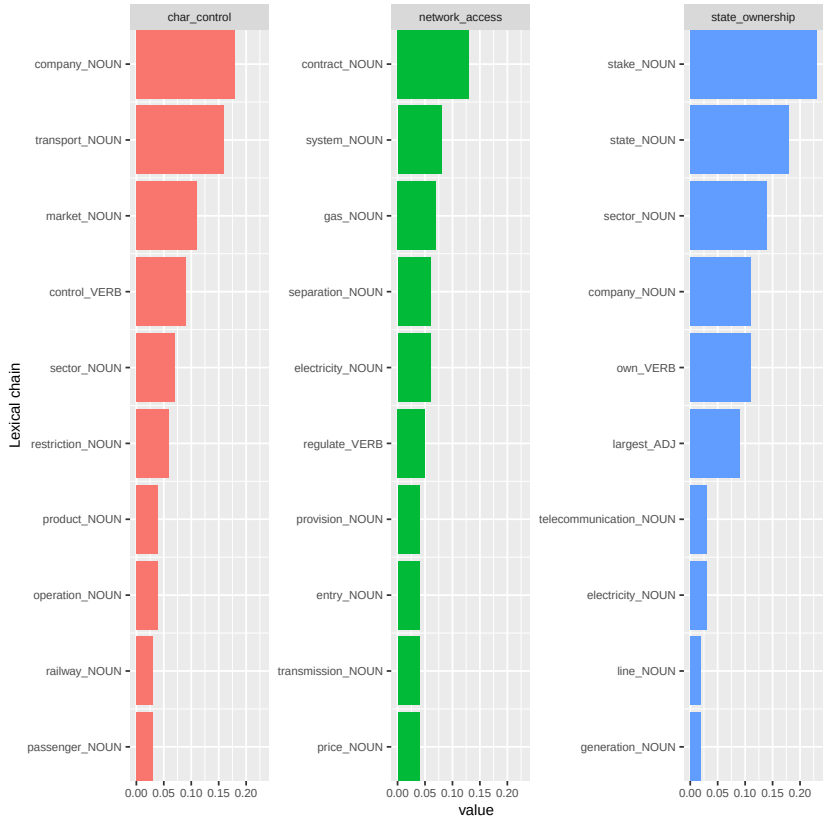


Figure A.6: Main concepts/terms by dimension

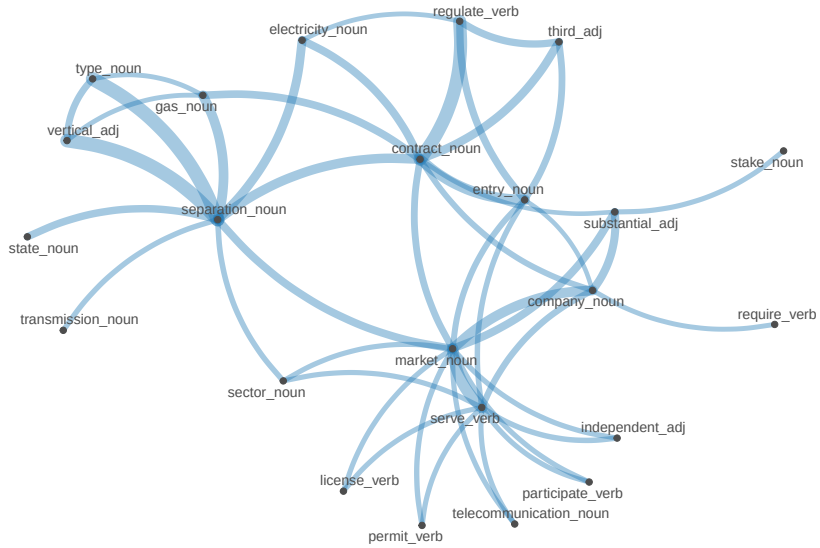


Figure A.7: Network access semantic network

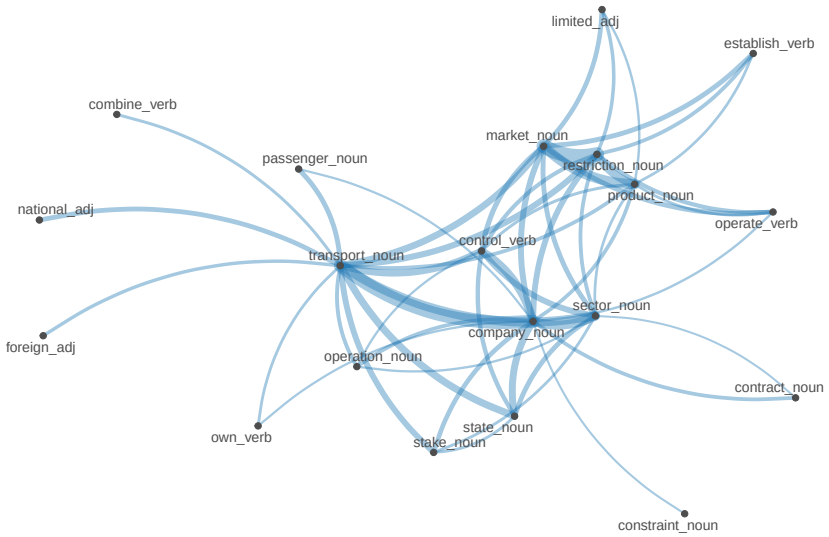


Figure A.8: Product characteristic control semantic network

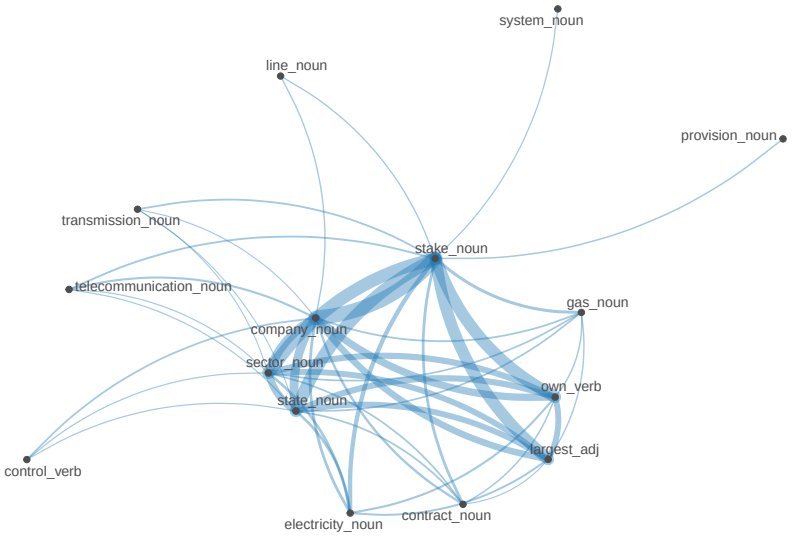


Figure A.9: State Ownership semantic network

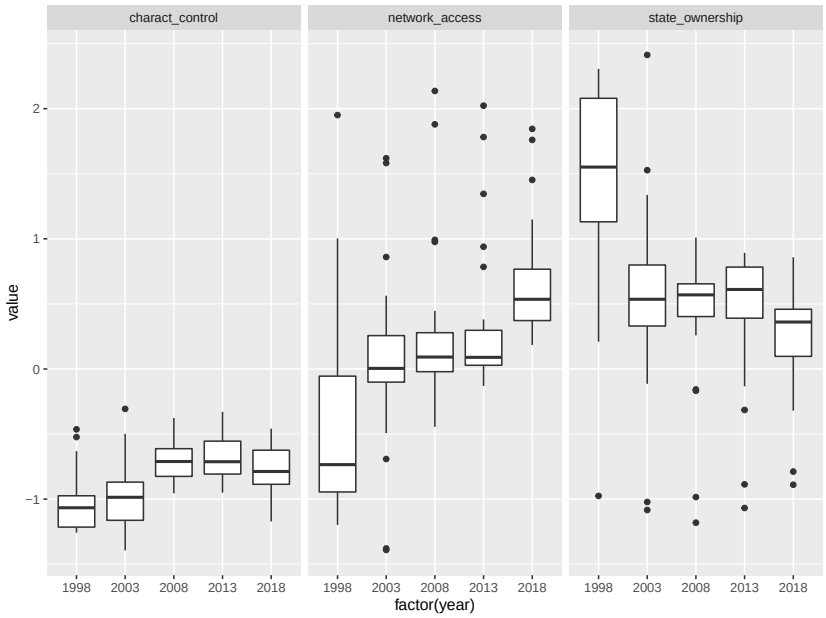


Figure A.10: Time variation in Electricity TA indicators' distributions

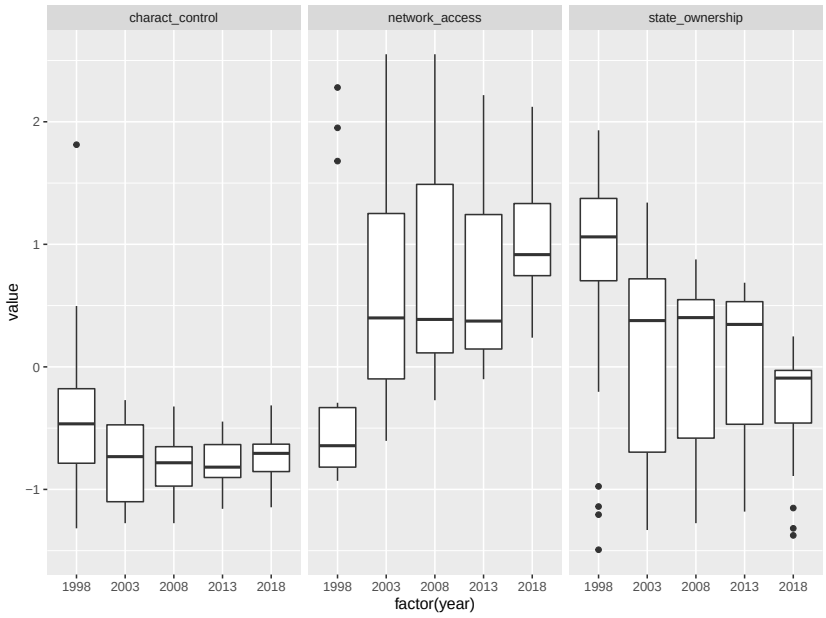


Figure A.11: Time variation in Gas TA indicators' distributions

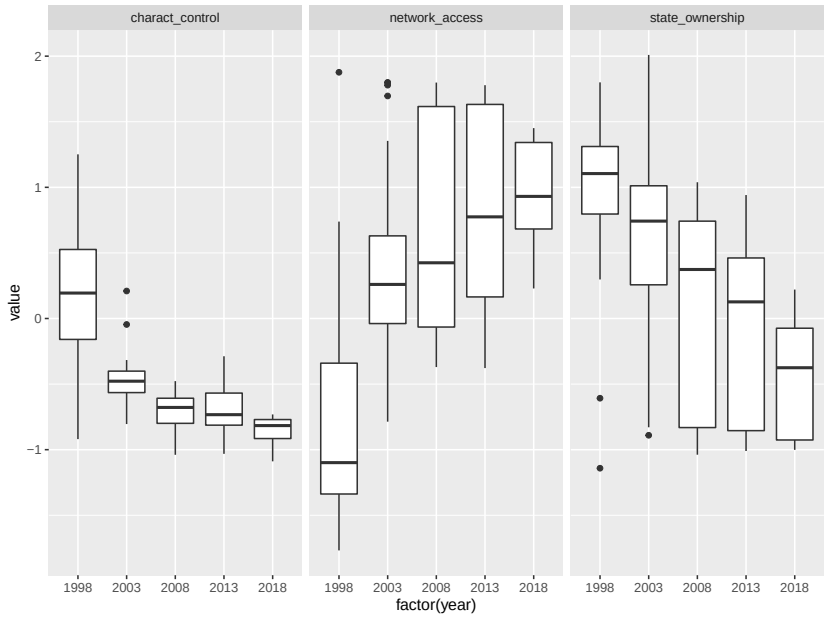


Figure A.12: Time variation in Telecom TA indicators' distributions

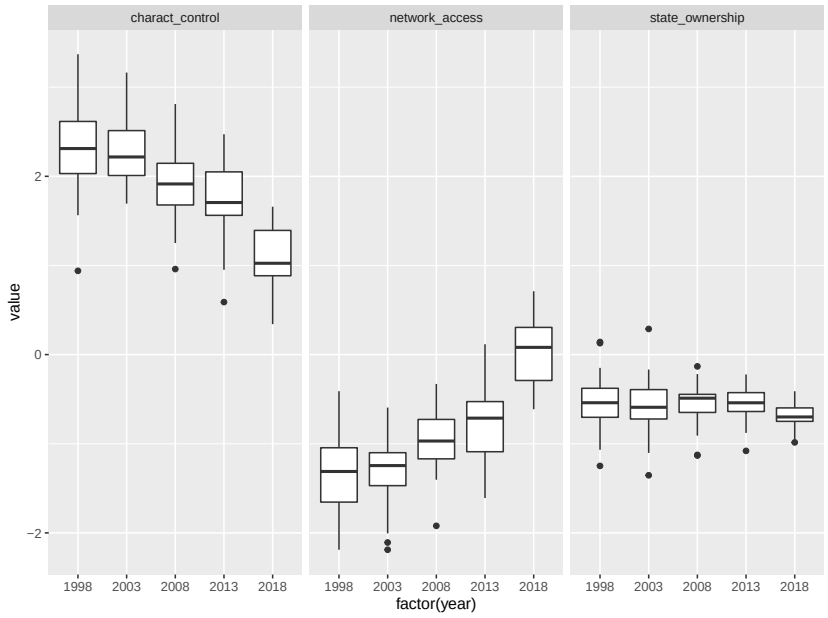


Figure A.13: Time variation in Air transport TA indicators' distributions

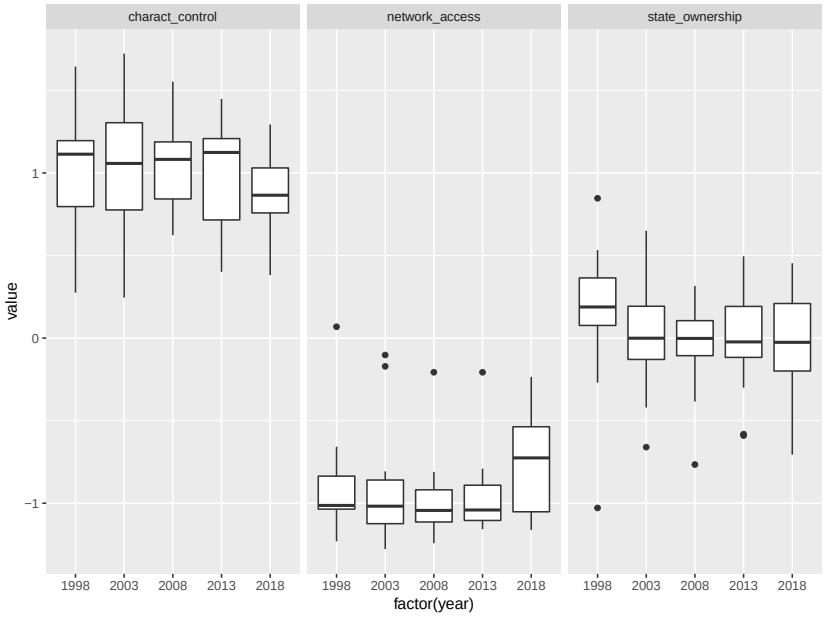


Figure A.14: Time variation in Rail transport TA indicators' distributions

A.6 Correlation TA PMR

Table A.14: Spearman correlation Government Ownership and PMR public ownership at national averages

PMR variable	gov_ownership
pubowner	-0.89

Table A.15: Spearman correlation between characteristic control/network access and PMR components at national averages

PMR variable	charact_control	network_access
entry	-0.51	0.79
mstruc	-0.41	0.66
vinteg	-	0.70

Table A.16: Spearman correlation between characteristic control/network access and PMR components

PMR variable	sector	charact_control	network_access
entry	air	-0.60	0.73
mstruc	air	-	-
vinteg	air	-	-
entry	ele	-	0.62
mstruc	ele	-	0.41
vinteg	ele	-	0.47
entry	gas	-0.51	0.64
mstruc	gas	-0.33	0.40
vinteg	gas	-0.33	0.57
entry	rail	-0.39	0.44
mstruc	rail	-0.40	0.46
vinteg	rail	-	0.42
entry	tel	-0.81	0.69
mstruc	tel	-0.80	0.73
vinteg	tel	-	-

Table A.17: Spearman correlation between *Government Ownership* and PMR public ownership

PMR variable	**sector**	**gov ownership**
pubowner	air	0.37
pubowner	ele	0.69
pubowner	gas	0.78
pubowner	rail	0.61
pubowner	tel	0.74

Table A.18: Spearman correlations between TA dimensions: individual observation level

Variable	gov_ownership	charact_control	network_access
gov_ownership	1.00	-0.34	-0.19
charact_control	-0.34	1.00	-0.74
network_access	-0.19	-0.74	1.00

Table A.19: Spearman correlations between TA dimensions: national average level

Variable	gov_ownership	charact_control	network_access
gov_ownership	1.00	0.16	-0.90
charact_control	0.16	1.00	-0.53
network_access	-0.90	-0.53	1.00

A.7 Distributional properties of the indicators

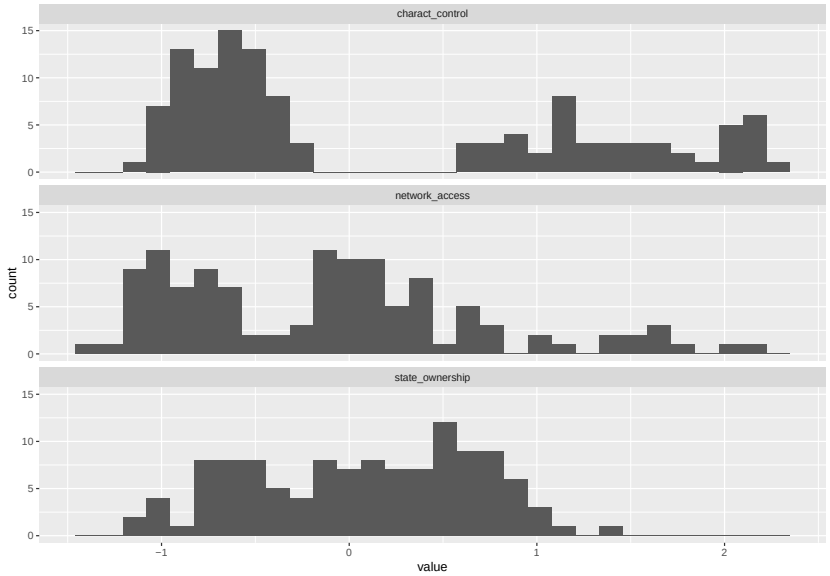


Figure A.15: Distribution of scores by dimension (sectoral-time averages)

Table A.20: Distributional statistics of market reform dimensions

Dimension	mean	sd	kurt	skew
charact_control	0.16	1.10	-1.28	0.59
network_access	-0.12	0.82	-0.08	0.70
state_ownership	0.08	0.59	-1.03	-0.17

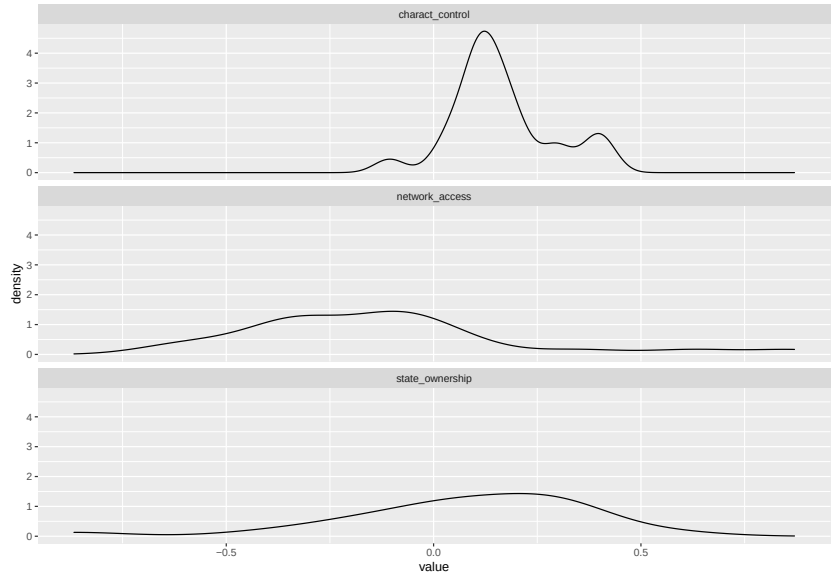


Figure A.16: Distribution of scores by dimension (national-time averages)

Table A.21: Distributional statistics of market reform dimensions

Compared dimensions	sector	mean diff	pval mean	evol diff	pval evol
network_access-charact_control	air	-2.72	0.00	1.58	0.00
state_ownership-charact_control	air	-2.42	0.00	-0.49	0.30
state_ownership-network_access	air	0.30	0.00	-2.08	0.00
network_access-charact_control	ele	1.03	0.00	2.30	0.00
state_ownership-charact_control	ele	1.43	0.00	-1.15	0.15
state_ownership-network_access	ele	0.40	0.01	-3.45	0.00
network_access-charact_control	gas	1.28	0.00	3.53	0.00
state_ownership-charact_control	gas	0.82	0.00	0.41	0.49
state_ownership-network_access	gas	-0.45	0.03	-3.12	0.00
network_access-charact_control	rail	-1.90	0.00	-0.03	1.00
state_ownership-charact_control	rail	-0.96	0.00	-0.03	1.00
state_ownership-network_access	rail	0.94	0.00	0.00	1.00
network_access-charact_control	tel	0.91	0.00	6.98	0.00
state_ownership-charact_control	tel	0.71	0.00	3.12	0.00
state_ownership-network_access	tel	-0.20	0.26	-3.86	0.00

Table A.22: Dimension scores summary statistics

sector	topic	mean	sd	min	max	n
air	charact_control	1.85	0.63	0.34	3.37	120
air	network_access	-0.87	0.65	-2.19	0.71	120
air	state_ownership	-0.58	0.26	-1.35	0.29	120
ele	charact_control	-0.83	0.24	-1.39	-0.31	120
ele	network_access	0.20	0.72	-1.39	2.14	120
ele	state_ownership	0.60	0.73	-1.18	2.41	120
gas	charact_control	-0.70	0.39	-1.32	1.81	115
gas	network_access	0.58	0.96	-0.93	2.55	115
gas	state_ownership	0.12	0.83	-1.49	1.93	115
rail	charact_control	0.98	0.30	0.25	1.72	115
rail	network_access	-0.92	0.27	-1.28	0.07	115
rail	state_ownership	0.02	0.29	-1.03	0.85	115
tel	charact_control	-0.51	0.45	-1.09	1.25	120
tel	network_access	0.41	0.94	-1.77	1.88	120
tel	state_ownership	0.20	0.83	-1.14	2.01	120

A.8 PMR evolution

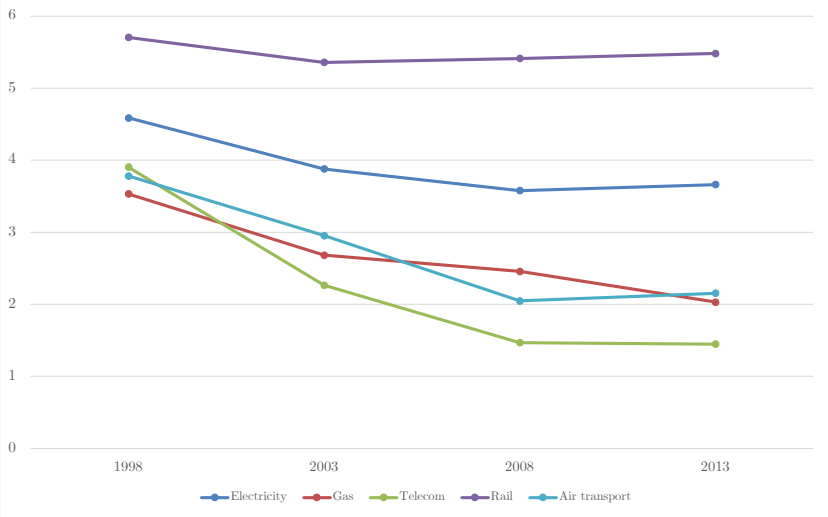


Figure A.17: OECD PMR index in government ownership evolution

A.9 Summary statistics and data sources

Table A.23: Summary statistics main variables - Energy

industry	variable	mean	min	max	n	units	source
ele	state_ownership	0.60	-1.18	2.41	120	z-score	constructed
ele	charact_control	-0.83	-1.39	-0.31	120	z-score	constructed
ele	network_access	0.20	-1.39	2.14	120	z-score	constructed
ele	invest_capital	1.44	2.62	0.15	88	log invest/f.cap	STAN (2022)
ele	elechou_price_net	4.85	3.18	5.56	107	log USD	IEA-OECD (2022)
ele	elecind_price_net	4.47	3.61	5.23	99	log USD	IEA-OECD (2022)
ele	share_co2	3.33	-4.64	4.60	120	log per.point	IEA-OECD (2022)*
ele	share_hydro	0.23	0.00	0.99	120	log per.point	IEA-OECD (2022)*
ele	share_nuclear	0.20	0.00	0.78	120	log per.point	IEA-OECD (2022)*
ele	share_solar	-2.35	-8.11	4.38	120	log per.point	IEA-OECD (2022)*
ele	share_wind	-0.95	-10.41	3.86	120	log per.point	IEA-OECD (2022)*
ele	total_elec_prod	11.07	7.13	13.32	120	log MWh	IEA-OECD (2022)
gas	state_ownership	0.12	-1.49	1.93	115	z-score	constructed
gas	charact_control	-0.70	-1.32	1.81	115	z-score	constructed
gas	network_access	0.58	-0.93	2.55	115	z-score	constructed
gas	invest_capital	1.44	2.62	0.15	88	log invest/f.cap	STAN (2022)
gas	elecgen_price_net	26.90	8.91	61.82	23	log USD	IEA-OECD (2022)
gas	elechou_price_net	3.83	1.69	4.81	97	log USD	IEA-OECD (2022)
gas	elecind_price_net	3.42	2.24	4.21	94	log USD	IEA-OECD (2022)
gas	gas_elec_gen	0.32	-3.91	4.27	114	log mill.m3	IEA-OECD (2022)
gas	gas_loss	-1.84	-3.91	1.40	115	log mill.m3	IEA-OECD (2022)
gas	gas_non_industry	0.05	0.00	0.37	111	log mill.m3	IEA-OECD (2022)
gas	gas_transport	-2.26	-6.32	2.38	115	log mill.m3	IEA-OECD (2022)

Dependent variables and main controls are transformed to logs as a mean to restrict the impact of outliers on the regression estimations. (*) Estimated variable by dividing the total electricity output of a source by the total electricity produced in the system.

Table A.24: Summary statistics main variables - Transport

industry	variable	mean	min	max	n	units	source
air	gov_ownership	-0.58	-1.35	0.29	120	z-score	constructed
air	liberalization	-1.85	-3.37	-0.34	120	z-score	constructed
air	network_access	-0.87	-2.19	0.71	120	z-score	constructed
air	invest_capital	1.76	3.22	-0.92	33	log invest/f.cap	STAN (2022)
air	air_freigh_tkgdp	-0.02	-6.00	4.99	105	log ton.km/gdp	EUROSTAT (2022)
air	air_pass_tkgdp	-3.39	-7.34	-0.83	109	log ton.km/gdp	EUROSTAT (2022)
air	airports_100ksqkm	2.17	0.80	3.72	48	log airp/100 km2	EUROSTAT (2022)
air	airports_millhab	-0.04	-1.61	3.61	48	log airp/million.hab	EUROSTAT (2022)
air	sh_co2_aviation	-0.29	-4.71	2.23	110	log per.point	EUROSTAT (2022)
rail	gov_ownership	0.02	-1.03	0.85	115	z-score	constructed
rail	liberalization	-0.98	-1.72	-0.25	115	z-score	constructed
rail	network_access	-0.92	-1.28	0.07	115	z-score	constructed
rail	invest_capital	1.70	3.63	-0.30	88	log invest/f.cap	STAN (2022)
rail	density_rail_sqkm	1.60	0.09	2.51	114	log trac.km/km2	ITF-OECD (2022)
rail	IND-MEAS-RAILPASS-GDP	29.81	3.16	182.40	114	log passen/GDP	ITF-OECD (2022)
rail	infr_invest_pc	4.36	1.94	6.36	111	log USD/mill.hab	ITF-OECD (2022)
rail	infr_invest_rail_GDP	-1.39	-4.31	-0.05	111	log USD/GDP	ITF-OECD (2022)
rail	rail_freigh_tkgdp	3.13	-1.67	6.98	113	log ton.km/gdp	ITF-OECD (2022)
rail	rail_freight_tonkm	8.84	4.29	11.78	113	log ton.km	ITF-OECD (2022)
rail	rail_pass_tonkm	8.84	5.20	11.59	114	log pass/km	ITF-OECD (2022)
rail	sh_co2_rail	-0.39	-2.13	2.10	110	log per.point	ITF-OECD (2022)
rail	sh_electric_rail	3.73	0.66	4.61	114	log per.point	ITF-OECD (2022)
rail	sh_highsp_rail	1.02	-0.83	2.77	32	log per.point	ITF-OECD (2022)
rail	sh_rail_fretransport	2.66	-0.52	4.24	110	log per.point	ITF-OECD (2022)
rail	sh_rail_passransport	1.99	1.01	2.83	85	log per.point	ITF-OECD (2022)
rail	sh_rail_totransport	3.42	1.45	4.40	110	log per.point	ITF-OECD (2022)

Dependent variables and main controls are transformed to logs as a mean to restrict the impact of outliers on the regression estimations. (*) Estimated variable by dividing the total electricity output of a source by the total electricity produced in the system.

Table A.25: Summary statistics main variables - Telecommunications

industry	variable	mean	min	max	n	units	source
tel	gov_ownership	0.20	-1.14	2.01	120	z-score	constructed
tel	liberalization	0.51	-1.25	1.09	120	z-score	constructed
tel	network_access	0.41	-1.77	1.88	120	z-score	constructed
tel	invest_capital	1.87	3.09	0.46	66	log invest/f.cap	STAN (2022)
tel	fixbbpricepc	1.15	0.45	2.98	72	log USD/mill.hab	ITU (2022)
tel	mobhighpricepc	1.01	0.33	3.31	24	log USD/mill.hab	ITU (2022)
tel	mobile_lowpricepc	0.97	0.09	4.03	72	log USD/mill.hab	ITU (2022)
tel	TELACCPATH100	4.97	3.30	5.49	119	acc.path/100.hab	EUROSTAT (2022)
tel	TELINVUSD	2.69	0.04	11.51	86	log 1000.USD	EUROSTAT (2022)
tel	TELINVUSD_pc	20.37	15.25	23.28	82	log USD/GDP	EUROSTAT (2022)
tel	TELMOBSUB100	4.44	1.62	5.23	119	log subs/100.hab	EUROSTAT (2022)
tel	TELREVUSD	18.19	0.23	91.62	93	log 1000.USD	EUROSTAT (2022)
tel	TELREVUSD_pc	22.19	16.68	25.32	89	log USD/mill.hab	EUROSTAT (2022)
tel	voicepricepc	0.66	0.18	1.44	24	log USD/mill.hab	EUROSTAT (2022)

Dependent variables and main controls are transformed to logs as a mean to restrict the impact of outliers on the regression estimations. (*) Estimated variable by dividing the total electricity output of a source by the total electricity produced in the system.

A.10 Regression tables

Table A.26: OLS estimations: Contemporaneous independent variables

	Dependent variable:			
	log(investment = GFCF/CAPG)			
	(1)	(2)	(3)	(4)
network access	0.065			0.059
	(0.041)			(0.049)
state ownership		−0.061		
		(0.056)		
charact. control			-0.069	-0.027
			(0.124)	(0.140)
Country FE	yes	yes	yes	yes
Industry FE	yes	yes	yes	yes
Time FE	yes	yes	yes	yes
$investment_{t-1}$	yes	yes	yes	yes
Observations	281	281	281	281
R^2	0.544	0.543	0.542	0.544
Adjusted R^2	0.493	0.492	0.491	0.491
Residual Std. Error	0.384	0.385	0.385	0.385
F Statistic	10.732^{***}	10.699^{***}	10.653^{***}	10.327^{***}

The dependent variable is the division of the gross fix capital formation by the total capital stock measured in current US. Robust standard errors in parenthesis. *p<0.1; **p<0.05; ***p<0.01

Table A.27: Summary: Regression estimates for energy variables

Dep Var	Dimension	Coeff	SE	Adj. R2	F-stat	N	Lagged depvar
elecind_price	lag_gov_owner	-0.16	0.09	0.79	12.59	82	-
elecind_price	lag_gov_owner	-0.25	0.13	0.79	11.09	72	t-1
gashou_price	network_access	0.16	0.07	0.88	29.11	97	-
gashou_price	gov_ownership	-0.16	0.08	0.88	29.06	97	-
gashou_price	network_access	0.13	0.07	0.91	30.96	73	t-1
gasind_price	network_access	0.13	0.06	0.94	44.65	70	t-1
gasind_price	gov_ownership	-0.15	0.05	0.94	44.93	70	t-1
gas_loss	charac_control	0.39	0.22	0.77	14.77	115	-
gas_transport	lag_charac_control	-0.90	0.44	0.78	13.07	92	-
gas_transport	lag_charac_control	-0.92	0.44	0.78	12.82	92	t-1
share_solar	gov_ownership	-1.10	0.50	0.80	17.58	120	-
share_solar	lag_gov_owner	-1.03	0.63	0.80	14.81	96	-
share_solar	network_access	1.05	0.59	0.79	17.38	120	-
share_wind	charac_control	2.64	0.98	0.86	27.30	120	-
total_elec_prod	gov_ownership	-0.09	0.04	0.99	325.09	120	-
total_elec_prod	gov_ownership	-0.09	0.04	0.99	414.94	96	t-1
total_elec_prod	network_access	0.11	0.05	0.99	327.05	120	-
total_elec_prod	network_access	0.08	0.04	0.99	409.35	96	t-1

The estimates are the product of the model: $y_{ict} = \alpha + \beta x_{ict} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict}$. The terms λ_t and θ_c capture time and fixed effects respectively. The column "Coeff lagged" reports the coefficient of the dependent variable lagged one period. The column "Lagged depvar" reports whether the sign of the coefficient in "Coeff" or "Coeff Lagged" shares the same sign, after the inclusion of the lagged value of the dependent variable in the model. This specification follows Alesina et al. (2005) to capture persistence. The price effects hold the same direction and significant for both, household and industrial costumers. Household estimates presented in the summary. Robust standard errors in column SE. The presented coefficients are significant at 10% level or below.

Table A.28: Summary: Regression estimates for telecommunication variables

Dep Var	Dimension	Coeff	SE	Adj.R2	F-stat	N	Lagged Dep-Var
fixbbpricepc	gov_ownership	0.39	0.24	0.58	4.82	72	-
fixbbpricepc	lag_gov_ownership	0.32	0.13	0.63	5.70	72	-
fixbbpricepc	lag_gov_ownership	0.96	0.25	0.76	6.72	48	t-1
fixbbpricepc	lag_charact_control	-0.75	0.32	0.58	4.75	72	-
fixbbpricepc	lag_network_access	-0.30	0.13	0.61	5.21	72	-
fixbbpricepc	lag_network_access	-0.86	0.28	0.68	4.77	48	t-1
mobile_lowpricepc	gov_ownership	0.65	0.34	0.57	4.59	72	-
mobile_lowpricepc	charact_control	-1.66	0.55	0.58	4.84	72	-
mobile_lowpricepc	lag_charact_control	1.44	0.76	0.55	3.21	48	t-1
mobile_lowpricepc	lag_network_access	-0.52	0.29	0.49	2.77	48	t-1
TELACCPATH100	gov_ownership	-0.08	0.03	0.90	37.32	119	-
TELACCPATH100	charact_control	-0.16	0.07	0.90	37.74	119	-
TELACCPATH100	network_access	0.11	0.04	0.90	41.04	119	-
TELACCPATH100	lag_network_access	-0.02	0.01	0.88	24.68	95	t-1
TELINVUSD_pc	lag_gov_ownership	0.16	0.06	0.98	130.12	82	-
TELINVUSD_pc	lag_network_access	-0.18	0.06	0.98	133.97	82	-
TELMOBSUB100	charact_control	0.-32	0.13	0.89	34.35	119	-
TELMOBSUB100	network_access	0.15	0.07	0.89	34.07	119	-
TELREVUSD_pc	lag_gov_ownership	0.22	0.13	0.97	110.30	89	-
TELREVUSD_pc	lag_gov_ownership	0.21	0.12	0.98	105.61	66	t-1

The estimates are the product of the model: $y_{ict} = \alpha + \beta x_{ict} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict}$. The terms λ_t and θ_c capture time and fixed effects respectively. The column "Coeff lagged" reports the coefficient of the dependent variable lagged one period. The column "Lagged depvar" reports whether the sign of the coefficient in "Coeff" or "Coeff Lagged" shares the same sign, after the inclusion of the lagged value of the dependent variable in the model. This specification follows Alesina et al. (2005) to capture persistence. The price effects hold the same direction and significant for both, household and industrial costumers. Household estimates presented in the summary. Robust standard errors in column SE. The presented coefficients are significant at 10% level or below.

Table A.29: Summary: Regression estimates for transport variables

Dep Var	Dimension	Coeff	SE	Adj.R2	F-stat	N	Lagger depvar
air_freigh_tkgdp	gov_ownership	0.69	0.39	0.90	26.30	81	t-1
air_freigh_tkgdp	charact_control	0.66	0.20	0.91	36.85	105	
air_freigh_tkgdp	charact_control	0.53	0.25	0.90	27.60	81	t-1
air_freigh_tkgdp	lag_charact_control	0.37	0.21	0.90	26.91	81	
air_freigh_tkgdp	network_access	-0.87	0.20	0.91	40.68	105	
air_freigh_tkgdp	network_access	-0.84	0.29	0.91	31.18	81	t-1
air_freigh_tkgdp	lag_network_access	-0.64	0.32	0.90	28.20	81	
air_freigh_tkgdp	lag_network_access	-0.60	0.34	0.90	26.73	81	t-1
air_pass_tkgdp	gov_ownership	0.60	0.23	0.75	9.88	85	t-1
air_pass_tkgdp	charact_control	-0.27	0.13	0.76	13.31	109	
air_pass_tkgdp	charact_control	-0.37	0.21	0.75	10.13	85	t-1
sh_co2_aviation	charact_control	0.27	0.12	0.96	87.25	110	
sh_co2_aviation	charact_control	0.26	0.13	0.96	87.76	87	t-1
sh_co2_aviation	lag_charact_control	0.28	0.15	0.96	79.43	89	
sh_co2_aviation	lag_charact_control	0.26	0.14	0.96	86.17	87	t-1
sh_co2_aviation	network_access	-0.27	0.14	0.95	86.49	110	
sh_co2_aviation	network_access	-0.31	0.14	0.96	89.34	87	t-1
sh_co2_aviation	lag_network_access	-0.34	0.20	0.96	79.22	89	
sh_co2_aviation	lag_network_access	-0.33	0.18	0.96	86.77	87	t-1
density_rail_sqkm	lag_network_access	-0.13	0.08	1.00	700.84	91	
density_rail_sqkm	lag_network_access	-0.17	0.08	1.00	804.75	90	t-1
infr_invest_pc	charact_control	0.52	0.27	0.72	11.56	111	
infr_invest_pc	lag_network_access	-1.33	0.70	0.71	9.42	90	
infr_invest_rail_GDP	lag_network_access	-1.16	0.69	0.45	3.85	90	
rail_freigh_tkgdp	charact_control	-0.44	0.20	0.94	70.91	113	
rail_freigh_tkgdp	network_access	0.59	0.25	0.94	70.20	113	
rail_freight_tonkm	network_access	0.38	0.19	0.97	124.71	113	
sh_electric_rail	lag_network_access	0.36	0.17	0.98	160.49	90	t-1
sh_highsp_rail	lag_gov_ownership	-1.30	0.46	0.94	37.53	27	
sh_highsp_rail	lag_gov_ownership	-1.08	0.46	0.95	36.30	23	t-1
sh_highsp_rail	lag_network_access	1.38	0.51	0.93	30.74	27	
sh_rail_fretransport	charact_control	-0.32	0.13	0.92	44.87	110	
sh_rail_fretransport	lag_charact_control	-0.29	0.16	0.95	60.97	87	
sh_rail_fretransport	network_access	0.53	0.17	0.92	45.55	110	
sh_rail_fretransport	network_access	0.27	0.14	0.95	68.59	87	t-1

The estimates are the product of the model: $y_{ict} = \alpha + \beta x_{ict} + \gamma_i + \lambda_t + \theta_c + \epsilon_{ict}$. The terms λ_t and θ_c capture time and fixed effects respectively. The column "Coeff lagged" reports the coefficient of the dependent variable lagged one period. The column "Lagged depvar" reports whether the sign of the coefficient in "Coeff" or "Coeff Lagged" shares the same sign, after the inclusion of the lagged value of the dependent variable in the model. This specification follows Alesina et al. (2005) to capture persistence. The price effects hold the same direction and significant for both, household and industrial costumers. Household estimates presented in the summary. Robust standard errors in column SE. The presented coefficients are significant at 10% level or below.

Appendix B

Appendices of Paper 2

B.1 Topic Modeling

Figure B.1: Term distribution per document

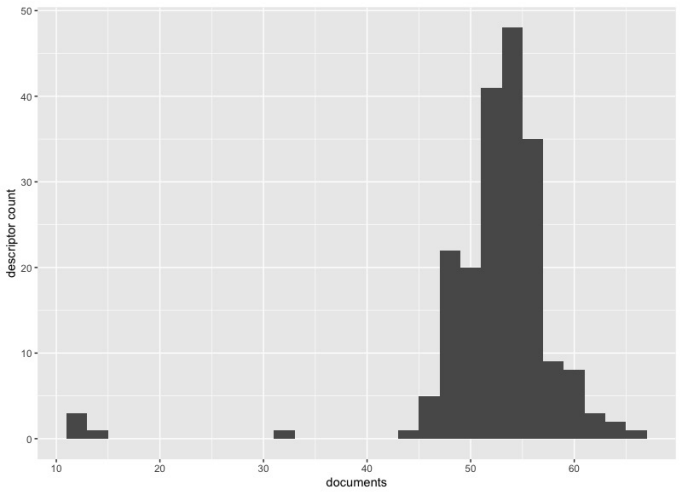


Figure B.2: Histogram of the agency mean dimension score

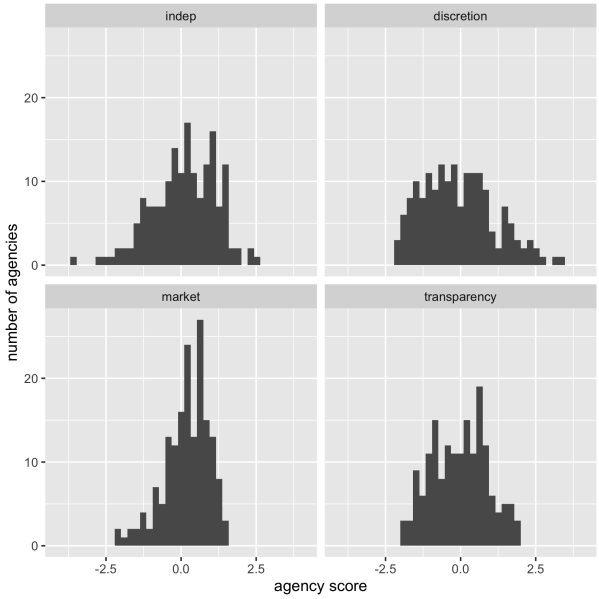
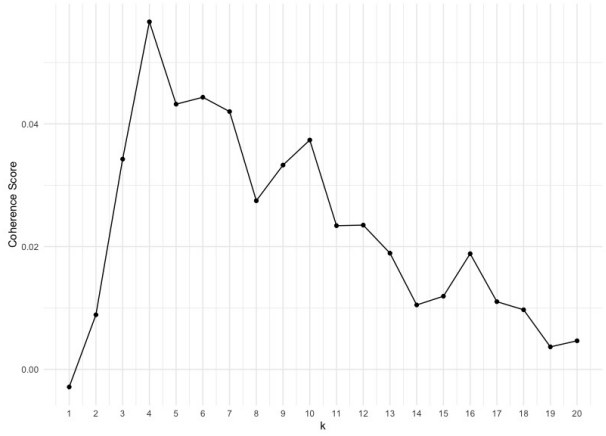


Figure B.3: Coherence score - optimal number of topics



B.1.1 Summary Statistics

Summary statistics and correlation tables

Table B.1: Summary Statistics for LDA dimension weight estimates (scaled)

sector	indicator	year	mean	sd	min	max	n
air	indep	2,013	-1.022	1.161	-3.509	0.690	18
air	indep	2,018	-0.316	1.262	-2.601	1.421	18
air	discretion	2,013	0.047	1.608	-1.983	2.760	18
air	discretion	2,018	0.152	1.476	-2.008	3.353	18
air	market	2,013	-0.231	0.960	-2.135	0.944	18
air	market	2,018	-0.476	0.830	-2.166	0.853	18
air	transparency	2,013	-0.838	0.599	-1.840	0.460	18
air	transparency	2,018	0.008	0.677	-1.098	1.150	18
ene	indep	2,013	-0.107	0.959	-2.364	1.571	23
ene	indep	2,018	0.410	0.774	-1.327	1.499	23
ene	discretion	2,013	-0.169	1.049	-1.747	1.762	23
ene	discretion	2,018	-0.553	0.900	-2.040	1.098	23
ene	market	2,013	0.438	0.555	-0.512	1.460	23
ene	market	2,018	0.410	0.459	-0.659	1.318	23
ene	transparency	2,013	-0.375	0.794	-1.610	1.380	23
ene	transparency	2,018	0.553	0.875	-1.460	1.910	23
rail	indep	2,013	-0.214	0.798	-1.610	1.380	22
rail	indep	2,018	0.781	0.730	-0.500	1.910	21
rail	discretion	2,013	0.640	1.274	-1.791	3.221	22
rail	discretion	2,018	0.397	0.870	-1.574	2.444	21
rail	market	2,013	-0.107	0.826	-1.610	1.181	22
rail	market	2,018	0.105	0.584	-1.194	1.080	21
rail	transparency	2,013	-0.747	0.744	-1.825	0.878	22
rail	transparency	2,018	0.279	0.595	-1.055	1.688	21
tel	indep	2,013	0.077	0.789	-1.610	1.380	22
tel	indep	2,018	0.863	0.826	-0.337	2.530	22
tel	discretion	2,013	-0.376	1.081	-2.103	2.389	22
tel	discretion	2,018	-0.536	0.932	-1.943	1.610	22
tel	market	2,013	0.462	0.599	-1.221	1.460	22
tel	market	2,018	0.653	0.411	0	1.307	22
tel	transparency	2,013	-0.009	0.940	-1.499	1.688	22
tel	transparency	2,018	0.746	0.702	-0.786	1.989	22

Table B.2: Pearson correlations for dimension mean-scores

var1	var2	agency	country	air	rail	ene	tel
indep	transparency	0.410	0.314	0.111	0.267	0.413	0.459
indep	market	0.331	0.163	0.214	0.207	-0.016	0.029
transparency	market	0.388	0.598	0.234	0.220	-0.043	0.234
indep	discretion	0.384	0.527	0.629	0.478	0.611	0.399
transparency	discretion	-0.512	-0.558	-0.462	-0.479	-0.336	-0.522
market	discretion	-0.581	-0.654	-0.516	-0.599	-0.442	-0.630

Table B.3: Pearson correlations for dimension evolution-scores

var1	var2	agency	country	air	rail	ene	tel
indep	transparency	0.419	0.314	0.111	0.267	0.413	0.459
indep	market	0.234	0.163	0.214	0.207	-0.016	0.029
transparency	market	0.093	0.598	0.234	0.220	-0.043	0.234
indep	discretion	0.284	0.527	0.629	0.478	0.611	0.399
transparency	discretion	-0.453	-0.558	-0.462	-0.479	-0.336	-0.522
market	discretion	-0.467	-0.654	-0.516	-0.599	-0.442	-0.630

Table B.4: Significant Pearson correlation coefficients TA and OECD scores

avg_var	indic	year_indic	correlcoef
indep	ACC	2018	0.479
indep	IND	2013	0.558
indep	IND	2018	0.580
discretion	ACC	2013	-0.473
discretion	SCO	2013	-0.584
discretion	SCO	2018	-0.470
market	ACC	2013	0.534
market	ACC	2018	0.542
market	IND	2018	0.405
market	SCO	2013	0.771
market	SCO	2018	0.655
transparency	ACC	2013	0.546
transparency	ACC	2018	0.557
transparency	IND	2018	0.543
transparency	SCO	2013	0.558
transparency	SCO	2018	0.442

Table B.5: Levene test for equality of sector distribution variance

dimension	meantest	evoltest
indep	0.122	0.289
discretion	0.075	0.505
market	0.005	0.46
transparency	0.375	0.612

Table B.6: Tukey test between sector distributional differences

sector1	sector2	dimension	meandif	meanpval	evoldif	evolpval
ene	air	indep	0.821	0.001	0.002	1
ene	rail	indep	-0.120	0.939	-0.104	0.317
rail	air	indep	0.941	0	0.105	0.388
tel	air	indep	1.139	0	0.085	0.570
tel	ene	indep	0.318	0.420	0.084	0.507
tel	rail	indep	0.198	0.785	-0.020	0.988
ene	air	discretion	-0.461	0.275	-0.125	0.556
ene	rail	discretion	-0.883	0.002	-0.042	0.965
rail	air	discretion	0.422	0.367	-0.083	0.825
tel	air	discretion	-0.556	0.141	-0.087	0.805
tel	ene	discretion	-0.095	0.980	0.038	0.973
tel	rail	discretion	-0.978	0.001	-0.004	1
ene	air	market	0.778	0	0.035	0.929
ene	rail	market	0.428	0.014	-0.058	0.699
rail	air	market	0.350	0.094	0.093	0.394
tel	air	market	0.911	0	0.071	0.624
tel	ene	market	0.134	0.775	0.036	0.907
tel	rail	market	0.561	0.001	-0.022	0.978
ene	air	transparency	0.504	0.051	0.010	1
ene	rail	transparency	0.335	0.275	-0.041	0.959
rail	air	transparency	0.169	0.826	0.050	0.943
tel	air	transparency	0.784	0.001	-0.041	0.968
tel	ene	transparency	0.279	0.431	-0.051	0.925
tel	rail	transparency	0.614	0.007	-0.092	0.693

Table B.7: Time differences and normality tests statistics

variable	sector	avgmean	sdmean	avgevol	sdevol	meandif	pval	pnormm	pnorme
indep	air	-0.678	1.047	0.076	0.265	0.582	0.064	0.788	0.093
indep	rail	0.249	0.677	0.182	0.153	0.971	0.000	0.4	0.696
indep	ene	0.152	0.676	0.078	0.209	0.517	0.017	0.118	0.626
indep	tel	0.461	0.677	0.162	0.169	0.808	0.000	0.697	0.205
discretion	air	0.099	1.306	0.081	0.44	-0.008	0.508	0.446	0.006
discretion	rail	0.532	0.897	-0.002	0.228	-0.226	0.791	0.647	0.513
discretion	ene	-0.361	0.748	-0.044	0.277	-0.384	0.921	0.173	0.131
discretion	tel	-0.472	0.888	-0.006	0.212	-0.142	0.754	0.026	0.228
market	air	-0.355	0.772	-0.029	0.23	-0.264	0.877	0.461	0.006
market	rail	-0.023	0.571	0.064	0.209	0.175	0.195	0.447	0.219
market	ene	0.424	0.343	0.006	0.142	-0.028	0.57	0.691	0.83
market	tel	0.555	0.421	0.042	0.127	0.164	0.116	0.42	0.16
transparency	air	-0.422	0.538	0.239	0.254	0.854	0.000	0.203	0.096
transparency	rail	-0.26	0.485	0.29	0.269	1.021	0.000	0.527	0.423
transparency	ene	0.089	0.545	0.249	0.311	0.929	0.001	0.39	1
transparency	tel	0.379	0.675	0.198	0.236	0.786	0.000	0.761	0.367

B.1.2 Summary statistics graphs

Figure B.4: TA Score box plots by sector - scaled scores

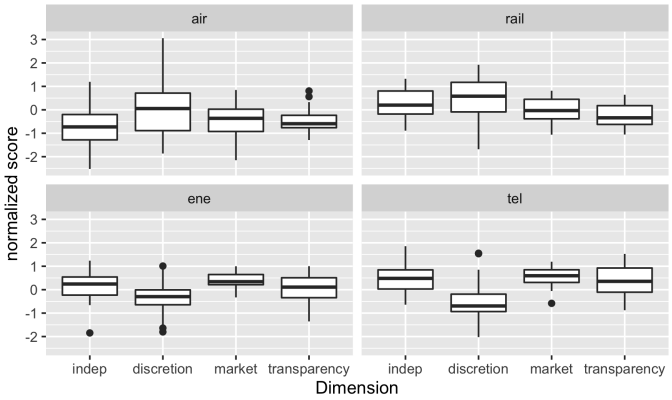


Figure B.5: Dimension national averages

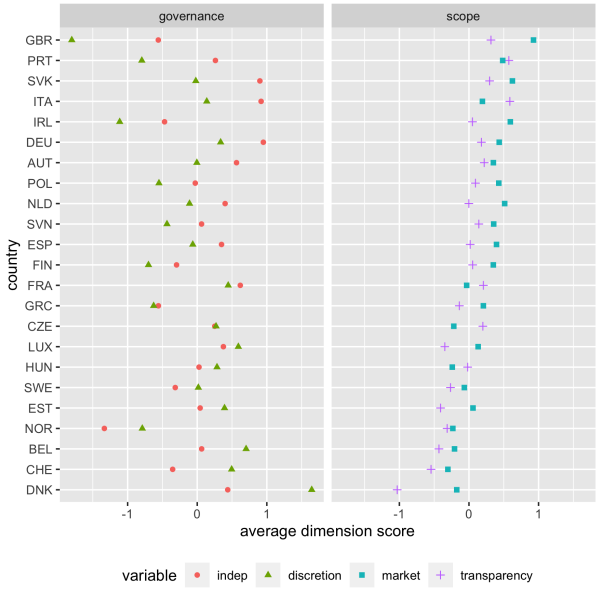
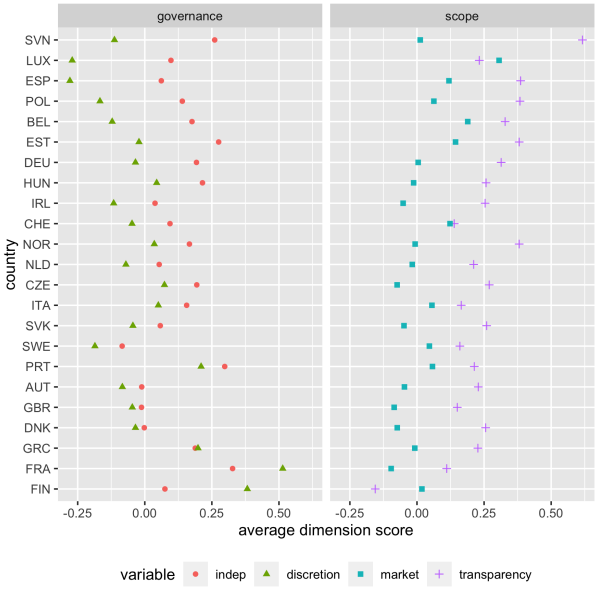


Figure B.6: Dimension National Evolution Scores



B.1.3 Semantic Networks

Figure B.7: Semantic Network: Independence from the government

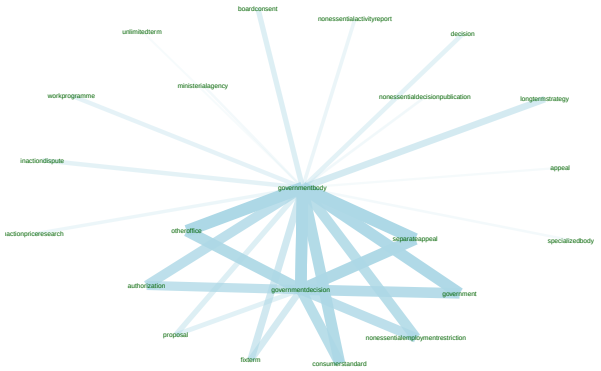


Figure B.8: Semantic Network: Discretion

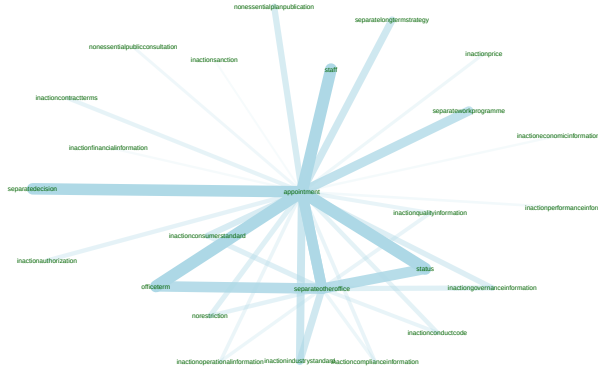


Figure B.9: Semantic Network: Transparency

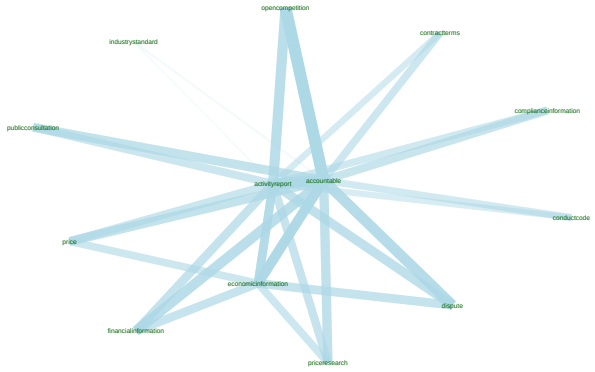
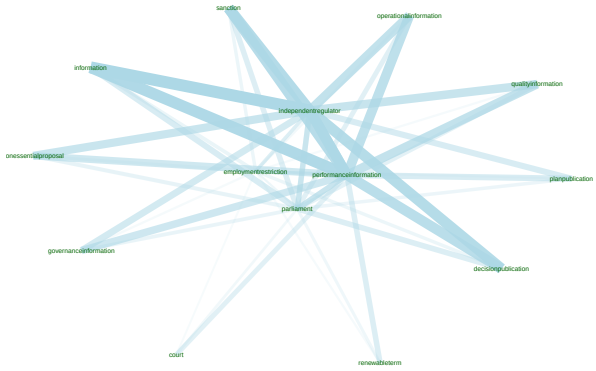


Figure B.10: Semantic Network: Scope of market monitoring



B.2 Regression Tables

B.2.1 Energy

Table B.8: Energy regression OLS estimates for Governance *mean* variables

var	gas	solarsur	renewprod	price_ind	hydroprod	exportelec	renewprod.1	elecprod	gas.1
indep_mean						191.5131	620.4069	922.632	-680.373
						(69.41025)	(181.8705)	(364.3199)	(217.7151)
discretion_mean	-528.4476	412.9042	409.1687	21.96157	-2928.95				
	(166.0969)	(174.7952)	(164.9765)	(9.899704)	(1289.467)				
captotcap	-0.07661	0.052396	0.082084	-0.004596	1.230435	0.032437	0.101413	0.056891	-0.065625
	(0.111708)	(0.053397)	(0.060419)	(0.002313)	(0.258757)	(0.018991)	(0.058522)	(0.054929)	(0.115315)
dis_equ	337.4918	-64.32178	223.1411	-26.91209	-7.379974	-45.46125	242.5701	-293.1488	304.5241
	(170.1391)	(113.0668)	(134.4615)	(8.198546)	(896.663)	(49.40928)	(132.5203)	(126.3413)	(163.9183)
ele_ind	18.11337	-1.246861	-2.733485		-4.599501	-3.005614	-4.147501	-17.23339	20.11745
	(5.734556)	(4.547674)	(1.978511)		(20.61011)	(1.700268)	(2.023774)	(5.185602)	(6.537703)
pmr_elec	2051.933	330.002	777.8526	100.4971	-5067.06	-853.6547	283.6566	-492.3604	2923.057
	(2033.979)	(1710.792)	(1106.97)	(62.44803)	(7031.376)	(426.3)	(1134.199)	(972.2684)	(2098.675)
nygdppcapkdzg	-1441.544	321.6297	361.8704	22.63531	-9073.06	-49.68165	72.37978	228.2639	-1071.611
	(705.3101)	(338.2226)	(242.2195)	(34.05805)	(2292.533)	(130.784)	(240.5352)	(379.5197)	(803.2321)
gctaxtotlgdzs	144.576	79.05196	682.0099	-49.95163	-11246.93	-293.5387	443.4676	-1138.004	286.8014
	(890.8261)	(1113.842)	(480.7065)	(39.6725)	(4021.883)	(189.6416)	(510.2935)	(683.8995)	(868.9075)
rgdpe_penn	0.006549	0.000672	0.002696	0.000359	-0.052893	0.000127	0.001417	0.012422	0.007416
	(0.003863)	(0.002096)	(0.002728)	(0.000102)	(0.011869)	(0.000925)	(0.002527)	(0.003035)	(0.003789)
N	18	18	19	22	22	22	22	22	N
r2	0.9011	0.9074	0.72	0.9142	0.7258	0.7622	0.7409	0.9672	r2

System variables: *elecprod* total electricity production in GWh, *exportelec* electricity exports in GWh.**Renewable:** *renewprod* production of electricity based in renewable sources in GWh (EUROSTAT classification), **CO2:** *gas* production of electricity based on gas in kilogram of oil equivalent (ktoe, 11.63 MWh). **Controls:** *captotcap* total system generation capacity in MWe, *dis_equ* absolute value of country latitude, *ele_ind* industrial consumer electricity price, *nygdppcapkdzg* GDP per capita growth rate, *gctaxtotlgdzs* tax revenue percentage in national budget, *pmr_elec* market regulation score (OECD, higher scores represent lower barriers to competition), *rgdpe_penn* GDP in constant USD. Summary statistics of each variables are found in Table B.24 Heteroskedasticity − robust standard errors in parenthesis.

Table B.9: Energy regression OLS estimates for Governance *growth* variables

var	price_hou	consPC	perenew	totcomb	pcgen	imports	windconv	solcap	intcomb
indep_growth					7.130443	8.018553	0.000831	-0.00067	0.269436
					(2.411024)	(2.673139)	(0.00026)	(0.000288)	(0.077964)
discretion_growth	3.718279	1.520725	-0.008709	6.883739					
	(0.976294)	(0.647922)	(0.002809)	(2.746245)					
capdif					0.004248	-0.001411	-1e-06	-2e-06	0.000371
					(0.003621)	(0.002409)	(1e-06)	(1e-06)	(0.001185)
captotcap	-0.000286	0.00152	-7e-06	0.005687					
	(0.005624)	(0.001769)	(8e-06)	(0.007032)					
dis_equ	-4.618439	5.383244	0.087133	-33.82603	24.58809	35.19547	0.001568	0.001152	0.323042
	(9.413106)	(6.079257)	(0.019567)	(13.29462)	(16.93258)	(13.9286)	(0.000943)	(0.001595)	(0.570591)
ele_ind	0.148011	0.13747	0.000895	-0.97201	0.583248	0.477248	-1.6e-05	-2.5e-05	0.018495
	(0.39515)	(0.185045)	(0.000451)	(0.337636)	(0.287746)	(0.209607)	(2.8e-05)	(4.7e-05)	(0.010382)
gdp	-0.306202	-12.45458	0.20402	-51.07284	-17.54792	-3.785293	-0.000146	0.002128	0.328989
	(25.64099)	(9.929145)	(0.04409)	(30.86446)	(6.121536)	(3.767324)	(0.000933)	(0.001024)	(0.469727)
pmr_elec	-34.76091	114.5131	0.569337	-168.3827	185.8199	109.1629	0.012576	-0.000223	-4.446918
	(100.7404)	(41.27312)	(0.121069)	(101.7721)	(85.28114)	(75.40224)	(0.008258)	(0.013385)	(6.003392)
nygdppcapkdzg	-55.17571	104.4289	0.01078	75.46355	144.4187	9.466684	-0.008432	-0.001622	0.408187
	(38.27071)	(23.39653)	(0.06734)	(48.77213)	(37.87256)	(13.57049)	(0.002804)	(0.00552)	(1.105121)
gctaxtotlgdzs	-37.12663	138.9555	0.295768	-4.769603	226.8207	81.88775	-0.011745	-0.012221	-0.666864
	(46.20404)	(35.90542)	(0.122555)	(59.46887)	(64.38649)	(43.54897)	(0.00439)	(0.010754)	(1.646644)
N	22	20	20	20	20	22	20	20	19
r2	0.2987	0.7951	0.9786	0.748	0.7442	0.6089	0.6718	0.5397	0.416

System variables: *pcgen* per capita electricity production in GWh, *imports* electricity imports in GWh, *price_ind* electricity price for industrial consumers in USD per GWh. **Renewable:** *solcap* solar electricity capacity in MWe, *windconv* electricity produced using wind sources divided by the total wind capacity, *hydro* electricity capacity based in hydropower. **CO2:** *intcomb* and *othcomb* electricity capacity based in internal combustion machines in MWe. **Controls:** $capdif$ period difference generation capacity in MWe, *dis_equ* absolute value of country latitude, *ele_ind* industrial consumer electricity price, *nygdppcapkdzg* GDP per capita growth rate, *gctaxtotlgdzs* tax revenue percentage in national budget, *pmr_elec* market regulation score (OECD, higher scores represent lower barriers to competition), *gdp* GDP in constant USD. Summary statistics of each variables are found in Table B.24 Heteroskedasticity − robust standard errors in parenthesis.

Table B.10: Energy regression OLS estimates for Scope *mean* variables

var	elecprod	natgassh	CO2sh	windgrate	windcap	newcapy	exportelec	totcap
market_mean	1054.805	7.694201	1.017747	0.029856	-130.0688	-272.5763	-414.1456	-453.1903
	(358.0604)	(3.104294)	(0.40576)	(0.012762)	(48.01594)	(108.2541)	(136.8174)	(185.148)
captotcap	0.196928	0.000142	0.000191	2e-06	-0.011746	-0.057327	0.01311	0.768542
	(0.043353)	(0.000348)	(5.4e-05)	(1e-06)	(0.006999)	(0.015137)	(0.01884)	(0.026038)
dis_equ	-97.05054	-2.356329	-0.097498	0.004045	19.59289	49.68168	-38.89753	100.0352
	(92.28043)	(0.925007)	(0.083413)	(0.003117)	(12.41234)	(31.32502)	(47.28245)	(49.81055)
ele_ind	2.904208	-0.003732	0.003467	-7.8e-05	-0.034723	-0.701017	-1.97456	-0.30613
	(1.755173)	(0.02555)	(0.001965)	(7.2e-05)	(0.621884)	(1.063686)	(1.110284)	(2.535911)
pmr_elec	-307.0361	2.121805	-0.415076	-0.012503	37.03241	489.2404	-556.5202	1160.493
	(628.1997)	(4.996507)	(0.714418)	(0.027066)	(143.9944)	(420.9482)	(355.4948)	(477.9121)
nygdppcapkdzg	-102.0134	-0.874849	-0.0918	-0.026374	17.10778	40.00167	43.9396	-187.3175
	(187.8727)	(3.503073)	(0.24485)	(0.008565)	(58.70098)	(129.8939)	(122.4144)	(236.9213)
gctaxtotlgdzs	262.8523	-11.38329	0.369352	-0.041627	27.57048	227.7059	-31.16829	453.5245
	(275.8318)	(5.540935)	(0.43415)	(0.017378)	(109.3227)	(258.1851)	(166.0583)	(298.4733)
rgdpe_penn	-0.007233	-1e-06	-7e-06	0	0.001229	0.004366	0.000964	0.014516
	(0.001967)	(1.9e-05)	(2e-06)	(0)	(0.000377)	(0.000794)	(0.000969)	(0.001435)
N	22	20	20	20	20	20	22	20
r2	0.8782	0.6368	0.88	0.686	0.8554	0.8856	0.7992	0.9995

System dependent variables: *totcap* total system capacity in MWe, *elecprod* total production in GWh, *newcapy* yearly growth rate of new deployed system capacity in percentage, *exportelec* electricity exports in GWh, *price_ind* electricity price for industrial consumers in USD per GWh. **Renewable sources:** *renewprod* production of electricity based in renewables and biofuels in GWh, *solarsur* solar panels surface in m^2, *hydroprod* electricity production based in hydroelectric plants in GWh, *windgrate* yearly growth rate of new system deployed wind capacity in percentage, *windcap* wind electricity capacity in MWe. **CO2 sources:** *gas* gas-based electricity produced in kilogram of oil equivalent (ktoe, 11.63 MWh), *natgassh* share of natural gas in electricity output in percentage, *CO2sh* CO2 technology electricity production in GWh. **Controls:** *captotcap* total system generation capacity in MWe, *dis_equ* absolute value of country latitude, *ele_ind* industrial consumer electricity price, *nygdppcapkdzg* GDP per capita growth rate, *gctaxtotlgdzs* tax revenue percentage in national budget, *pmr_elec* market regulation score (OECD, higher scores represent lower barriers to competition), *rgdpe_penn* GDP in constant USD. Summary statistics of each variables are found in Table B.24. Heteroskedasticity − robust standard errors in parenthesis.

Table B.11: Energy regression OLS estimates for Scope *growth* variables

var	solarpv	othcomb	price_ind
market_growth	38.3938	11.93457	
	(16.33782)	(4.418271)	
transparency_growth			-2.996146
			(1.212834)
capdif			-0.00015
			(0.00472)
captotcap	-0.10611	-0.030174	
	(0.015541)	(0.004067)	
dis_equ	80.07472	26.31493	0.469309
	(36.71269)	(8.102074)	(5.944399)
ele_ind	0.302847	-0.012361	
	(1.157639)	(0.253171)	
gdp	663.9564	165.9719	9.780258
	(84.96778)	(17.36037)	(3.931562)
pmr_elec	338.5195	225.4796	-63.47445
	(182.0332)	(74.1332)	(61.41701)
nygdppcapkdzg	-92.01582	-27.57465	-2.92636
	(98.06669)	(33.23933)	(14.62252)
gctaxtotlgdzs	163.1922	21.35686	13.29657
	(123.4109)	(37.58155)	(28.62713)
N	21	18	18
r2	0.9404	0.8404	0.9361

System dependent variables: $consPC$ electricity consumption per capita in GWh, $price_hou$ electricity price for household consumers in USD per GWh. **Renewable sources:** *solarpv* solar photovoltaic electricity capacity, *perrenew* yearly growth rate of new system deployed renewable capacity in percentage. **CO2 sources:** *totomb* and *othcomb* electricity capacity based in all internal combustion technologies in MWe. **Controls:** *captotcap* total system generation capacity in MWe, *dis_equ* absolute value of country latitude, *ele_ind* industrial consumer electricity price, *nygdppcapkdzg* GDP per capita growth rate, *gctaxtotlgdzs* tax revenue percentage in national budget, *pmr_elec* market regulation score (OECD, higher scores represent lower barriers to competition), *rgdpe_penn* GDP in constant USD. Summary statistics of each variables are found in Table B.24 Heteroskedasticity − robust standard errors in parenthesis.

B.2.2 E-communication

Table B.12: E-communication regression OLS estimates for scope *growth* dimensions

var	pcprice	penrate	accpath	cabsubs	totsubs
transparency_growth	0.008476	0.175436	0.221049	0.044571	0.287369
	(0.003154)	(0.074681)	(0.100345)	(0.017051)	(0.08944)
fix_broad_100	-0.024578				
	(0.019311)				
gdp	-0.022185	0.53558	-0.220101	0.127651	0.289701
	(0.035079)	(0.3565)	(0.477189)	(0.037534)	(0.465064)
pmr	-0.004105	-11.80108	0.464027	0.24355	-11.14732
	(0.218928)	(6.079729)	(2.768864)	(0.346336)	(5.249404)
npopdnst	-0.000433	0.000546	-0.014754	-0.002242	-0.016589
	(0.000643)	(0.024869)	(0.015852)	(0.002902)	(0.022703)
fix_bprice			-0.554055	-0.091416	-0.699121
			(0.384395)	(0.047985)	(0.378433)
mob_bprice		-0.136276			
		(0.12969)			
nights	0.002688	-0.058973	0.035974	-0.008181	-0.038704
	(0.002528)	(0.020507)	(0.03552)	(0.002629)	(0.035068)
nygdppcapkdzg		-0.188892			
		(1.226448)			
spurbtotlinzs	-0.047828	1.12518	4.16893	0.172853	1.290843
	(0.104202)	(2.153122)	(2.009066)	(0.353986)	(2.375703)
rule_wb	0.372966	-9.539293	-0.946497	0.055453	-6.355056
	(0.266377)	(4.661781)	(3.208414)	(0.592442)	(3.741083)
N	19	20	20	20	19
r2	0.3934	0.5381	0.5776	0.6241	0.6876

Capacity dependent variables: *mobsubs* number of subscribers to mobile broadband services. **Quality:** *bbsubs*100 number of subscribers to fixed broadband internet service per 100 habitants, *mobpenrate* penetration rate for mobile services. **Prices:** *pprice* price for 5gb fixed internet bundle in PPP USD. **Controls:** *rule_wb* rule of law index from the World Bank, *pmr* telecom market regulation score from OECD (higher values show higher support for market competition). *rgdpe_penn* GDP in PPP USD, *npopdnst* population density, *spurbtotlinzs* percentage of population living in urban areas, *nights* number of hotel nights spent by tourists in a given country, fix_bprice average price for fixed and mobile broadband services in PPP USD. Summary statistics of each variables are found in Table B.25. Heteroskedasticity − robust standard errors in parenthesis.

Table B.13: E-communication regression OLS estimates for scope *mean* dimensions

var	fix100low	fixtot	mobterm	accpathtot	fixprate	fixtotal	fix100	prixfix	prixmob
market_mean	0.845317	-56658.72	-0.217578						
	(0.331209)	(24382.35)	(0.090024)						
transparency_mean				1302041	-1.293476	-1.320625	-1.337509	-1.721405	-2.015619
				(464440.6)	(0.255003)	(0.243481)	(0.263749)	(0.621008)	(0.710632)
fix_broad_100								-1.07599	-0.670534
								(0.366758)	(0.592341)
pmr	2.328794	-231727.4	0.345476	-3504518	2.992274	3.00351	3.124162	4.806679	-0.456085
	(1.213525)	(138776.3)	(0.216179)	(2610092)	(2.065594)	(2.002638)	(2.592419)	(1.703813)	(2.351073)
npopdnst	-0.004195	-412.0885	0.002592	12217.94	0.000876	-0.000996	-0.001267	-0.00414	-0.021189
	(0.005332)	(444.5797)	(0.000746)	(10821.24)	(0.006642)	(0.006559)	(0.007267)	(0.008493)	(0.017177)
fix_bprice	-0.181236	4704.125		64550.64	-0.20164	-0.211048	-0.172223		
	(0.132058)	(9589.399)		(264638.7)	(0.15141)	(0.146502)	(0.223292)		
mob_bb_penrate			0.004687						
			(0.006397)						
nights	0.015546	-621.0986	-0.00148	29286.57	0.010496	0.010965	0.008962	-0.040403	-0.109382
	(0.018145)	(980.7844)	(0.002406)	(33339.54)	(0.014924)	(0.014754)	(0.019564)	(0.028334)	(0.033819)
nygdppcapkdzg			0.136858						
			(0.063171)						
spurbtotlinzs	-1.475392	-111005	-0.089569	-241128.4	2.491411	2.802557	3.24595	6.171125	2.153008
	(0.805647)	(79866.89)	(0.118724)	(1265760)	(0.780003)	(0.720634)	(1.229441)	(1.367849)	(3.680011)
rgdpe_penn	-2e-06	0.112326	0	43.91722	1e-06	1e-06	1e-06	9e-06	1.9e-05
	(3e-06)	(0.11486)	(0)	(5.024587)	(2e-06)	(2e-06)	(3e-06)	(4e-06)	(5e-06)
rule_wb	1.667939	-314249.9	-0.082948	-4965209	3.321087	2.976541	1.784598	-1.108354	-4.995374
	(1.373395)	(132993.5)	(0.28375)	(3078189)	(1.495009)	(1.505223)	(1.682501)	(3.111963)	(2.468287)
N	20	19	20	21	21	21	20	20	20
r2	0.6017	0.5494	0.7187	0.9912	0.8477	0.8487	0.8125	0.6059	0.6518

Capacity dependent variables: $fixtot$ number of subscribers to fixed broadband internet service, $server$ number of internet servers available in a country, $accpath$ number of access paths for telecom services. **Quality:** $fixprate$ penetration rate for fixed broadband internet services, $fix100$ number of subscribers to fixed broadband internet service per 100 habitants, $fix100low$ number of subscribers to low-speed fixed broadband internet service per 100 habitants. **Prices:** $prixfix$ price for 5gb fixed internet bundle in PPP USD, $prixmob$ price for 5gb mobile internet bundle in PPP USD, $mobterm$ price of termination rates in another network in USD. **Controls:** $rule\_wb$ rule of law index from the World Bank, pmr telecom market regulation score from OECD (higher values show higher support for market competition). $rgdpe\_penn$ GDP in PPP USD, $npopdnst$ population density, $spurbtotlinzs$ percentage of population living in urban areas, $nights$ number of hotel nights spent by tourists in a given country, fix_bprice average price for fixed and mobile broadband services in PPP USD. Summary statistics of each variables are found in Table B.25. Heteroskedasticity − robust standard errors in parenthesis.

Table B.14: E-communication regression OLS estimates for governance *mean* dimensions

var	server	fixprate	prixmob	prixfix	fix100	accpath	telVoIP	prixfixbb	landli
indep_mean							1227790	0.042146	-851839.6
							(532485.3)	(0.015492)	(358780.9)
discretion_mean	1032.236	0.770641	0.73183	0.024248	-0.663838	-835946.7			
	(412.3172)	(0.230808)	(0.311497)	(0.008635)	(0.297508)	(319045)			
fix_broad_100			0.023956	-0.023855				-0.008269	
			(0.359059)	(0.013966)				(0.009952)	
pmr	-7893.629	0.287964	-0.996348	-0.023251	-1.764443	-637660.6	-620053.9	-0.077502	-664689.1
	(4083.536)	(1.960541)	(1.903697)	(0.087635)	(2.659266)	(2852977)	(1276125)	(0.09696)	(2254060)
npopdnst	29.19601	0.004672	0.011056	-0.000403	-0.019495	9014.28	-4290.117	-0.000348	7121.56
	(21.78903)	(0.009484)	(0.009799)	(0.000381)	(0.008001)	(10215.62)	(6122.6)	(0.000321)	(8359.55)
fix_bprice	404.7259	0.161626			-0.711761	-319615.6	278877.6		25179.19
	(224.4883)	(0.147108)			(0.234432)	(274799.6)	(190955.4)		(152114.1)
nights	-59.03848	-0.015859	-0.041692	-0.003865	0.054205	57612.44	-33484.38	-0.004104	40210.66
	(24.14568)	(0.015628)	(0.031449)	(0.001093)	(0.022912)	(36831.39)	(14725.75)	(0.001048)	(19012.57)
spurbtotlinzs	458.6984	2.029297	0.961974	0.223054	-3.864636	205611.5	729767.3	0.1613	142210.9
	(2291.74)	(1.211452)	(1.600968)	(0.059884)	(0.93349)	(1632289)	(559750.7)	(0.047281)	(873204.9)
rgdpe_penn	0.00524	3e-06	5e-06	1e-06	-9e-06	41.05072	10.61219	0	1.167534
	(0.004012)	(2e-06)	(4e-06)	(0)	(3e-06)	(5.704789)	(1.779096)	(0)	(3.934059)
rule_wb	8410.973	5.702149	-3.545942	-0.430276	9.907512	-7276818	3914841	-0.369936	-2754472
	(2540.235)	(1.99965)	(3.829511)	(0.125517)	(2.300331)	(2738688)	(2030179)	(0.119118)	(1365662)
N	21	21	20	20	21	21	19	20	21
r2	0.707	0.7932	0.5359	0.8148	0.8282	0.9909	0.9317	0.8435	0.8299

Capacity dependent variables: $telVoIP$ number of subscribers of VoIP services, $landli$ number of landline subscribers, $accpathtot$ number of access paths for telecom services. **Quality:** $fixprate$ penetration rate for fixed broadband internet services, $fix100$ and $fixitu100$ number of subscribers to fixed broadband internet service per 100 habitants. **Prices:** $prixfix$ and $prixfixbb$ price for 5gb fixed internet bundle in PPP USD, $prixmob$ price for 5gb mobile internet bundle in PPP USD. **Controls:** $rule\_wb$ rule of law index from the World Bank, pmr telecom market regulation score from OECD (higher values show higher support for market competition). $rgdpe\_penn$ GDP in PPP USD, $npopdnst$ population density, $spurbtotlinzs$ percentage of population living in urban areas, $nights$ number of hotel nights spent by tourists in a given country, fix_bprice average price for fixed and mobile broadband services in PPP USD. Summary statistics of each variables are found in Table B.25. Heteroskedasticity − robust standard errors in parenthesis.

Table B.15: E-communication regression OLS estimates for governance *growth* dimensions

var	ppprice	mobpenrate	mobsubs	bbsubs100	ppprice.1	voipsubs	cabsubs
indep_growth					-0.149343	41.86174	0.02741
					(0.06657)	(16.18913)	(0.011902)
discretion_growth	-0.44641	0.331822	81.58199	0.408568			
	(0.124691)	(0.133698)	(31.20843)	(0.138559)			
fix_broad_100	-0.472402				-0.428646		
	(0.448526)				(0.663264)		
gdp	0.433275	-1.347462	344.5446	-1.692517	-0.122876	499.8525	0.060193
	(0.597726)	(0.610543)	(249.8055)	(0.77083)	(0.951962)	(75.09492)	(0.046835)
pmr	-2.73734	-4.309135	4326.147	-5.638853	2.160783	446.1506	0.03486
	(5.318986)	(6.278435)	(1856.861)	(7.497756)	(6.39717)	(422.0932)	(0.669656)
npopdnst	-0.015612	0.027893	5.221454	0.045838	0.022452	4.266321	-0.001932
	(0.019556)	(0.024842)	(6.901828)	(0.025592)	(0.014592)	(2.309611)	(0.002571)
fix_bprice						15.68655	-0.120851
						(46.3468)	(0.050404)
mob_bprice		-0.013203	93.64867	0.121931			
		(0.147861)	(42.76748)	(0.165334)			
nights	0.005145	0.0751	15.40989	0.096938	0.022099	-18.2502	-0.001617
	(0.035421)	(0.03262)	(13.16374)	(0.040716)	(0.067622)	(5.394723)	(0.004393)
nygdppcapkdzg		2.089168	731.2595	2.072755			
		(0.995649)	(194.1195)	(1.457811)			
spurbtotlinzs	2.282722	-9.502063	187.6668	-8.134859	-1.143994	-132.9306	0.187391
	(3.305546)	(2.890715)	(1174.543)	(3.456588)	(3.215978)	(315.4793)	(0.275598)
rule_wb	5.509252	15.45004	5500.934	21.99715	8.042235	-211.549	0.111145
	(3.395972)	(7.742872)	(1093.597)	(8.312667)	(5.791605)	(512.1559)	(0.684223)
N	19	20	20	20	17	19	N
r2	0.5137	0.4689	0.7927	0.5064	0.957	0.4915	r2

Capacity dependent variables: *voipsubs* number of subscribers of VoIP services, *landli* number of landline subscribers, *accpath* number of access paths for telecom services. **Quality:** *totsubs* number of subscribers to fixed broadband internet service per 100 habitants, *cabsubs* and *cabsubs*.1 number of cable internet subscribers per 100 habitants, *mobpenrate* penetration rate for mobile services, *accpath* telecom access paths per 100 habitants. **Prices:** *pprice* price for 5gb fixed internet bundle in PPP USD, *pcprice* price for 5gb fixed internet bundle as percentage of per capita income. **Controls:** *rule_wb* rule of law index from the World Bank, *pmr* telecom market regulation score from OECD (higher values show higher support for market competition). *rgdpe_penn* GDP in PPP USD, *npopdnst* population density, *spurbtotlinzs* percentage of population living in urban areas, *nights* number of hotel nights spent by tourists in a given country, fix_bprice average price for fixed and mobile broadband services in PPP USD. Summary statistics of each variables are found in Table B.25. Heteroskedasticity − robust standard errors in parenthesis.

B.2.3 Rail Transport

Table B.16: Rail Transport regression OLS estimates for governance *mean* dimension

var	fallback	passinjurtot	allaccidkm	activecross	injurpasskm
indep_mean				0.011793	1.08445
				(0.003824)	(0.216034)
discretion_mean	48825.09	0.592615	-0.050583		
	(19431.51)	(0.242838)	(0.021707)		
pmr	-66672	-1.309245	-0.018754	-0.030305	-2.940149
	(148101.9)	(1.517681)	(0.154142)	(0.027476)	(1.084991)
nygdppcapkdzg	-539814.5	-0.935285	0.162279	-0.054874	-1.687914
	(174325.6)	(1.628982)	(0.257176)	(0.025586)	(0.915558)
mean_rai_35	5.589703	0.000167	2e-05	6e-06	0.000359
	(30.46726)	(0.000353)	(3.9e-05)	(7e-06)	(0.000221)
rgdpe_penn	-0.112622	2e-06	0	0	-2e-06
	(0.36135)	(4e-06)	(0)	(0)	(2e-06)
rule_wb	908176.5	-2.96204	-0.525559	-0.039008	-3.21056
	(161267.6)	(1.181995)	(0.225068)	(0.04323)	(1.401852)
wage_d302a9_st	21.54706	0.000274	-1.3e-05	1.3e-05	0.000474
	(23.58796)	(0.000122)	(3.7e-05)	(2e-06)	(0.000103)
N	17	17	17	17	17
r2	0.858	0.7202	0.6552	0.6736	0.8337

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes absolute system variables (e.g., length of rail tracks), *quality* describes safety measures (absolute or relative) (e.g., number of rail incidents by km of track). **Quality dependent variables:** *activecross* number of automatic devices to handle crossings in tracks, *injurpasskm* number of incidents that ended in passenger injury per track km. **Controls:** *pmr* market regulation score (OECD), *rgdpe_penn* GDP in PPP USD, *mean_rai_35* total system rail track length. Summary statistics of each variables are found in Table B.26. Heteroskedasticity − robust standard errors in parentheses.

Table B.17: Rail Transport regression OLS estimates for governance *growth* dimension

var	activeleverkm	goodskm	accunpeop	derail	activecrosskm
indep_growth			-0.001022	0.028111	0.000887
			(0.000348)	(0.011596)	(0.000256)
discretion_growth	-0.000447	-0.064901			
	(0.000193)	(0.026216)			
dis_equ	0.001417	-0.059316			
	(0.000697)	(0.072476)			
gdp	0.002868	-0.063107	0.003378	0.142767	-0.003483
	(0.00319)	(0.106653)	(0.002896)	(0.07142)	(0.001876)
pmr	9.6e-05	-0.393697	0.003464	0.041635	-0.007797
	(0.008545)	(0.514458)	(0.008556)	(0.271844)	(0.005586)
nygdppcapkdzg			-0.025894	-0.490054	-0.013854
			(0.02175)	(0.402229)	(0.008646)
mean_rai_35	-4e-06	-1.2e-05	-4e-06	-0.000309	4e-06
	(4e-06)	(9e-05)	(3e-06)	(6.6e-05)	(2e-06)
ravar_mean_i14	-0.017249	0.632937			
	(0.003849)	(0.359531)			
rule_wb			-0.022118	-0.849578	-0.018733
			(0.028049)	(0.311254)	(0.012834)
valk_d49t53_st	0	0	0	4e-06	0
	(0)	(1e-06)	(0)	(1e-06)	(0)
N	19	19	19	19	18
r2	0.5966	0.576	0.6099	0.8942	0.6974

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes absolute system variables (e.g., length of rail tracks), *quality* describes safety measures (absolute or relative) (e.g., number of rail incidents by km of track). **Quality dependent variables:** *accunpeop* number of incidents that ended in the injure of unathorized persons in rails, *activecrosskm* number of automatic devices to handle crossings in tracks per track km, *accicross* number of incidents in road crossings, *accidempl* number of incidents that end in injure of rail employees. **Controls:** *pmr* market regulation score (OECD), *rgdpe_penn* GDP in PPP USD, *mean_rai_35* total system rail track length. Summary statistics of each variables are found in Table B.26. Heteroskedasticity − robust standard errors in parentheses.

Table B.18: Rail Transport regression OLS estimates for scope *mean* dimensions

var	goodskm	tracklen	accicross	accidempl
market_growth	0.066559	55.28378		
	(0.02001)	(19.74639)		
transparency_growth			-0.102378	-0.084804
			(0.045412)	(0.025749)
dis_equ	-0.139743	-123.63		
	(0.067132)	(45.8665)		
gdp	-0.042071	-364.6775	0.41409	0.284582
	(0.091444)	(117.7816)	(0.311852)	(0.164491)
pmr	-0.726052	-1354.248	-0.259799	0.014267
	(0.526271)	(354.4423)	(0.873714)	(0.506825)
nygdppcapkdzg	0.289878	674.0361	0.185388	2.061711
	(0.38828)	(497.7444)	(1.236131)	(0.755293)
mean_rai_35	-7.2e-05	0.346434	-0.000469	-0.000404
	(0.000103)	(0.115206)	(0.000373)	(0.000183)
ravar_mean_c25			1.2e-05	8e-06
			(1.6e-05)	(8e-06)
rule_wb				
valk_d49t53_st	0	-0.004157	-2e-06	-1e-06
	(1e-06)	(0.000939)	(2e-06)	(1e-06)
N	19	19	19	19
r2	0.6546	0.791	0.544	0.7586

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes absolute system variables (e.g., length of rail tracks), *quality* describes safety measures (absolute or relative) (e.g., number of rail incidents by km of track). **Capacity dependent variables:** $freight$ volume of goods transported by rail system in metric tons. **Quality:** *delaymin* minutes of delay product of rail incidents, *injurpasskm* number of incidents that end in passenger injury per track km, *econimpact* economic impact in USD of rail incidents, $fallback$ signals made in case of ATP communication failure, *passinjurtot* number of incidents that end in passenger injury, *allaccidkm* total number of incidents in the rail system per track km. **Controls:** *pmr* market regulation score (OECD), *rgdpe_penn* GDP in PPP USD, *mean_rai_35* total system rail track length. Summary statistics of each variables are found in Table B.26. Heteroskedasticity − robust standard errors in parentheses.

Table B.19: Rail Transport regression OLS estimates for scope *growth* dimensions

var	goodskm	tracklen	accicross	accidempl
market_growth	0.066559	55.28378		
	(0.02001)	(19.74639)		
transparency_growth			-0.102378	-0.084804
			(0.045412)	(0.025749)
dis_equ	-0.139743	-123.63		
	(0.067132)	(45.8665)		
gdp	-0.042071	-364.6775	0.41409	0.284582
	(0.091444)	(117.7816)	(0.311852)	(0.164491)
pmr	-0.726052	-1354.248	-0.259799	0.014267
	(0.526271)	(354.4423)	(0.873714)	(0.506825)
nygdppcapkdzg	0.289878	674.0361	0.185388	2.061711
	(0.38828)	(497.7444)	(1.236131)	(0.755293)
mean_rai_35	-7.2e-05	0.346434	-0.000469	-0.000404
	(0.000103)	(0.115206)	(0.000373)	(0.000183)
ravar_mean_c25			1.2e-05	8e-06
			(1.6e-05)	(8e-06)
rule_wb				
valk_d49t53_st	0	-0.004157	-2e-06	-1e-06
	(1e-06)	(0.000939)	(2e-06)	(1e-06)
N	19	19	19	19
r2	0.6546	0.791	0.544	0.7586

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes absolute system variables (e.g., length of rail tracks), *quality* describes safety measures (absolute or relative) (e.g., number of rail incidents by km of track). **Capacity dependent variables:** *goodskm* and *goodskm.1* volume of goods transported by rail system in metric tons per km, *tracklen* rail system track length in km. **Quality:** *activeleverkm* number of automatic devices to handle crossings in tracks per km. **Controls:** *pmr* market regulation score (OECD), *rgdpe_penn* GDP in PPP USD, *mean_rai_35* total system rail track length. Summary statistics of each variables are found in Table B.26. Heteroskedasticity − robust standard errors in parentheses.

B.2.4 Air Transport

Table B.20: Air regression OLS estimates for governance *mean* dimension

var	operincid	operincid.1	aipmain	airptot
indep_mean		-1.160263	-0.719815	-1.703685
		(0.39057)	(0.290233)	(0.691937)
discretion_mean	-0.927337			
	(0.224943)			
pmr	-12.54804	-8.012944	3.898383	9.385553
	(3.71466)	(2.774684)	(2.188433)	(5.327671)
airflights	1.4e-05	2e-06	-3e-06	-7e-06
	(6e-06)	(6e-06)	(6e-06)	(1.5e-05)
nygdppcapkdzg	12.98137	9.727678	-6.687607	-14.96657
	(4.072082)	(3.779362)	(2.53163)	(6.386715)
nights	-0.149415	-0.119082	0.08473	0.122043
	(0.040911)	(0.035958)	(0.018542)	(0.051814)
rgdpe_penn	1.8e-05	2.6e-05	1e-06	0
	(5e-06)	(6e-06)	(6e-06)	(1.3e-05)
valk_d51_st	-0.002007	-0.001673	0.000573	0.001374
	(0.000472)	(0.000466)	(0.000308)	(0.000762)
N	15	15	15	N
r2	0.8777	0.9297	0.844	r2

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes system variables (e.g., number of operating airports, number of arrivals), *quality* describes safety measures (absolute or relative) (e.g., number of air incidents). **Capacity dependent variables:** *aipmain* number of large commercial airports operating in a country, *airptot* number of total airports operating in a country. **Quality:** *operincid* number of incidents related to airline operations.**Controls:** *pmr*: product market regulation in air sector, $airflights$ average number of aircrafts in a country airspace (measure of traffic), *nygdppcapkdzg* GDP per capita growth rate, *nights* number of hotel nights spent by tourists in a given country, $rgdpe_penn$ country GDP in constant USD, $valk_d51_st$ air sector national accounts added value in constant USD. For additional control information refer to Table B.27. Heteroskedasticity – robust standard errors in parentheses.

Table B.21: Air regression OLS estimates for governance *growth* dimension

var	totdisrup	numairpo
indep_growth		-0.169532
		(0.026562)
discretion_growth	3908.336	
	(821.3871)	
gdp	19650.03	0.138654
	(9723.635)	(0.136115)
pmr	2426.411	0.074127
	(24733.81)	(0.813815)
airflights	0.08967	-1e-05
	(0.098674)	(2e-06)
nights	-1630.702	0.004899
	(532.9435)	(0.008166)
rule_wb	59430.88	-3.672242
	(56711.66)	(1.02675)
N	16	16
r2	0.855	0.9138

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes system variables (e.g., number of operating airports, number of arrivals), *quality* describes safety measures (absolute or relative) (e.g., number of air incidents). **Capacity dependent variables:** *numairpo* number of total airports operating in a country, *arrivals* number of year arrivals in all airports countrywide, *numplanes* number of operating aircrafts registered in a country. **Quality:** *capacinci* number of incidents related to airport land operations. **Controls:** *pmr*: product market regulation in air sector, $airflights$ average number of aircrafts in a country airspace (measure of traffic), *nygdppcapkdzg* GDP per capita growth rate, *nights* number of hotel nights spent by tourists in a given country, $rgdpe_penn$ country GDP in constant USD, $valk_d51_st$ air sector national accounts added value in constant USD. For additional control information refer to Table B.27. Heteroskedasticity − robust standard errors parentheses.

Table B.22: Air regression OLS estimates for scope *mean* dimension

var	air250	air150
market_mean	4.476154	4.994706
	(0.842899)	(1.052329)
pmr	-21.06812	-19.36173
	(4.852095)	(6.71555)
airflights	4e-05	4.2e-05
	(1.1e-05)	(1.9e-05)
nygdppcapkdzg	24.54264	25.64561
	(6.248572)	(10.19166)
nights	-0.152139	-0.289778
	(0.067372)	(0.083071)
rgdpe_penn	3.4e-05	4.4e-05
	(1e-05)	(1.3e-05)
valk_d51_st	-0.002519	-0.00191
	(0.000905)	(0.001087)
N	15	15
r2	0.9793	0.9387

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes system variables (e.g., number of operating airports, number of arrivals), *quality* describes safety measures (absolute or relative) (e.g., number of air incidents). **Capacity dependent variables:** $air150$ number of aircrafts with capacity below or equal to 150 passengers, $air250$ number of aircrafts with capacity from 150 to 250 passengers.**Quality:** *operincind* number of incidents related to airline operations. **Controls:** *pmr*: product market regulation in air sector, $airflights$ average number of aircrafts in a country airspace (measure of traffic), $nygdppcapkdzg$ GDP per capita growth rate, $nights$ number of hotel nights spent by tourists in a given country, $rgdpe_penn$ country GDP in constant USD, $valk_d51_st$ air sector national accounts added value in constant USD. For additional control information refer to Table B.27. Heteroskedasticity − robust standard errors parentheses.

Table B.23: Air regression OLS estimates for scope *growth* dimension

var	totdisrup	capacinci	arrivals	numplanes
market_growth				
transparency_growth	151.2698	-283.8258	664.3851	0.913646
	(15.96126)	(110.0897)	(168.7554)	(0.198186)
gdp	-815.3353	558.1283	-1180.638	-0.526386
	(338.9403)	(2153.295)	(1920.907)	(3.496685)
pmr	-6434.93	17829.38	-4591.767	-14.11368
	(2170.754)	(9382.646)	(8052.042)	(12.20801)
airflights	0.019647	0.017727	0.010579	3e-06
	(0.003277)	(0.0193)	(0.017361)	(2.7e-05)
nygdppcapkdzg	10296.56	-21295.77	1999.503	16.28361
	(2373.485)	(10852.65)	(9398.181)	(13.75266)
nights	17.59089	-111.5151	100.6455	-0.068853
	(19.93378)	(120.4289)	(120.4423)	(0.176202)
rule_wb				
valk_d51_st	-1.16274	2.037845	-0.666831	-0.00038
	(0.277474)	(1.195069)	(1.094078)	(0.001525)
N	14	14	14	14
r2	0.9587	0.8023	0.7896	0.8197

The column *class* shows whether the regression uses structural *mean* or variation *growth* dependent variable, as explained in Section 4.3.3. The column *varia* shows the type of variable: *capacity* describes system variables (e.g., number of operating airports, number of arrivals), *quality* describes safety measures (absolute or relative) (e.g., number of air incidents). **Quality:** *totdisrup* total number of disruptions of any kind in air operations. **Controls:** *pmr*: product market regulation in air sector, $airflights$ average number of aircrafts in a country airspace (measure of traffic), *nygdppcapkdzg* GDP per capita growth rate, *nights* number of hotel nights spent by tourists in a given country, $rgdpe_penn$ country GDP in constant USD, $valk_d51_st$ air sector national accounts added value in constant USD. For additional control information refer to Table B.27. Heteroskedasticity − robust standard errors parentheses.

B.2.5 Summary of main variables

Table B.24: Energy sector main dependent and independent variables

	count	mean	sd	min	max
energy_transparency_growth	24	23.3908	31.30449	-38.95349	96.22093
energy_indep_growth	24	12.8737	24.65712	-18.26211	97.66924
energy_market_growth	24	1.07955	14.07552	-27.45455	27.27273
energy_bureau_growth	24	-3.189624	27.72122	-43.71765	62.7907
lev_enenew13	21	224.68	449.4059	-299	1574.83
capOTHCOMB_TOTAL	20	230.0686	583.2736	-56.08525	2532.65
pro_TOTPRO_Impor_b	24	1273.205	2448.952	-3136.214	8580.164
mean_enenew47	21	-.0476191	.8576823	-2	1.6
ELE_IND	23	-224.644	182.8657	-582.0122	73.83592
capINTCOMB_TOTAL	20	3.419913	12.6303	-17.99721	34.33411
lev_enenew26	21	.0657143	.04556	0	.17
mean_enenew30	21	.0285714	.0293744	-.01	.11
pro_TOTPRO_Impor_b	23	46.07296	230.8647	-784.3334	501.5268
lev_enenew38	21	54.26525	389.5657	-871.71	575.46
lev_enenew44	18	-6.893334	10.41312	-43.92	2.260002
mean_enenew48	20	.32	1.070956	-1.6	3.2
lev_capOTHCOMB_TOTAL	20	174.7744	515.8631	-124	2313
lev_capSOLARPV_TOTAL	23	1156.692	2319.613	-5	9839
lev_capCOMBINED_TOTAL	22	-117.5203	583.0404	-1985.49	846
mean_enenew9	21	1.795238	2.194315	.0200001	7.860001
lev_enenew49	21	-52.31001	230.2	-585.8101	317.76
mean_enenew52	21	41.28333	80.47345	-2.199997	292.4
lev_ELE_HOU	23	-218.1411	284.4144	-674.1957	562.2061
gdp	23	8.336106	10.37013	.1553978	38.27657
lag_pmr_elec	23	-2.082174	.6799128	-3.23	-.87
dis_equ	23	50.75279	7.476148	39.16258	67.46999
capTOTCAP_MAINTOT	24	38635.76	49004.22	1682.015	195559.5
ELE_IND	23	1297.618	359.5961	572.0584	2233.161
m_nygdppcapkdzg	23	2.335652	1.926905	.82	9.62
rest_m_gctaxtotlgdzs	23	.538261	1.537731	-3.719999	3.59

mean: Dependent variables are the (5-year) average change between 2009-2013 to 2014-2018. Variables with no *mean* specification stand for mean values corrected by country population size. *lev*: Dependent variable change between 2013 and 2018. $capOTHCOMB\_TOTAL$: CO2 electricity generation capacity based on technologies other than internal combustion in MW, $pro\_TOTPRO\_Impor\_b$: yearly energy imports in MW from third-countries, *enenew*47: number of electricity producers that cover more than 5% of the industry supply, ELE_IND: industrial consumer retail prices in USD, *enenew*26: wind and solar electricity generation capacity in MW, *enenew*30: Wind generation efficiency conversion in MW, *enenew*38:total electricity generated per capita in MW, *enenew*44 market share of largest electricity producer in percentage, $capSOLARPV\_TOTAL$: solar photovoltaic electricity generation capacity in MW, $capCOMBINED\_TOTAL$: electricity generation capacity based on gas and steam (fuel efficient) in MW, *enenew*9: percentage of renewable electricity generation production, *enenew*49: electricity consumption per capita in MW. *enenew*52: number of electricity retailers, ELE_HOU: household consumer prices in USD, *gdp*: Gross domestic product PPP base (), dis_equ: absolute latitude value, lag_rail_pmr: rail product market regulation index (OECD) for 2013, $capTOTCAP\_MAINTOT$: total electricity generation capacity in MW, *gctaxtotlgdzs*: tax revenue as a percentage of GDP.

Table B.25: E-Communication sector main dependent and independent variables

	count	mean	sd	min	max
telecom_transparency_growth	22	18.52249	23.81705	-16.30252	74.37908
telecom_indep_growth	22	22.36652	29.36359	-14.8087	100.6742
telecom_market_growth	22	3.847192	12.48907	-11.74056	35.36173
telecom_discretion_growth	22	-.5082586	20.65252	-31.57895	41.17647
lev_bbwp100tot	23	33.74087	12.45864	7.240005	58.14
mean_bbp100cab	24	1.827083	1.298472	0	4.329999
mean_telaccpath100	24	1.934584	8.260808	-10.35001	15.45
level_mob_bb_penrate	23	34.35	11.91868	7.65	57.75
lev_fixbbas5gbtelpripc	23	.2030435	.3896669	-.8599999	.8900001
lev_bbp100cab	23	1.344348	1.273206	-.3999996	3.87
voip	20	1642.716	3239.391	-160.8322	13876
lev_fixbbas5gbtelprippp	23	12.58043	11.25792	-7	38.45
mean_bbwp100stan	24	40.02333	13.87384	19.93	88.89
totmob	24	2143.423	5951.085	-8687.292	21733
mean_mob_bb_penrate	23	40.20696	14.55367	24.72	82.6
lev_fixbbas5gbtelprippp	23	12.58043	11.25792	-7	38.45
gdp	23	8.336106	10.37013	.1553978	38.27657
rule_wb	24	1.363833	.5874164	.194	2.052
lag_telecom_pmr	23	.9534783	.619337	.27	2.66
fix_broad_100_Total	22	35.29864	6.799405	20.2	46.78
le_enpopdnst	23	151.0174	119.2623	14.55	511.48
rest_m_spurbtotlinzs	23	1.025217	.8991659	-.6599998	2.920002
nights	23	129	158.5514	2.9	471.2

mean: Dependent variables are the (5-year) average change between 2009-2013 to 2014-2018. Variables with no *mean* specification stand for mean values corrected by country population size. *lev*: Dependent variable change between 2013 and 2018. *bbwp*100*tot*: total number of subscriptions of fixed internet broadband connection by 100 people, *bbp*100*cab*: total number of subscriptions of cable internet connection by 100 people, *telaccpath*100: total number of access paths by 100 people, *mob_bb_penrate*: mobile communication services penetration rates in percentage, *fixbbas*5*gbtelpripc*: estimated price of a fixed internet connection (5gb) per capita in USD, *voip*: total number of VoIP subscriptions, *fixbbas*5*gbtelprippp*: estimated price of a fixed internet connection (5gb) USD corrected for purchase parity, *bbwp*100*stan*: total number of mobile broadband subscribers per 100 habitants, *totmob*: change in total number of mobile services subscriptions in thousands, *fixed_broad_*100*_Total*: total number of internet subscriptions per 100 habitants, *le_enpopdnst*: population density per square km, *rest_m_spurbtotlinzs*: percentage of pupulation living in urban areas. *gdp*: Gross domestic product PPP base (), *dis_equ*: absolute latitude value, *lag_rail_pmr*: rail product market regulation index (OECD) for 2013.

Table B.26: Rail sector main dependent and independent variables

	count	mean	sd	min	max
rail_transparency_growth	21	28.97117	26.93066	-23.61546	73.44538
rail_indep_growth	21	25.00061	21.41624	-8.766803	60.57835
rail_market_growth	21	6.409455	20.89313	-27.16279	48.23529
rail_discretion_growth	21	-.2110982	22.82539	-34.95798	41.62791
mean_ss00	22	-.8363636	2.483957	-8	2.6
lev_ps24	22	-.0186364	.0362919	-.15	.01
mean_n03	22	-3.418182	3.939984	-17.2	.4000015
mean_tgoodsrltot	22	1229.325	2983.439	-3013.2	12971.59
mean_c25	22	-33717.45	76280.69	-315841.8	0
lev_t16	20	-.0095	.0308605	-.1	.04
mean_n02	22	-.9818181	2.902156	-9.4	4.2
mean_n21	22	.0045455	.0147122	-.03	.04
mean_us10	22	-.0181818	.05679	-.17	.12
lev_n07	22	-8.727273	24.85612	-102	34
lev_n10	22	.0036364	.2954504	-.4399999	.9300001
lev_r03	22	528.5621	2220.278	-2170	9013.299
mean_i14	22	.2718182	1.20712	-.6999999	5.5
mean_r06	22	-.4872721	2.096269	-5.790001	3.43
mean_t29	22	.0104545	.0450901	-.1	.16
lev_n10	22	.0036364	.2954504	-.4399999	.9300001
lev_tk10	22	-.0281818	.2085468	-.45	.7399999
mean_i14	22	.2718182	1.20712	-.6999999	5.5
mean_r06	22	-.4872721	2.096269	-5.790001	3.43
mean_t29	22	.0104545	.0450901	-.1	.16
mean_rai_35	22	-34.42509	580.8192	-1813.9	1582.5
gdp	46	7.949646	9.77064	.1322581	38.27657
dis_equ	46	50.75279	7.392613	39.16258	67.46999
VALK_D49T53_ST	48	114329.5	281322.3	1136.157	1477314
lag_rail_pmr	23	3.273478	1.081122	.25	5.41

mean: Dependent variables are the (5-year) average change between 2009-2013 to 2014-2018. *lev*: Dependent variable change between 2013 and 2018. $ss00$: total operational accidents that involved rail employees, $ps24$: Total accidents that involve passengers, $n03$: total accidents at lever crossings, $tgoodsrltot$: total freight traffic, $c25$: estimated costs of delays due to operational incidents, $t16$: active lever crossings per line km., $n02$: train derail incidents, $n21$: total number of accidents that involve the transport of dangerous goods, $us10$: total number of accidents that involve unauthorized personnel, $n07$: total number of suicides in railways, $n10$: total number of incidents per line km, $r03$: rail line lenght in km, $i14$: accidents precursors before incidents per line km, $r06$: freight transport in tons per line km, $t29$: total lever crossings per line km, $tk10$: total number of faltal victims involved in rail incidents, rai_35: total line length in km. *gdp*: Gross domestic product PPP base (), dis_equ: absolute latitude value, lag_rail_pmr: rail product market regulation index (OECD) for 2013, $VALKD49T53ST$ transport industry added value.

Table B.27: Air sector main dependent and independent variables

	count	mean	sd	min	max
air_transparency_growth	16	23.92396	25.39048	-12.79904	94.35216
air_indep_growth	16	13.12934	26.51194	-26.35372	57.81898
air_market_growth	16	-2.926813	22.99693	-37.2093	53.84615
air_discretion_growth	16	8.115754	43.9825	-43.97727	128.9157
mean_air_5	23	-26.7913	35.52737	-98.4	28.6
mean_airifrarrivalsnm	22	18586.86	21216.43	-1489.5	80932
mean_airercapacityatc	21	11968.62	205896.8	-620901.6	618735.1
mean_airerdisruptions	21	3551.462	11105.15	-10175.3	42600.8
mean_air_19	23	-4.41087	7.300762	-28.6	2
mean_air_14	23	-6.763043	8.828649	-30	3.5
lev_airsmindic	22	11.40909	7.048533	0	33
mean_air_20	23	.0608696	1.141864	-2.85	2.8
mean_airercapacityatc	21	11968.62	205896.8	-620901.6	618735.1
gdp	46	7.949646	9.77064	.1322581	38.27657
airflights	44	1007015	834804	62017	3257894
dis_equ	46	50.75279	7.392613	39.16258	67.46999
lag_air_pmr	23	.9291304	1.226169	0	3.55
nights	46	129	156.7798	2.9	471.2

The dependent variables are the (5-year) average change between 2009-2013 to 2014-2018. $mean\_air\_5$: total number of aircrafts, $mean\_airifrarrivalsnm$: total number of arrivals, $mean\_airercapacityatc$: total number of operational disruptions per year, $mean\_airerdisruptions$ total number of disruptions per year, $mean\_air19$: total number of main airports (more than 25000 passengers), $mean\_air14$: number of small size aircrafts, $levairsmindic$: safety performance index, $mean\_air20$: total number of airports, gdp: Gross domestic product PPP base (), $airflights$ total number of flights, dis_equ: absolute latitude value, lag_air_pmr: air product market regulation (OECD) for 2013, $nights$ number of nights a year tourist spend in a hotel on a given country.

Appendix C

Appendices of Paper 3

C.1 Data description

Table C.1: Descriptive summary of variables used in the empiric analysis

Type	Variable name	Description (units)	Source	Min	Mean	Max	SD
Main dependent variables	Sh. renewables	Share of renewable energy (%)	EUROSTAT	3.499	20.1	54.7	12.38
	Ind. electric	Tariff charged for consumption of a KWh by hou. (log(EUR/KWh))		4.245	4.8	5.47	0.272
Secondary dependent variables	Sh. windgen	Share of renewable energy wind (%)	EUROSTAT	0.021	9.5	45.8	10.75
	Sh. solar	Share of renewable energy solar (%)		0	2.15	7.82	2.194
	Hou. elecprice	Tariff charged for consumption of a KWh by households (log(EUR/KWh))		4.879	5.44	5.96	0.267
Governance and reform variables	Independence	Independence index (0 – 1)	Brousseau & Gonzalez, 2020)	0.185	0.3	0.37	0.043
	Scope	Market coord. Gov. index (0 – 1)		0.216	0.27	0.32	0.027
	Transparency	Transparency index (0 – 1)		0.167	0.25	0.35	0.052
	Discretion	Discretion index (0-1)		0.144	0.24	0.34	0.048
	OECD PMR	OECD PMR (1 - 6)	OECD-PMR	0.14	1.28	2.19	0.523
	TA mkt access	Market access index (0 - 1)	Constructed PMR survey	0.11	0.15	0.2	0.023
Electricity supply, demand, and security controls	Elec gen.	Total electricity supply (log GWh)	IEA OECD database	7.688	11	13.4	1.398
	Elec cons	Total electricity supply (log GWh)		15.27	17.3	19.6	1.211
	Trade balance	Elec. exports – imports (log GWh)		5.367	8.14	9.15	0.718
	GDP	GDP in const. (log 2017 million USD)	PWT ver10	24.3	26.6	29	1.318
	Income PC	GDP per capita (log USD/population)		10.05	10.6	11.4	0.363
Renewable's support controls	Years lawren	Policy time that supports renewable generation (log years)	Constructed IEA policy database	2.485	4.19	5.66	0.773
	Green Party	Green party seat in the Legislative	Comparative Political Dataset	0	2.34	12.4	3.28
	1-IHH sshare	Diversification of elec. generation sources (0 – 1)	Constructed IEA-OECD database	-0.441	0.47	0.72	0.248
	1-IHH sshare NR	Diversification of elec. generation non-renewable sources (0 – 1)		0.082	0.58	0.95	0.214
Institutions and government efficiency controls	FH civil law	Freedom House civil law scores (0-60)	Freedom in the World Report, 2021	44	55.9	60	3.471
	FH pol rights	Freedom House pol. rights scores (0-40)		28	38.1	40	2.29
	FH index	Freedom House total scores (0-100)		72	93.9	100	5.567
	IHS RL	HIS rule of law index (0-1)	IHS Markit	0.67	0.86	1	0.092
	TI CPI	Transp. International corruption perception index (0-100)	Transparency International	43	67.4	91	14.07

C.2 Textual analysis construction variable

To measure the intensity of market reform, we assessed the regulatory environment using survey questions from the OECD PMR (Vitale et al., 2020). Instead of using the categorical content of the survey, we tracked changes in replies by assessing the textual information embedded in the survey. We applied the following steps to the data.

1. We created a set of documents using the textual information from the survey. The textual information comes from the words used to express country replies. In the following question, "Are market prices regulated?", we registered "market prices are regulated" for a positive answer, and "prices are unregulated" for a negative one in our database.

2. We constructed text documents for every country and time with the previous information. Based on co-occurring terms in every document, we fit a topic model (LDA) and identify four groups of terms that describe the country market reform, as shown in Figure C.1.

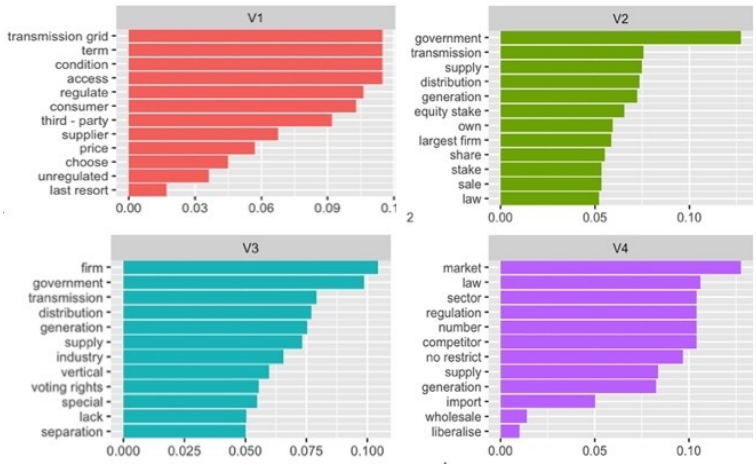


Figure C.1: Text Analysis of market regulation dimensions

C.3 Additional controls renewable energy shares

Table C.2: Additional controls renewable energy shares

	(1)	(2)	(3)
Independence	-0.817**	-0.861**	-0.861**
	(0.334)	(0.365)	(0.324)
Household Elec.Price		0.259	
		(0.223)	
Share L.incumbent			-0.293***
			(0.049)
Individual effects	yes	yes	yes
Time effects	yes	yes	yes
Controls	yes	yes	yes
adj. R^2	0.87	0.854	0.948
AIC	-141.475	-126.115	-161.093
Observations	48	44	42
F-statistic	33.137	39.885	240.344

Model (1) of Table 5.2 is used in all specifications. *Household Elec.Price*: electricity prices paid by residential consumers in EUR per GWh. *Share L.incumbent*: share of the largest electricity producer in percent points. Heteroskedasticity robust standard errors in parentheses * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Table C.3: Different support mechanisms

	(1)	(2)
Independence	-0.817**	-0.994*
	(0.334)	(0.545)
Years ren. laws	0.262***	
	(0.058)	
Share Subsidies		-0.142
		(0.149)
Time effects	yes	yes
Controls	yes	yes
adj. R^2	0.87	0.833
AIC	-141.475	-118.835
Observations	48	42
F-statistic	33.137	26.951

Model (1) of Table 5.2 is used in all specifications. *Share Subsidies*: Share in percentage points (logs) of the legislation that grants subsidies to renewable energy generators over the total number of legal instruments that support green electricity. Heteroskedasticity robust standard errors in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01.

Table C.4: Alternative dependent variable and overlapping sample

	(1) Base	(2) Wind-Solar.SH
Independence	-0.764*	-0.130*
	(0.413)	(0.065)
mkt access	1.585**	-0.269
	(0.719)	(0.183)
FH pol. rights	0.037***	0.002***
	(0.006)	(0.001)
1-IHH gen.	1.035***	0.409***
	(0.311)	(0.051)
GDP	2.122**	-0.172
	(0.866)	(0.126)
incomePC	-2.209**	0.18
	(0.928)	(0.132)
trade balance	0.102	0.025
	(0.107)	(0.015)
years ren. laws	0.209**	-0.026*
	(0.080)	(0.013)
patenthundred	0.129**	0.003
	(0.058)	(0.011)
Individual effects	yes	yes
Time effects	yes	yes
adj. R^2	0.85	0.938
AIC	-125.413	-291.447
Observations	44	44
F-statistic	32.819	59.566

Model (1) of Table 5.2 is used in all specifications. The dependent variable *Wind-Solar.SH* in model (2) is the sum of wind and solar shares as part of the total electricity produced in GWh. The value varies between 0 and 1. Heteroskedasticity robust standard errors in parentheses * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Table C.5: Fixed Effects estimation: Impact of governance regime in electricity price – complete table

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Independence	-0.116				0.225
	(0.291)				(0.438)
Transparency		-0.512*			-0.767*
		(0.298)			(0.410)
Scope			0.387		0.727
			(0.639)		(0.563)
Discretion				0.31	
				(0.303)	
TA market access	0.91	0.626	1.069	0.8	0.761
	(1.176)	(1.280)	(1.179)	(1.440)	(1.286)
FH civil laws	-0.009	-0.0104	-0.0103	-0.0076	-0.0144
	(0.011)	(0.011)	(0.013)	(0.011)	(0.0145)
incomePC	-0.57***	-0.60***	-0.57***	-0.60***	-0.61***
	(0.176)	(0.174)	(0.184)	(0.176)	(0.184)
Elec. Supply	0.243	0.297	0.184	0.249	0.221
	(0.183)	(0.198)	(0.197)	(0.208)	(0.200)
1-IHH generat	0.0132	-0.006	0.0728	-0.0249	0.0939
	(0.106)	(0.112)	(0.152)	(0.135)	(0.148)
Individual effects	yes	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes
adj. $R\hat{2}$	0.828	0.845	0.83	0.834	0.851
AIC	-144.5	-149.5	-145.1	-146.1	-149.8
Observations	48	48	48	48	48
F-statistic	27.87	32.1	32.96	30.59	28.66

Model (1) of Table 5.2 is used in all specifications. Heteroskedasticity robust standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

RÉSUMÉ

Les réformes du marché européen ont modifié le fonctionnement et la structure des services publics et des entreprises de transport verticalement intégrés. Dans le cadre du programme de construction du marché unique, les directives et règlements européens ont commencé à imposer des changements importants aux industries de réseau au début des années 1990. Les pays ont laissé entrer la concurrence dans leurs industries de réseau autant que possible, ont réglementé un accès raisonnable au réseau et ont donné un pouvoir de réglementation à des agences bureaucratiques pour augmenter la couverture des services, les investissements dans des actifs hautement spécialisés et les loyers des consommateurs. La mise en œuvre de la réforme diffère largement selon les pays et les secteurs. Les chercheurs et les organisations internationales ont conçu des paramètres pour mesurer la réforme, ses causes et son impact sur les performances industrielles (couverture des services, qualité et prix). L'agrégation des données est utilisée pour fournir des métriques synthétiques. Les limites des techniques ont une incidence sur la manière d'interpréter et de transmettre les mesures. Les stratégies utilisent la structure des données pour mesurer l'importance des qualités à l'aide d'un modèle statistique ou pondèrent arbitrairement les caractéristiques de la réforme (en fonction des jugements des experts). Les hypothèses de distribution limitent l'utilisation des structures de données. Les pondérations arbitraires peuvent ne pas être une évaluation juste de la réforme, mais la position politique/idéologique du chercheur. L'analyse textuelle est utilisée pour étudier les changements de marché et les régimes de gouvernance. Les algorithmes transforment les données catégorielles en sources textuelles codées et utilisent le comptage des mots et des termes pour déterminer les paramètres de réglementation et de gouvernance. Cette stratégie réduit l'impact des croyances politiques et idéologiques, assouplit les hypothèses du modèle traditionnel concernant la distribution et permet de comparer différents secteurs, pays et périodes de l'histoire. Le premier chapitre présente les défis de la quantification des réformes du marché, ainsi qu'un bref examen de la législation européenne qui a introduit la concurrence dans les industries de réseau. Le chapitre 2 analyse l'hétérogénéité des changements du marché des produits de réseau et leurs conséquences sur la productivité de 1998 à 2018. Le questionnaire de l'OCDE sur la réglementation des marchés de produits est codé et converti à l'aide du Traitement automatique des langues (TAL). Les données codées sont ensuite modélisées par thème. Cet examen porte sur les réformes du marché sous trois angles : la propriété de l'État, l'accès aux réseaux et le contrôle des caractéristiques des produits. Le chapitre 3 examine l'influence des configurations du régime de gouvernance 2013-2018 sur la performance de l'industrie. L'analyse textuelle est utilisée pour modéliser les données d'enquête du questionnaire de l'OCDE sur la gouvernance des régulateurs. L'indépendance vis-à-vis du gouvernement, le pouvoir discrétionnaire, la transparence et la surveillance du marché sont examinés. Enfin, le chapitre 4 étudie comment la gouvernance et les règles affectent le marché européen de l'électricité. Le chapitre étudie l'impact de l'indépendance réglementaire sur le mix électrique.

MOTS CLÉS

Libéralisation, réforme du marché, réglementation, industrie des réseaux, gouvernance, agence de réglementation indépendante.

ABSTRACT

European market reforms have modified the operation and structure of vertically integrated government utilities and transportation companies. As part of the single market construction program, European directives and regulations began imposing significant changes on network industries in the early 1990s. Countries let competition into their network industries as much as possible, regulated reasonable network access, and gave regulatory power to bureaucratic agencies to increase service coverage, investments in highly specialized assets, and consumer rents. The reform's implementation differs widely between countries and sectors. Researchers and international organizations have devised metrics to measure reform, its causes, and its impact on industrial performance (service coverage, quality, and prices). Data aggregation is used to provide summary metrics. The techniques' limitations affect how to interpret and convey measurements. The strategies either use the data structure to measure the qualities' importance using a statistical model or arbitrarily weigh reform features (depending on experts' judgments). Distributional assumptions limit the usage of data structures. Arbitrary weights may not be a fair evaluation of the reform but the researcher's political/ideological position. Text analysis is used to investigate market changes and governance regimes. The algorithms turn categorical data into coded text sources and utilize word and term counts to determine regulation and governance metrics. This strategy reduces the impact of political and ideological beliefs, relaxes traditional model assumptions about distribution, and enables people to compare different sectors, countries, and times in history. The first chapter presents the challenges of quantifying market reforms, along with a brief review of the European legislation that brought competition to network industries. In Chapter 2, the heterogeneity of network product market changes and their consequences on productivity from 1998 to 2018 are analyzed. The OECD Product Market Regulation questionnaire is coded and converted using Natural Language Processing (NLP). The coded data is then topic-modeled. This examination discusses market reforms from three perspectives: state ownership, network access, and product characteristic control. Chapter 3 examines the influence of 2013-2018 governance regime configurations on industry performance. Text analysis is used to model survey data from the OECD Governance of Regulators questionnaire. Independence from government, discretion, transparency and market monitoring are discussed. Finally, chapter 4 investigates how governance and rules affect the European electricity market. The chapter investigates regulatory independence's impact on the electricity mix.

KEYWORDS

Liberalization, market reform, regulation, network industry, governance, independent regulatory agency