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TESIS DOCTORAL/ DOCTORAL DISSERTATION

GESTIÓN DEL CAMBIO TECNOLÓGICO EN LA INDUSTRIA ELÉCTRICA.

UN ENFOQUE AMBIDIESTRO.

MANAGING TECHNOLOGICAL CHANGE IN THE ELECTRICITY INDUSTRY.

AN AMBIDEXTROUS APPROACH.

CRISTIÁN JAVIER FLANAGAN BÓRQUEZ

SEGOVIA, 2023



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DOCTORAL THESIS ADVISOR: PROFESSOR CATERINA MOSCHIERI

ABSTRACT

MANAGING TECHNOLOGICAL CHANGE IN THE ELECTRICITY INDUSTRY. AN AMBIDEXTROUS APPROACH.

The \$900 billion write-off of 'stranded energy assets' needed to make climate targets will be one of the biggest capital shifts ever. (Financial Times 2020)

This multi-method study examines whether and how technological change influences a firm's performance, specifically depending on the firm's inertia or ability to adapt. The tension between exploiting an old business model and exploring new technology in an adapted business model, especially when there is a technological shock in the environment, is arduous for firms operating in capital intensive industries characterized by investments in fixed assets, because these assets may create inertia. Building on research on ambidexterity, I argue that technological change can improve a firm's performance, which is different from previous findings of declining performance of firms in the face of radical technological change. This assertion stems from the observation that current technological change frees productive factors. Particularly, the shift to renewable energy sources signifies a move from stock based to flow based energy models, contrasting with traditional fossil fuel technologies. However, this presents a paradox; a firm may be unable to adapt to technological change even if it possesses all the core knowledge related to the innovation. Successful adaptation also requires the complementary assets and the capabilities to commercialize the technological change. The study focuses on electric firms worldwide between 2012 and 2019. This context is ideal to examine how technological change influences firm's performance. Firms in the electricity industry have a business model that has not significantly changed for a long time and are characterized by investments in fixed assets. However, several new energy management change drivers are emerging to uproot this status quo and to erode "traditional" electric firms' legitimacy, among them the rising demand for electricity, the emergence of renewable energy sources, the appearance of electrified transportation and batteries, the deregulation of power markets, and innovations in the smart grid technology.

I used data about electric firms worldwide from Orbis, merged with industry and technological change data from World Bank, Lazard and the International Renewable Energy Agency (IRENA). I performed a full statistical analysis using data from 504 electricity firms obtained from Orbis. To test the soundness of the hypotheses and conceptual model and the meaningfulness of the expected theoretical mechanism, I interviewed 26 executives from electric firms, and processed the interviews with topic modeling methodology as well as NVIVO.

The results show an increase in firm's performance due to technological change. However, contrary to what I expected, such impact is amplified when the effect is moderated by firm's Inertia, which could be due to the fact that the advantages of firm size are greater than its costs in the electric industry, even under technological changes. I also found that this impact is amplified when the effect is moderated by firm's Adaptability.

RESUMEN

GESTIÓN DEL CAMBIO TECNOLÓGICO EN LA INDUSTRIA ELÉCTRICA. UN ENFOQUE AMBIDIESTRO

El castigo de \$ 900 billones de Activos Energéticos que se necesita para cumplir con las metas del cambio climático, será uno de los mayores deterioros en inversiones nunca antes visto. (Financial Times 2020)

Este estudio multi-método investiga si y cómo el cambio tecnológico influye en los rendimientos de las empresas, y como esto depende de la inercia de la empresa o su capacidad de adaptación. La tensión entre explotar un modelo de negocio antiguo y explorar una nueva tecnología en un modelo de negocio adaptado, especialmente cuando hay un choque tecnológico en el entorno, es ardua para las empresas que operan en industrias intensivas en capital, caracterizadas por inversiones en activos fijos, ya que estos activos pueden crear inercia. Basándome en investigaciones sobre ambidestreza, sostengo que el cambio tecnológico puede mejorar el rendimiento de una empresa, lo cual es diferente a hallazgos previos de un rendimiento decreciente de las empresas ante un cambio tecnológico radical. Esta afirmación surge de la observación de que el cambio tecnológico actual libera factores productivos. En particular, el cambio a fuentes de energía renovable significa un paso de modelos de energía basados en reservas a modelos basados en flujos, en contraste con las tecnologías tradicionales de combustibles fósiles. Sin embargo, esto presenta una paradoja; una empresa puede ser incapaz de adaptarse al cambio tecnológico incluso si posee todo el conocimiento relacionado con la innovación. La adaptación exitosa también requiere los activos complementarios y las capacidades para comercializar el cambio tecnológico. El estudio se centra en empresas eléctricas en todo el mundo entre 2012 y 2019. Este contexto es ideal para examinar cómo el cambio tecnológico influye en el rendimiento de la empresa. Las empresas en la industria eléctrica tienen un modelo de negocio que no ha cambiado significativamente durante mucho tiempo y se caracterizan por inversiones en activos fijos. Sin embargo, nuevos catalizadores del cambio en la gestión de la energía están emergiendo para romper este status quo y erosionar la legitimidad de las empresas eléctricas "tradicionales", entre ellos la creciente demanda de electricidad, la aparición de fuentes de energía renovable, la aparición del transporte electrificado y las baterías, la desregulación de los mercados de energía e innovaciones en la tecnología de redes de distribución inteligentes.

Utilicé datos de empresas eléctricas en todo el mundo de Orbis, fusionados con datos de cambio industrial y tecnológico del Banco Mundial, Lazard y la Agencia Internacional de Energía Renovable (IRENA). Realicé un análisis estadístico completo utilizando datos de 504 empresas eléctricas obtenidos de Orbis. Para probar la solidez de las hipótesis y el modelo conceptual y el significado del mecanismo teórico esperado, entrevisté a 26 ejecutivos de empresas eléctricas y procesé las entrevistas con la metodología de análisis de texto Topic Modeling, así como con NVIVO.

Los resultados muestran un aumento en el rendimiento de la empresa debido al cambio tecnológico. Sin embargo, contrariamente a lo que esperaba, dicho impacto se amplifica cuando el efecto está moderado por la Inercia de la empresa, lo que podría deberse al hecho de que las ventajas del tamaño de la empresa son mayores que sus costos en la industria eléctrica, incluso

bajo cambios tecnológicos. También encontré que este impacto se amplifica cuando el efecto está moderado por la Adaptabilidad de la empresa.

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And finally, I dedicate this work to the enduring aspiration to improve the world we live in, a goal not solely driven by technological advancements but also by their legitimacy and social acceptance.

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INTRODUCCIÓN

El cambio tecnológico es un cambio hacia una nueva función de producción causado por un aumento en la eficiencia de un producto o proceso, es una modificación positiva que a menudo llega en oleadas de innovaciones relacionadas (Norcliffe 2018). Estudios anteriores en administración han estudiado cómo las empresas pueden tener dificultades para adaptarse al cambio tecnológico y cómo, a pesar de estas tensiones, algunas empresas pueden superar la inercia organizacional que puede impedir dicha adaptación (Christensen and Bower 1996; Eggers and Park 2018). Los estudios pasados se centran principalmente en factores externos, como el efecto del ecosistema y la incertidumbre asociada al cambio tecnológico (Hill and Rothaermel 2003; Eggers 2016; Tushman and Anderson 1996). Otros trabajos sugieren que el intelecto gerencial y organizacional también es importante para que las empresas se adapten al cambio tecnológico (Garud and Rappa 1994; Kammerlander, König, and Richards 2018; Kaplan 2011; Martins, Rindova, and Greenbaum 2015; Raffaelli, Glynn, and Tushman 2019; Roessler, Velamuri, and Schneckenberg 2019; Tripsas and Gavetti 2000).

El cambio tecnológico y los cambios asociados en el ecosistema de la empresa, la incertidumbre y la modificación en el intelecto de la empresa y de los directivos pueden crear una tensión entre la explotación de un modelo de negocio antiguo y la exploración de nuevas tecnologías en un modelo de negocio adaptado (Kaulio, Thorén, and Rohrbeck 2017; O'Reilly and Tushman 2013; Ossenbrink, Hoppmann, and Hoffmann 2019). Una posible explicación de las dificultades de las empresas durante un período de cambio tecnológico es su incapacidad para comprender que las tecnologías no reemplazan a otras tecnologías en un cambio tecnológico significativo. En cambio, las empresas tienen éxito durante los cambios tecnológicos cuando se adaptan y comprenden que los modelos de negocio deben reemplazar modelos de negocio (Johnson and Suskewicz 2009). Este estudio aborda esta tensión y examina *cómo el cambio*

tecnológico influye en el resultado de las empresas, específicamente en función de su inercia o capacidad de adaptación .

Los modelos de negocio pueden ser importantes para estructurar el resultado de una empresa. Reflejan por qué y cómo la empresa crea y entrega valor a los clientes, empleados y propietarios, enmarcando su posición competitiva y su propuesta de valor (Moellers et al. 2019). En presencia de cambio tecnológico, dos mecanismos en competencia (inercia y adaptabilidad) pueden afectar el resultado de la empresa. Por un lado, “una empresa establecida puede no ser capaz de adaptarse a un cambio tecnológico incluso si posee todos los conocimientos básicos necesarios asociados con la innovación” (Eggers and Park 2018). Por otro lado, las tecnologías disruptivas en factores de producción generan “economías de escala externas” que incentivan a las empresas a adoptar la nueva tecnología para explotar beneficios externos, creando oportunidades e incentivos para adoptar tecnologías superiores (Cozzolino and Rothaermel 2018; Cozzolino, Verona, and Rothaermel 2018).

Para explorar cómo el cambio tecnológico influye en el desempeño de las empresas, específicamente dependiendo de su inercia o capacidad de adaptación, estudio la industria eléctrica. La industria eléctrica es ideal para este análisis debido a la transición energética en curso hacia un sistema energético sostenible y con bajas emisiones de carbono debido al cambio tecnológico junto con la conciencia ambiental. Propongo que los cambios tecnológicos tienen consecuencias para el resultado de las empresas en la industria eléctrica. Específicamente, propongo que el cambio tecnológico actual en las empresas eléctricas aumenta el resultado porque libera factores productivos. En segundo lugar, al estudiar las limitantes de la hipótesis principal, me concentro específicamente en el efecto de dos fuerzas en competencia, es decir, la inercia y la adaptabilidad temprana. Mi hipótesis es que la inercia, es decir, el tamaño de la empresa, tiene un impacto negativo en el efecto del cambio tecnológico en el resultado de la

empresa, debido a la dependencia de un modelo de negocio intensivo en el uso de activos; y que la adaptabilidad, es decir, la cantidad de electricidad generada por las empresas con la nueva tecnología, tiene un impacto positivo en el efecto previsto, ya que acelera los cambios regulatorios además de expandirlo a los agentes relevantes de la red para aumentar la penetración de la tecnología.

Pruebo estas hipótesis en una muestra de empresas y su resultado durante el reciente cambio tecnológico en la industria eléctrica mundial en el período 2012 a 2019. Para examinar la tensión entre la exploración y la explotación, respectivamente, de un modelo de negocio nuevo y antiguo, aprovecho tres elementos principales de este contexto. El primer elemento se relaciona con las ventajas que supusieron las inversiones iniciales en la nueva tecnología para las empresas, ya que tienen cero costos variables para producir energía en comparación con las centrales eléctricas de combustibles fósiles que necesitan comprar carbón, diésel o gas para generar electricidad. En segundo lugar, estudio la disrupción de la operación de activos renovables a costos variables cero, que cambian el orden de despacho de las plantas de generación, aumentando los costos operativos y de mantenimiento de los activos de combustibles fósiles debido a la intermitencia de su producción para cubrir la generación renovable. Sin embargo, la disminución de los costos y la presión para mantener su competitividad finalmente empujan a las empresas a adaptarse a la tecnología, incluso a riesgo de canibalizar sus actuales activos de combustibles fósiles. En tercer lugar, estudio la adaptabilidad a la nueva tecnología. A medida que aumenta la generación de electricidad mediante nuevas tecnologías, hay un aumento correspondiente en el número de empresas que adoptan esta tecnología. Esta tendencia va acompañada de un creciente consenso entre las partes interesadas sobre la necesidad de modificaciones regulatorias para dar cabida a la nueva tecnología en el sistema eléctrico. Un acuerdo amplio entre los actores facilita el proceso de obtención e implementación de estas

modificaciones regulatorias, acelerando así la incorporación de la nueva tecnología al sistema. Provocando más inversiones y atrayendo más participantes.

Analizo cómo el cambio tecnológico influye en el resultado de las empresas, específicamente en función de su inercia o capacidad de adaptación, utilizando datos sobre empresas eléctricas de todo el mundo de Orbis, fusionados con datos de la industria y el cambio tecnológico de la base de datos del Banco Mundial, Lazard y la Agencia Internacional de Energías Renovables (IRENA). Del universo de empresas eléctricas cubiertas en la base de datos Orbis (N= 80.640), la combinación de las cuatro fuentes de datos arrojó una muestra de 504 empresas que operan en 63 países diferentes. Consideré el período de 2012 a 2019 porque hubo un cambio tecnológico dramático en el sector, reflejado en una disminución relevante de costos, y también por su disponibilidad de datos.

Analicé cómo el cambio tecnológico afecta el resultado de una empresa y cómo la inercia y la capacidad de adaptación de la empresa moderan este impacto. La principal variable independiente es el cambio tecnológico, medido a nivel industrial como Costo Nivelado de Energía relacionado con plantas de energía en base a paneles solares (y turbinas eólicas terrestres para la prueba de robustez). Una disminución en el Costo Nivelado de la Energía, significa que la tecnología se ha hecho más barata, entonces ha ocurrido un Cambio Tecnológico. Los dos moderadores son la inercia y la adaptabilidad. Inercia medida por medio de los Activos Fijos de la Empresa, reflejando también los recursos acumulados y el tamaño de la empresa. Adaptabilidad medida en la generación anual de electricidad solar del país (y eólica para la prueba de robustez), lo que refleja cuán intensivamente se ha adoptado la tecnología en el mercado. La variable dependiente es el valor actual de la capitalización de mercado de la empresa.

Los análisis mostraron que una disminución de 1 USD/MWh en el costo nivelado de la energía solar fotovoltaica está asociada con un aumento de 19,7 millones de USD en la capitalización de mercado de las empresas. El efecto aumenta hasta los 52,2 millones en capitalización bursátil cuando la tecnología es eólica. Estas cifras son significativas, ya que la capitalización de mercado promedio de las empresas de la muestra es de 3.911,3 millones de dólares. El coste nivelado de la energía solar fotovoltaica disminuyó 82 USD/MWh durante el período de observación. Este efecto se traduce en un aumento del 40% en la capitalización de mercado (tanto solar como eólica). Sin embargo, contrariamente a lo que esperaba, dicho impacto se amplifica cuando el efecto es moderado por la inercia. Este resultado podría deberse al hecho de que las ventajas de la inercia representadas por el tamaño de la empresa son mayores que sus costos en la industria eléctrica, incluso bajo cambios tecnológicos. Siguiendo mi predicción, este efecto se amplifica cuando el efecto principal es moderado por la Adaptabilidad. Este resultado podría deberse a externalidades positivas de la adopción de una tecnología en particular: es posible que cuanto mayor sea el número de empresas que estén dispuestas a adoptar la nueva tecnología, mayor será el consenso entre las partes interesadas sobre los cambios regulatorios necesarios para internalizar el nuevo costo de operación del sistema con la nueva tecnología, haciendo que la adaptación de la normativa sea fácil de obtener e implementar.

Postulo que el mecanismo detrás de estos hallazgos es que el cambio tecnológico observado desafía la legitimidad de las empresas eléctricas “tradicionales”. En el estudio de la ambidestreza organizacional, el papel de la legitimidad emerge como un factor clave que intensifica la tensión entre explotación y exploración (Zhong, Zhao, and Song 2023; Hahn et al. 2015). La tensión radica en la capacidad de una organización para mantener su legitimidad y al mismo tiempo participar en prácticas disruptivas, necesarias para la supervivencia y la prosperidad futuras. La legitimidad se considera un recurso político que debe establecerse antes

de alcanzar objetivos económicos (Shaffer 1995; Bucheli and Salvaj 2013; Bucheli and Salvaj 2018). La legitimidad actúa como facilitador y limitante en la implementación efectiva de estrategias ambidiestras, lo que la convierte en un elemento crítico para comprender cómo las organizaciones se adaptan a entornos institucionales de múltiples lógicas (Patala et al. 2019; Bucheli and Salvaj 2013; Greenwood et al. 2011).

Para explorar esta idea, utilicé modelos de análisis de texto (Topic Modeling) y análisis en NVIVO de 26 entrevistas a ejecutivos de compañías eléctricas. En el campo de las ciencias sociales, los modelos de análisis de texto han encontrado numerosas aplicaciones, que incluyen, entre otras, identificar las preferencias de los consumidores, descubrir estructuras semánticas, mejorar los sistemas de recomendación y respaldar la gestión estratégica en análisis de negocios (Pröllochs and Feuerriegel 2020; Egger and Yu 2022). Estos análisis sugieren que la legitimidad puede actuar como un mecanismo crucial para que las empresas alcancen sus objetivos económicos. Influye en la adaptabilidad del modelo de negocio a lo largo de la vida del activo y es vital para las decisiones de inversión, atraer inversores y adquirir y mantener talento (Mahmud 2019). La legitimidad opera como una licencia social, protege la marca y las operaciones de una empresa, y es esencial para las empresas sostenibles que buscan impactos sociales y ambientales positivos (Ferreira, Merendino, and Meadows 2021). Aceptar la diversidad en la organización aumenta las respuestas a los desafíos y la rentabilidad. La legitimidad es fundamental para el éxito, la aceptación social y poder triunfar en un entorno empresarial dinámico (Biloslavo et al. 2020).

Estos hallazgos contribuyen a las discusiones académicas en curso sobre el cambio tecnológico y la ambidestreza. En primer lugar, este estudio contribuye a las conversaciones en curso sobre el desempeño de las empresas al ofrecer ideas novedosas sobre cómo continuar desempeñándose en situaciones de cambio tecnológico: las empresas no solo necesitan innovar

sino también adaptar su modelo de negocio (Foss and Saebi 2016; Vorbach, Wipfler, and Schimpf 2017; Massa, Tucci, and Afuah 2017; Calia, Guerrini, and Moura 2007; Zott and Amit 2008). Los modelos de negocio son esenciales cuando se crea una empresa; pero mantener la viabilidad del modelo es una tarea continua (Teece 2010). La falta de consideración de los modelos de negocios en la teoría administrativa probablemente se debe a la presencia de construcciones teóricas que sustentan que los mercados resuelvan los problemas, que en la práctica hace necesario la creación de modelos de negocios (Teece 2010).

La segunda contribución de este estudio es ofrecer la ambidestreza como marco teórico para los investigadores que exploran el fenómeno de la adopción del cambio tecnológico. Las organizaciones intentan gestionar una serie de dualidades, como exploración y explotación, integración y capacidad de respuesta, bajo costo y diferenciación, eficiencia y flexibilidad, etc. El manejo simultáneo de estas tensiones se ha enmarcado como una cuestión de ambidestreza, y la teoría que sustenta la ambidestreza se ha utilizado para explorar las respuestas a dichas preguntas. La gestión de dos tecnologías en conflicto es sólo una más de estas dualidades que debe afrontar una empresa. Como resultado, la literatura sobre ambidestreza puede guiar la discusión sobre cómo hacer esto (Gulati and Puranam 2009; Markides 2013; Cozzolino, Verona, and Rothaermel 2018; Winterhalter, Zeschky, and Gassmann 2016; Kaulio, Thorén, and Rohrbeck 2017; Raisch et al. 2009; Alänge and Steiber 2018; O'Reilly and Tushman 2013; He and Wong 2004; Ossenbrink, Hoppmann, and Hoffmann 2019; Chakma, Paul, and Dhir 2021; Andriopoulos and Lewis 2009; Katou, Budhwar, and Patel 2021; Jansen et al. 2009; Zhong, Zhao, and Song 2023; Hahn, et al. 2015; Luo et al. 2019). La creciente atención a esta literatura proviene del hecho de que cada industria tiene su propio conjunto único de desafíos y oportunidades, tanto para las empresas establecidas como para las entrantes. Entre estas industrias, el sector eléctrico – debido a los recientes cambios tecnológicos asociados a las energías renovables se caracteriza por la

tensión clásica de exploración y explotación— permanece relativamente inexplorado en términos de su dinámica de ambidestreza.

Desde una perspectiva gerencial, estos hallazgos también mejoran nuestra comprensión del impacto del cambio tecnológico en el resultado de la empresa. El estudio sugiere que el cambio tecnológico actual en el sector eléctrico, al agregar nuevos factores productivos, no deteriorará el resultado del modelo de negocios de la empresa. Esto implica que el fenómeno empírico de la caída en resultado de las empresas ante un cambio tecnológico radical puede no observarse en esta oportunidad (Cozzolino, Verona, and Rothaermel 2018; Cozzolino and Rothaermel 2018). Además, comprender cómo el cambio tecnológico impacta en el resultado de las empresas, específicamente en función de su inercia y capacidad de adaptación, podría mejorar la transición de las empresas establecidas a la nueva tecnología. Esto adquiere especial relevancia ya que permite preservar las inversiones en activos existentes así como sus puestos de trabajo. A nivel mundial, se estima que el sector eléctrico tiene inversiones superiores a los 23.000 billones de dólares y emplea a 28 millones de personas solo en el sector de generación (Montt, Maître, and Amo-Agyei 2018).

CONCLUSIÓN

Muchos imponderables están absorbiendo los beneficios de las tecnologías emergentes. Si fuera fácil, todas las empresas lo harían y la ventaja competitiva desaparecería fácilmente. De hecho, para las empresas resulta extremadamente difícil y desafiante crear valor con nuevas tecnologías.

El mercado de la electricidad y los modelos de negocio actuales de las empresas de servicios públicos tradicionales se encuentran en un momento precario de la historia, tratando de manejar la creciente disrupción que ocurre en el mercado. Por un lado, las empresas están tratando de aprovechar las oportunidades creadas por sus activos y operaciones actuales, incluso, en algunos casos, haciendo que el Gobierno actúe como un gran consumidor de energía y como un accionista relevante. Por otro lado, la necesidad de avanzar hacia nuevas estructuras de mercado energético con empresas más ágiles y emprendedoras debido a la incapacidad de las actuales empresas, grandes y reacias al riesgo, para transformar sus modelos de negocio de manera real.

La industria eléctrica está entrando en un proceso similar al experimentado anteriormente por la industria de las telecomunicaciones. Ambas industrias eran industrias de servicios públicos, tenían características de monopolios naturales y eran intensivas en capital. Sin embargo, la industria de las telecomunicaciones inició su revolución tecnológica en los años 80 con la desregulación y la introducción de los primeros teléfonos móviles. Hoy en día, las telecomunicaciones como industria pueden parecer contradictorias. Por un lado, es una industria madura, con una competencia feroz entre los actores existentes basada principalmente en el precio y el rendimiento; por otro lado, es una industria emergente en la que surgen y convergen nuevas tecnologías y lógicas de negocio (Kaulio, Thorén, and Rohrbeck 2017).

De esta forma, esta investigación comienza a contribuir a una mejor comprensión de la adaptación al cambio tecnológico de las empresas eléctricas y su impacto en el desempeño. Este estudio también tiene implicaciones interesantes para los directivos, especialmente desde la perspectiva de la mejora de los modelos mentales de los directivos. El proceso de adaptación del modelo de negocio impone desafíos importantes a los gerentes que se basan en representaciones cognitivas incompletas mientras intentan comprender las dinámicas ambientales que determinan el desempeño futuro de un modelo de negocio (Moellers, et al. 2019). Los resultados exploratorios de las entrevistas mostraron que i) una gran mayoría de las transformaciones organizacionales se lograron mediante un cambio rápido y discontinuo en la mayoría o en todos los dominios de la actividad organizacional, ii) los pequeños cambios en estrategias, estructuras y distribuciones de poder no se acumularon para producir cambios fundamentales, transformaciones, y iii) cambios externos relevantes y la sucesión de los gerentes generales influyeron en las transformaciones, lo cual es consistente con Romanelli y Tushman.

A la luz de este análisis, el camino fundamental del CEO en la transformación del desempeño de la empresa es crítico, ya que podría desencadenar las condiciones para desarrollar un modelo de negocio basado en la ambidestreza. Si esto no ocurre, el propio cambio del CEO podría influir en la transformación del modelo de negocio de la empresa. Algunas de las firmas chilenas que han visto un cambio de CEO que respaldan este modelo son Engie y Gasco.

La legitimidad cada vez menor de las tecnologías energéticas convencionales ha quedado poderosamente ilustrada por la declaración del representante de la industria del carbón europea en el acuerdo COP 21 de París: “Seremos odiados y vilipendiados, de la misma manera que alguna vez los traficantes de esclavos fueron odiados y vilipendiados” (Clark 2015). En respuesta, los operadores tradicionales del sector energético están diversificando su cartera de tecnologías y gastando más recursos en nuevas tecnologías renovables. Sin embargo, al mismo tiempo, muchas

empresas siguen invirtiendo en tecnologías convencionales de combustibles fósiles que eventualmente pueden verse afectadas por juicios generalizados de ilegitimidad.

Tres aspectos de la legitimidad hacen que su mantenimiento sea intermitentemente problemático: i) las partes son a menudo heterogéneas, ii) la estabilidad a menudo implica rigidez, y iii) la institucionalización a menudo genera su propia oposición (Suchman 1995). A largo plazo, los cambios en los hábitos de la sociedad y las regulaciones, a menudo respaldados por movimientos sociales, alteran los criterios mediante los cuales se evalúa la legitimidad, desafiando a aquellas organizaciones que tardan en adaptarse o no son capaces de escuchar las diferentes demandas que el ecosistema empresarial plantea constantemente.

INTRODUCTION

Technological change is a shift to a new production function caused by an increase in the efficiency of a product or process, it is a positive modification that often arrives in waves of related innovations (Norcliffe 2018). Past studies in management have examined how firms may struggle to adapt to technological change and how despite these struggles, some firms can overcome the organizational inertia that may prevent such adaptation (Christensen and Bower 1996; Eggers and Park 2018). This past literature mainly focused on environmental factors, such as the effect of the external ecosystem and the nature of uncertainty in the era of technological shift (Hill and Rothaermel 2003; Eggers 2016; Tushman and Anderson 1996). Other works suggest that managerial and organizational cognition are also important for firms to adapt to technological change (Garud and Rappa 1994; Kammerlander, König, and Richards 2018; Kaplan 2011; Martins, Rindova, and Greenbaum 2015; Raffaelli, Glynn, and Tushman 2019; Roessler, Velamuri, and Schneckenberg 2019; Tripsas and Gavetti 2000).

Technological change and the associated changes in the firm's ecosystem, uncertainty, and modification in firm's and manager's cognition may create a tension between exploiting an old business model and exploring new technology in adapted business model (Kaulio, Thorén, and Rohrbeck 2017; O'Reilly and Tushman 2013; Ossenbrink, Hoppmann, and Hoffmann 2019). A possible explanation for firms' struggles during a period of technological change is their failure to understand that technologies do not replace other technologies in a significant technological shift. Instead, firms succeed during technological shifts when they adapt and understand that business models need to replace business models (Johnson and Suskewicz 2009). This study addresses this tension and examines *how technological change influences firm's performance, specifically depending on their inertia or ability to adapt.*

Business models can be important in shaping a firm's performance. They reflect why and how the firm creates and delivers value to customers, employees, and owners, framing its competitive position and value (Moellers, et al. 2019). In the presence of technological change, two competing mechanisms (inertia and adaptability) may affect the firm's performance. On the one hand, “an incumbent firm may be unable to adapt to a technological change even if it possesses all the necessary core knowledge associated with the innovation” (Eggers and Park 2018). On the other hand, disruptive technologies in factors of production generate “external economies of scale” incentivizing firms to adopt the new technology to exploit external benefits, creating opportunities and incentives to adopt superior technologies (Cozzolino and Rothaermel 2018; Cozzolino, Verona, and Rothaermel 2018).

To explore how technological change influences firms' performance, specifically depending on their inertia or ability to adapt, I examine the electricity industry. The electricity industry is ideal for this analysis because of the ongoing energy transition to a low carbon, sustainable energy system due to a technology shift and environmental awareness. I propose that technological changes are consequential for firm's performance in the electricity industry. Specifically, I propose that current technological change in electric firms increases performance because it frees productive factors. Second, examining the boundary conditions of this main prediction, I focus specifically on the effect of two competing forces, i.e. inertia and early adaptability. I hypothesize that Inertia, i.e. firm size, has a negative impact on the effect of technological change on firm's performance, because of dependence on high asset utilization business model; and that adaptability, i.e. the amount of electricity generated by firms with the new technology, has a positive impact on the effect predicted, as it accelerates regulatory changes as well as expand it to the relevant network agents to increase its penetration.

I test these prediction in a sample of firms and their performance during the recent technological shift in the worldwide electricity industry over the period 2012 to 2019. To examine the tension between exploration and exploitation respectively of a new and the old business model, I leverage three main elements of this context. The first element relates to the upside that brought initial investments in the new technology for firms as they have zero variable costs to produce energy compared to fossil fuel power plants that need to buy coal, diesel or gas to generate electricity. Second, I examine the disruption of operating renewable assets at zero variable costs, which change the order of dispatch of generation plants, increasing operational and maintenance costs of fossil fuel assets due to intermittency of their production to cover renewable generation. However, the decrease in costs and the pressure to maintain its competitiveness finally pushes firms to adapt to the technology, even at the risk of jeopardizing their current fossil fuel assets. Third, I examine the adaptability to the new technology. As electricity generation through new technology increases, there is a corresponding rise in the number of firms adopting this technology. This trend is accompanied by an escalating consensus among stakeholders regarding the necessity for regulatory amendments to accommodate the new technology in the electric system. Such a widespread agreement eases the process of obtaining and implementing these regulatory adaptations, thereby accelerating the incorporation of the new technology in the system. Causing more investments and attracting more participants.

I analyze how technological change influences firms' performance, specifically depending on their inertia or ability to adapt, using data about electric firms worldwide from Orbis, merged with industry and technological change data from World Bank database, Lazard, and the International Renewable Energy Agency (IRENA). Of the universe of electric firms covered in the Orbis database (N= 80,640), merging the four data sources yielded a sample of 504 firms that operate in 63 different countries. I considered the period from 2012 to 2019 because it includes a

dramatic technological change in the sector, reflected by relevant costs decrease, and also its data availability.

I analyzed how technological change impacts a firm's performance, and how the firm's inertia and ability to adapt moderate this impact. The main independent variable is Technological change, measured at the industry level as Levelized Cost of Energy related to solar panels power plants (and onshore wind turbines in a robustness test). A decrease in the Levelized Cost of Energy, means that technology has become cheaper, then a Technological Change has occurred. The two moderators are inertia and adaptability. Inertia measured at Firm's Fixed Assets, reflecting also the cumulative firm's resource and size. Adaptability measured at Country Solar electricity yearly generation, (and Wind in a robustness test), reflecting how intensive the technology has been adopted in the market. The dependent variable is the current value for Firm's Market Capitalization.

The analyses showed that a decrease of 1 USD/MWh in the levelized cost of energy for solar photovoltaic is associated with an increase of 19.7 USD million in Market Capitalization for firms. The effect increases to 52.2 million in Market Capitalization when the technology is wind. These numbers are significant, as the average market capitalization of the firms in my sample is 3,911.3 USD million. The levelized cost of energy for solar photovoltaic decreased by 82 USD/MWh over the observation period. This effect translates into a 40% increase in market capitalization (solar and wind alike). However, contrary to what I expected, such impact is amplified when the effect is moderated by Inertia. This result could be due to the fact that the advantages of inertia proxied by firm size are greater than its costs in the electric industry, even under technological changes. Following my prediction, this effect is amplified when the main effect is moderated by Adaptability. This result could be due to positive externalities of adopting a particular technology: it is possible that the higher the number of firms that are inclined to

adopt the new technology, the higher the consensus among stakeholders about regulatory changes needed to internalize the new cost of operating the system with the new technology, making the adaptation of regulations easy to obtain and implement..

I posit that the underlying mechanism behind these findings is that the observed technological change challenges the legitimacy of “traditional” electric firms. In the study of organizational ambidexterity, the role of legitimacy emerges as a key factor that intensifies the tension between exploitation and exploration (Zhong, Zhao, and Song 2023; Hahn, et al. 2015). The tension lies in the ability of an organization to maintain its legitimacy while also engaging in disruptive practices for future survival and prosperity. Legitimacy is viewed as a political resource that must be established before attaining economic goals (Shaffer 1995; Bucheli and Salvaj 2013; Bucheli and Salvaj 2018). Legitimacy serves as both a facilitator and a constraint in the effective implementation of ambidextrous strategies, making it a critical element for understanding how organizations adapt to multi-logic institutional environments (Patala, et al. 2019; Bucheli and Salvaj 2013; Greenwood, et al. 2011).

To explore this idea, I used topic modeling and NVIVO analysis of interviews to 26 executives from electric companies. In the field of social sciences, topic models have found numerous applications, including but not limited to identifying consumer preferences, uncovering semantic structures, enhancing recommendation systems, and supporting strategic management in business analytics (Pröllochs and Feuerriegel 2020; Egger and Yu 2022). These analyses suggest that that legitimacy can act as a crucial mechanism for firms to achieve their economic goals. It influences the adaptability of the business model throughout the asset's life and is vital for investment decisions, attracting investors, and acquiring and maintaining talent (Mahmud 2019). Legitimacy operates as a social license, protecting a company's brand and operations, and is essential for sustainable businesses seeking positive social and environmental impacts

(Ferreira, Merendino, and Meadows 2021). Embracing diversity in the organization increases responses to challenges and profitability. Legitimacy is fundamental for success, social acceptance, and succeeding in a dynamic business environment (Biloslavo, et al. 2020).

These findings contribute to ongoing scholarly conversations on technological change and ambidexterity. First, this study contributes to ongoing conversations on firm's performance by offering novel insights about how to continue to perform in situations of technological change, firms need not only to innovate but also to adapt their business model (Foss and Saebi 2016; Vorbach, Wipfler, and Schimpf 2017; Massa, Tucci, and Afuah 2017; Calia, Guerrini, and Moura 2007; Zott and Amit 2008). Business models are essential when the enterprise is first created; but keeping the model viable is also likely to be a continuing task (Teece 2010). The absence of focus on business models within management theory may stem from the dominance of theoretical frameworks that propose market mechanisms as solutions to challenges that, in practice are addressed by business models (Teece 2010).

The second contribution of this study is to offer ambidexterity as the theoretical framework for researchers exploring the phenomenon of technological change adoption. Organizations attempt to balance a number of dualities, including exploration versus exploitation, integration versus responsiveness, cost efficiency versus differentiation, and efficiency versus flexibility, and so on. These concurrent challenges are often conceptualized as issues of organizational ambidexterity. Ambidexterity theory provides a foundation for investigating these subjects. The challenge of managing two conflicting technologies is another duality confronting firms. As a result, the ambidexterity literature can guide the discussion on how to do this (Gulati and Puranam 2009; Markides 2013; Cozzolino, Verona, and Rothaermel 2018; Winterhalter, Zeschky, and Gassmann 2016; Kaulio, Thorén, and Rohrbeck 2017; Raisch, et al. 2009; Alänge and Steiber 2018; O'Reilly and Tushman 2013; He and Wong 2004; Ossenbrink, Hoppmann, and

Hoffmann 2019; Chakma, Paul, and Dhir 2021; Andriopoulos and Lewis 2009; Katou, Budhwar, and Patel 2021; Jansen, et al. 2009; Zhong, Zhao, and Song 2023; Hahn, et al. 2015; Luo, et al. 2019). The growing attention to this literature derives from the fact that each industry has its own unique set of challenges and opportunities, both for incumbent firms and new ventures. Among these industries, the electricity sector – which due to recent technological shifts associated to renewable energies is characterized by the classic tension of exploration and exploitation – remains relatively unexplored in terms of its ambidexterity dynamics.

From a managerial perspective, these findings also advance our understanding of the impact of technological change on firm's performance. Our study suggests that current technological change in the electric sector, as it adds new productive factors, will not harm firm's business model performance, as much as it was not the case. This implies that the empirical phenomenon of the declining performance of firms in the face of radical technological change may not be observed under these circumstances (Cozzolino, Verona, and Rothaermel 2018; Cozzolino and Rothaermel 2018). Furthermore, understanding how technological change influences firm performance, specifically depending on their inertia and ability to adapt, could improve incumbent firms' transition to the new technology. This becomes especially relevant as it allows for the preservation of investments in existing assets and their related jobs. Worldwide, the electric sector could be assumed to have investments above USD 23.000 billions and employs 28 million people just in the generation sector (Montt, Maître, and Amo-Agyei 2018).

LITERATURE REVIEW

Literature on Exploration and Exploitation

An ambidextrous person can use both the left and right hand equally. Similarly, an ambidextrous organization can explore new business opportunities while exploiting and

capitalizing on its existing businesses (Moschieri 2019). Adaptive systems that participate in exploration, excluding exploitation, are likely to find that they have the costs of experimentation without its benefits. Conversely, systems that participate in exploitation excluding exploration are likely to find themselves caught in suboptimal stable equilibria. A result, maintaining an appropriate balance between exploration and exploitation is a relevant factor in system survival and prosperity (March 1991).

Exploration and exploitation have emerged as sibling concepts supporting organizational adaptation research, yet some central issues related to them remain unknown. Among them, the organizational balance between exploration and exploitation, and the focus for the long term success (Gupta, Smith, and Shalley 2006).

Exploration and Exploitation and Business Models

Technological change can activate modifications in a firm's operational and commercial activities, and hence in its business model (Calia, Guerrini, and Moura 2007). The process of business model adaptation is not linear, and firms may need to come back to invest in their old business before they fully adjust. According to Cozzolino possible reasons for further exploitation of the old business model are i) firms' initial failures to adapt; ii) the residual value in the old model; iii) and/or new exogenous changes in the market conditions" (Cozzolino, Verona, and Rothaermel 2018). However, there are still firms that fail in the process, some of the reasons are that firms are not able to manage multiple business models and accept (partial) cannibalization of parallel business models. Another explanation may also be that they cannot discontinue established business models as they build new ones (Kaulio, Thorén, and Rohrbeck 2017).

Inertia and Adaptability

To examine how technological change influences firm's performance, we explore its boundary conditions in the forms of inertia and adaptability. Inertia is the tendency of an object to resist change and stay in its current state of motion. Scholars in management have mentioned as reasons for firms' inertia in the face of disruptions: resource dependence upon mainstream customers, the rigidity of existing routines and competences, demand uncertainty, institutional tensions in managing the different organizational demands of disruptive innovations, the propensity of firms to imitate one another, exploitation of existing knowledge instead of an exploration of new knowledge as well as economic incentives and reliance on established value networks (Konig, Schoberl, and Graf-Vlachy 2020; Tripsas and Gavetti 2000; Vorbach, Wipfler, and Schimpf 2017). Together, these elements act as inertial forces impeding profound modification of existing business models, which is typically required after disruptions (Hannan and Freeman 1977; Hannan and Freeman 1984; Hannan, Polos, and Carroll 2002; Hannan, Polos, and Carroll 2004; Cozzolino, Verona, and Rothaermel 2018).

When environmental factors change, new forms of competition emerge to challenge an organization's once protected position. In such circumstances, successful adaptation would seem to require that decision makers redefine competitive groups accordingly. However, Hannan and Freeman (1977, 1988) argued that inertial forces often prevent an organization from adapting in this way. It would seem that one critical source of inflexibility is the cognitive inertia that comes from the presence of a well-formed cognitive taxonomy (Porac and Thomas 1989).

A firm's past is assumed to create inertia in routines and structures that compromise a firm's ability to change. Acquiring a better understanding of the role of history can improve a manager's ability to put in practice organizational change (Suddaby et al. 2020). Despite its evident grasp of the objective history of its core technology and a clear future vision of where the

thread of technology would lead, Polaroid still failed. The failure was attributed to an inability to alter its business model to low-cost/high volume production and a failure to apply its extensive knowledge of digital photography to products that were inconsistent with this business model.

An additional factor of inertia is the degree of the firm's frame flexibility. This could be understood as the capability to cognitively expand an innovation's categorical boundaries and cast it as emotionally resonant with the organization's identity and competencies and competitive boundaries. Inertial forces generally constrict how firms perceive innovations, but that frame flexibility can overcome these constraints, increasing the likelihood of adoption and broadening the organization's innovation practices (Raffaelli, Glynn, and Tushman 2019).

The diffusion and adoption of new technologies are influenced by various factors such as information availability, cost, risk, and public support(Lund 2006). Disruptive technologies can create 'external economies of scale,' encouraging firms to adopt these new technologies for added benefits. This diminishes the value of previous 'internal economies of scale,' further incentivizing the adoption of disruptive technologies(Cozzolino and Rothaermel 2018; Cozzolino, Verona, and Rothaermel 2018).

Literature on Technological Change

Technological change, defined by economists as a shift to a new production function resulting from an increase in the efficiency of a product or process, is the primary source of economic growth (Solow 1957). In strictly economic terms, technological change is presented as a positive transformation that often arrives in waves of related innovations (Norcliffe 2018).

Mainstream studies divide technological change into two types. There are two general classes of technologies: i) Disruptive Technologies, which may also be termed as revolutionary, discontinuous, breakthrough, radical, emergent, or step-function technologies; ii) Incremental

Technologies, often described as evolutionary, continuous, or "nuts and bolts" technologies (Yu and Hang 2010).

A disruptive technology is a technical advance so significant that no increase in scale, efficiency, or design can make older technologies competitive with the new technology (Cozzolino and Rothaermel 2018). Disruptive innovations deserve examination. It is crucial to discuss the definition in any further research on disruptive innovation and clarify some potential misunderstandings. Some of them are disruption is a relative phenomenon, and it depends on the industry, disruptive innovation does not always imply that entrants will replace incumbents, and disruptive innovation is not equal to destructive innovation, a technological innovation that has superior performance in key dimensions with a relatively low cost structure would directly invade the mainstream market and cause more destructive effects than a normal disruptive innovation that focuses on low cost but initially lower performance (Yu and Hang 2010).

Incremental technology sees technological change originated as a process, under this conceptualization we have authors like Utterback, who relates technological change to industry life cycle. He argued that demand growth and the production and diffusion of knowledge are the forces that drive industry evolution. Changes in demand growth and technology over the period have implications for firms within an industry through industry structure, the population of the firms, and competition (Utterback 1987; Utterback 1994).

A different approach have Tushman and Anderson, who describe that technology evolves through periods of incremental change punctuated by technological breakthrough that either enhance or destroy the competence of firms in an industry (Tushman and Anderson 1986).

Firms and Legitimacy

Emerging firm's business models which harness available resources as renewable energy or big data can often be disruptive to entire sectors, industries and even the social structures in which the disruptor operates. Occurrences of disruption, while often delivering benefits to consumers, can lead to negative outcomes. These include, among others, job losses, increased inequality and diminished social cohesion, affecting firm's legitimacy (Ferreira, Merendino, and Meadows 2021; Millar, Lockett, and Ladd 2018; O'Neil 2016). "Organizations that [...] lack acceptable legitimated accounts of their activities...are more vulnerable to claims that they are negligent, irrational or unnecessary" (Meyer and Rowan 1977, p.350). Additionally most stakeholders will only engage with legitimate organizations (Deephouse et al. 2017).

The most recognized definition of legitimacy in management studies is "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman 1995, p. 574). The current literature identifies three types of legitimacy: pragmatic, normative and cognitive. All three types require a generalized assumption that organizational activities are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions. However, each type of legitimacy rests on a somewhat different behavioral dynamic (Suchman 1995).

Pragmatic legitimacy involves finding ways to identify and to satisfy the interests of specific stakeholders. In exchange, these stakeholders confer legitimacy to the organization, often resulting in commitments and resources favorable to that organization. Normative legitimacy refers to moral judgments made by the organization seeking legitimacy considering the following aspects: i) consequential, where legitimacy is given based on the firm's ability to achieve certain outcomes or its potential to do so; ii) procedural, where the legitimacy is based on the

acknowledgement of the organization's processes; iii) structural, which concerns the adoption of expected organizational forms and structures; and iv) personal, focusing on the charisma and qualities of key members of the organization seeking legitimacy. Cognitive legitimacy refers to the foundations in cognition connected with third party unquestioning of the need for, or the taken for grantedness of, the focal organization (Genus and Iskandarova 2020).

Mainstream studies see legitimacy in three different ways, as a property, process, or perception (Suddaby, Bitektine, and Haack 2017). As a property, legitimacy is viewed as an asset or resource, occurring between the organization and its external environment, facilitated by a fit between organizational attributes and external audience expectations (Suchman 1995). As a process, legitimacy is seen as an interactive social construction, occurring among multiple social actors, especially those seeking or opposing change, and is facilitated through the calculated efforts of change agents and other social actors (Johnson, Dowd, and Ridgeway 2006). As a perception, legitimacy is viewed as a social judgment, occurring between individual and collective evaluators, facilitated through judgments and actions of individuals under the influence of collective-level institutionalized judgments (Bitektine and Haack 2015). Research recognizing legitimacy as a property focuses critically on understanding how organizations create and maintain congruence between internal structural characteristics and external environmental pressures to preserve legitimacy. The process view of legitimacy draws from social construction notions, seeing reality as the daily creation and maintenance of meaning through constant interaction and language use, with legitimacy being actively and continually negotiated, rather than assumed to be a stable condition. Legitimacy-as-perception research explores how legitimacy is perceived and judged at individual and collective levels, rather than merely as a fixed property, acknowledging legitimacy's existence both at an individual level as propriety

judgment, and at a collective level as validity, encompassing shared or authorized opinions within a community.

In the longer term, changing social habits and regulations, often backed by social movements, alter the criteria by which legitimacy is evaluated, challenging those organizations that are slow to adapt (Deephouse, et al. 2017). The process of maintaining legitimacy involves moving over time between satisfying what is important to an organization and to external audiences (Genus and Iskandarova 2020). Three aspects of legitimacy make its maintenance at least intermittently problematic: i) third parties are often heterogeneous, ii) stability often entails rigidity, and iii) institutionalization often generates its own opposition (Suchman 1995).

Unlike legitimacy maintenance, legitimacy repair represents a reactive answer to an unexpected crisis of meaning. Such situations generally arise due to managers who have become engaged in their own legitimating stories and overlook a warning of cultural support. This lack of awareness persists until a triggering event, such as an interruption of resources, sounds the alarms. By the time these managers start to address the issue, their usual strategies and claims for legitimacy may have already lost credibility. Suddenly, the successes of the past become impediments to the future (Suchman 1995).

The search of proactive legitimation approaches is vital for the success of firm's business model innovation, as the gaining of legitimacy in this case is more difficult than is the case of innovating a specific product, process or management technique because more stakeholders are involved. Adopting a sustainable business model approach helps to know how businesses can create benefit not only for customers but also for employees, vendors, society and the environment in general and how this value is captured and distributed across this broad set of parties (Biloslavo et al. 2020)

The findings indicate that the disruption caused by business models undermines the firms' legitimacy, frequently affecting multiple dimensions of legitimacy. Consequently, firms face the need to actively manage their legitimacy by involving external stakeholders and implementing moderate changes to the way they compete. This approach aims to recuperate some degree of legitimacy while continuing to be disruptive (Ferreira, Merendino, and Meadows 2021).

Exploration and Exploitation and Legitimacy

In the study of organizational ambidexterity, the role of legitimacy emerges as a key factor that intensifies the tension between exploitation and exploration. The intersection of legitimacy and ambidexterity becomes especially salient when navigating multiple institutional logics. The tension lies in the ability of an organization to maintain its legitimacy while also engaging in disruptive practices for future survival and prosperity. Failure to manage this equilibrium could lead to severe loss of legitimacy, and outcome that is particularly detrimental in controversial industries where the standard for scrutiny are elevated (Bucheli and Salvaj 2013). Thus, legitimacy serves as both a facilitator and a constraint in the effective implementation of ambidextrous strategies, making it a critical element for understanding how organizations adapt to a multi-logic institutional environments (Zhong, Zhao, and Song 2023; Reast et al. 2013; Hahn, et al. 2015; Patala, et al. 2019; Greenwood, et al. 2011).

THE EMPIRICAL CONTEXT: THE ELECTRICITY INDUSTRY WORLDWIDE

During the last 100 years, "energy industries have barely evolved" (Seba 2014). The electric power grid was developed on an architectural assumption of a centralized generation being delivered to passive distributed loads irrespective of the cost required to do so. The primary sources of energy came from large scale exploitation and utilization of fossil fuels, mainly coal. From a regulatory point of view, because of its "natural monopoly concept", the electric power

sector was a vertically integrated utility, regulated by the state of the country in which the service operated. However, several new energy management change drivers are emerging to uproot this status quo, among them the rising demand for electricity, the emergence of renewable energy sources, the appearance of electrified transportation and batteries, the deregulation of power markets and innovations in smart grid technology (Muhanji, Flint, and Farid 2019). All of them can create commercial and technological innovations and disrupt the traditional utility business model.

While during the last 100 years, the electric firms' business model circled about sustaining innovation on the possessed technology, becoming the firms the expert on the field, and the ones who pursued regulatory changes. The customer just took what was available either in form, price, and reliability. However, during the last years, the industry has been impacted by disruptive technological changes and deregulation, which has allowed competition through new entrants and changing customers' behavior. This new environment creates internal tension in the organization. On the one side, the "old business model" provides current performance through revenues and return. On the other side, the external forces push top management teams to innovate their business model.

The Electricity Sector as Socio Technical System.

Electric power systems are not just technical structures but also reflect the resources, knowledge, and values of the societies that build them, they are socio technical systems. To understand how power systems evolve, researchers need to consider the changing resources and aspirations of organizations, groups, and individuals. While power systems across societies and time share fundamental technical elements and connections, differences in these systems often reflect variations in resources, traditions, politics, and economics (Hughes 1993).

Technological innovations in the electricity industry, supported by public policy agendas and changing consumer profiles are pressuring stable and reliable systems. For understanding its adaptation process, it becomes relevant to remind that power systems are cultural objects (Hughes 1993; Pereira et al. 2018). Significant amounts of labor, capital, and effort are invested in established socio-technical systems, leading to the development of their own inertia or lock-in effect, making them highly resistant to change (Sovacool 2016a). As Lund (2005, p 3317) notes, “the inertia of energy systems against changes is large, among others because of the long investment cycles of energy infrastructures or production plants”(Lund 2006).

The objective of market liberalization in the electricity industry was to improve the affordability and quality of electricity services. However, in times of disruptive change within the electricity sector, it can be advantageous to have a comprehensive understanding of the sector, particularly when considering its socio-technical aspects, as it was the case in vertically integrated utilities business models. Taking into account the entire electricity sector becomes beneficial when striving for innovation (Pereira, et al. 2018).

Electricity as a commodity and its implications in the structure of the industry

The electricity industry is heavily dependent on natural resources for power generation. Fossil fuels like coal, oil, and natural gas, which are non-renewable natural resources, have traditionally been the primary sources of electricity. These resources are extracted, processed, and burned to generate electricity, releasing greenhouse gases. Renewable resources like wind, solar, and hydro power are increasingly being used, harnessing natural phenomena to generate electricity with less environmental impact (IEA 2023; IRENA 2021). As such, the electricity industry and the natural resource industries share some common characteristic like i) the standardized nature of their products, ii) their emphasis on process-based innovations, iii) the

presence of dual physical and financial derivative markets, and iv) the importance of nonmarket forces that affect the creation and appropriation of rents from natural resources (Casarin, Lazzarini, and Vassolo 2020).

Energy landscapes vary locally, and technological substitution depends on the interactions possible within a specific region. The availability of natural resources largely determines the energy portfolio of each region. Local resources are evaluated and ranked based on extraction costs, shaping the regional electricity sector unless trading with neighboring regions proves more cost-effective. The cost-supply curves in each region establish the marginal cost of electricity production, resulting in different electricity prices worldwide. Consequently, electricity trading occurs between regions with connected grids, allowing resource-poor regions to access electricity from resource-rich ones (Mercure 2012).

The trend of decreasing prices observed in industries where products have distinguishing features and face growing competition, does not necessarily apply to natural resource industries. Instead, the prices of natural resources experience periods of fluctuation known as shorter cycles or super cycles depending on its duration (Casarin, Lazzarini, and Vassolo 2020). Electricity is a basic commodity for which reason the price often dominates the competition over innovative features. To survive in industries without product differentiation, firms need highly efficient cost structures to maintain long-term viability (Vassolo and Weisz 2022; Lund 2006; Mercure 2012). As such, one of the most important drivers of change in the electricity sector is the cost reduction that stems from technological learning triggered by cumulative investment (Mercure 2012). Technological change has not altered the product per se, only the way is produced. Electron stills an electron.

When the primary focus of innovations lies in increasing the productivity of existing resources through process improvements, it tends to raise specialization. As time passes,

commodity producers become more effective, leading to a greater inclination to invest in initiatives specific to their own firms to leverage their improved competitive advantage. Moreover, the decreased frequency of major product innovations restricts the emergence of new competitors equipped with fresh business models or unique capabilities (Casarin, Lazzarini, and Vassolo 2020).

The relevance of regulation and political engagement in the electricity industry

Regulation in the electricity industry is crucial due to the sector's unique characteristics. Electricity is a good of first necessity, and its production often depends on natural resources, while its transmission and distribution depends on the grid, making it susceptible to monopolistic tendencies. For example, the electricity grid, a key component of the industry, is a natural monopoly due to high infrastructure costs and the impracticality of multiple competing networks. Therefore, regulation is necessary to prevent monopolistic exploitation, ensure fair pricing, and promote competition where possible. It also helps to increase investment attractiveness, and ensure sustainable use of resources (Berlach 2019).

The regulation and exposure of electricity firms to government policies create a need for firms to formulate strategies that can adapt to and even influence these policies. Firms employ various tactics, such as environmental scanning, lobbying, coalition building, and even trade associations, to safeguard and promote their political interests. Many senior executives view attention to government affairs as an essential aspect of their roles, serving both as a defensive measure against regulatory interference and as a method of gaining a competitive edge for their organizations (Shaffer 1995).

Business Model and Performance in the Electricity Industry

The electric sector has long been viewed as having economies of scale and scope. The term economies of scale implies that larger firms are more efficient than smaller firms, causing natural monopolies. In this case, the term economies of scope mean that one firm can provide generation, transmission, and distribution service more efficiently than separate firms providing each type of service. Such a type of firm is referred to as a vertically integrated firm (Blumsack 2020). For nearly one hundred years, the electric sector was a vertically-integrated utility, however during the last 30 years, many countries unbundled generation, transmission and distribution and privatized their electricity sectors. In most cases, the generation has been liberalized and opened to competition. While both transmission and distribution remain "natural monopolies" price caps have dramatically changed how they are regulated.¹

On one hand the electric sector is intensive in capital, as it shows figure 1, it has been increasing its investment during the last 10 years, just in 2018 reached USD 775 billions. It could be assumed that the sector has a stock investment above USD 23.250 billions.² During 2018 overall, low-carbon power generation (renewables and nuclear) comprised nearly three-quarters of generation spending. Figure 2 shows how coal maintains its installed capacity while there is an exponential increase in solar photovoltaic and wind for the coming years, reflecting the competitiveness of those technologies as well as environmental awareness.

Insert Figure 1 about here

¹ Most regulation tariffs occur through a process known as "rate of return regulation." Under rate of return regulation, the utility sets prices (rates that are paid by retail customers) to recover the costs associated with providing service, plus a level of profit determined by the state.

² Considering a 30 years average useful life, and assuming 2018 investment equal for each year during that period

Insert Figure 2 about here

On the other hand, over the period 2000-2014, as shown in figure 3, employment in the electricity generation sector increased by more than 63%. More than 15 million jobs existed worldwide in the sector in 2000; by 2014, almost 25 million people were employed in the electricity generation sector. Employment growth is driven, almost exclusively, by a practically constant growth in developing and emerging economies, adding, on average, 534 800 jobs a year to the sector (Montt, Maître, and Amo-Agyei 2018). Based on the before mentioned 28 millions jobs in the sector were expected by 2020.

Insert Figure 3 about here

As market dynamics continue to force the hand of electric generation firms globally, changing the business models away from one of a conventional large scale, centralized grid based system to one that embraces distributed renewable generation and storage across the entire network could cause that centralized power stations, whose business cases are reliant on high utilization, start decreasing its uses, increasing the risk of stranded assets, large write-downs and accountants having to mark these once assets as liabilities. Asset holders, then, could find themselves with a large sunk cost that can never recover from the project itself.

Thus, large electric generation firms need new organizational solutions and business activities, which can be achieved through innovation according to market trends. However, the rigorous regulation and the rigid institutional context limit opportunities. Moreover, the large size of the electric generation firms, the highly concentrated markets, and traditional technologies'

dominance result in organizational inertia and path dependency, suppressing innovation and organizational change (Zavarkó et al. 2017).

One effective approach to understanding the connection between business models and energy transitions involves considering the coordination between activities and socio-technical systems. In this regard, accomplished entrepreneurs or managers who develop successful business models play the role of system architects. They achieve this by forming partnerships to access resources like financial support and technical knowledge, and by weaving together various technological, political, economic, and social elements into a coherent framework. The key challenge lies in aligning the substance, arrangement, and management of the business model with the evolving socio-technical context. This requires adapting to dynamic changes in regulatory structures, such as energy markets and utility business practices, as well as the political framework that shapes decision-making processes (Bolton and Hannon 2016).

Electric generation firms undertaking future business planning and strategy development should be open to business model explorations, although this may require a change in mindset to see technology innovations as growth opportunities rather than as existential threats, acknowledging that innovation is inevitable and may drive existing business models to become obsolete (Tayal and Rauland 2017). As the market changes, firms try to adapt in different forms their business models, reflecting dissimilar results in the financial markets, as shown in Figure 4. As electric generation firms fulfill an important role in asset allocation, understanding its process becomes important.

Insert Figure 4 about here

Technology and the Energy Transition

The increase in renewable investments has primarily been driven by a high reduction in costs, making them competitive against fossil fuel sources. Special consideration needs to be given to solar and wind technologies, as shown in figure 5. To effectively keep reducing costs, the variable nature of the solar and wind resources will require significant changes to how the power system operates as the share of variable renewable energy, as solar and wind, reach high levels. This will require adequate flexibility to maintain grid stability and reliability. Changes will be needed to manage the grid on a minute-by-minute basis while also taking into consideration seasonal variations in solar and wind output. Therefore storage plays a key role in allowing higher rates of renewable energy penetration. During the last years, its cost has been reduced dramatically, as it shows in figure 6.

Insert Figure 5 about here

Insert Figure 6 about here

However, fossil fuels still domain in the world electricity matrix. Until 2016 they were responsible for 66% of electricity generation. Even more, driven by higher energy demand in 2018, especially electricity and heat producer (responsible for close to 41% of total CO2 emissions), global energy related CO2 emissions rose to a historic high. Following the decrease of investment costs, on the price side, auction energy prices for long term contracts are continually decreasing, supported in the maturity that has reached Photovoltaic Solar and Wind

technologies. Other factors are public policies related to renewable energy and the design of the auction itself (IRENA 2019).

Insert Figure 7 about here

During the last years, the trend has continued. Reaching historically low prices. The world is living an energy transition, according to some definition it refers as "the time that elapses between the introduction of a new primary energy source, or prime mover, and its rise to claiming a substantial share of the overall market"(Sovacool 2016b). Major European energy transitions since 1800 all went through phases of having a core or innovation center, where that innovation began, moving upward to early adopters to, lastly, the late adopters. The time it took to transition from pre-industrial biomass ("traditional renewables") to coal ranged from 96 to 160 years. The shift again from coal to oil and electricity was more rapid, but it still ranged from 47 to 69 years for those technologies (Sovacool 2016a).

Studies of industry evolution following significant changes in technology have documented a consistent pattern of progress, falling into three prototypical stages: an era of ferment, convergence on a dominant design, and an era of incremental change (Benner and Tripsas 2012). Understanding how long it takes to pass through an energy transition provides context on how firms should adapt their business model. History also provides some lessons about the way countries and firms had lived it. As big transitions are the sum of many small ones, looking only at overall energy consumption will miss the small-scale changes that are the foundation of the transitions. As an example, the big ascent of oil at the start of the previous century can also be understood as a series of less grand changes involving: i) The change from animal power to internal combustion engines for private vehicles and the social refusal of electric

vehicles; ii) The conversion of steam engines on ships and locomotives to diesel for marine vessels and trains; iii) The shift from candles and kerosene for lighting to oil based lamps ; iv) The adaptation of coal boilers to oil boilers for the generation of electric power ; v) The exchange of wooden fireplaces and coal stoves to oil and gas furnaces in homes (Sovacool 2016a). History in Europe reveals a pattern of "first in, last out; and last in, first out" for the lifecycle of related energy technologies and systems. Sometimes, late adopters stick with the technology even past its point of competitiveness or attractiveness. In other situations, early adopters overinvest in technology and get stuck. They find it difficult to get out compared to latecomers (Sovacool 2016a).

Legitimacy in the Electric Industry

Despite their long-standing existence, the electricity industry can be considered controversial, often struggling to maintain its organizational legitimacy. Controversial industries are perceived as unethical or offensive due to their potential social, environmental, and economic impacts (Reast, et al. 2013). Balancing the need to manage these impacts while maintaining service quality, setting fair prices, navigating complex stakeholders' relations, and renting longstanding assets become crucial. By adopting an ambidextrous approach, organizations can manage their controversial status and enhance their ability to succeed in the challenging contexts. The electric industry is transitioning from fossil fuels to renewable energy, from centralized generation to distributed generation, from asset-oriented to customer focus. This transition is creating significant challenges for firms, regulators, and communities.

Considering the source of energy to generate electricity, the exploitation of natural resources also produces unique challenges in terms of dealing with stakeholder relations and interacting with multiple public and private actors directly or indirectly affected by firm level

strategies. Managing this relationship could go from the assumption that there is a power imbalance between the organization and external groups who could employ different strategies to withhold the resource (Berman, Phillips, and Wicks 2005) to that the exploitation of local resources can be seen as illegitimate, particularly when conducted by firms that lack a shared social identity with the communities (Casarin, Lazzarini, and Vassolo 2020).

Transitioning from assets based on fossil fuels to renewables maintaining the electric system's reliability is another challenge. Especially when considering the intermittency of renewable energy, in conjunction with the scarcity of complementary sources of electricity due to: i) lower levels of hydropower because of the drought and ii) fossil fuels' loss of legitimacy due to their impact on climate change because of their related emissions.

In general, electric firms' business models have been based on long-term investments, 20 or more years, located close to the trunk system to inject electricity in the system. Although the assets are built complying with all regulations, it is expected that somebody will be disturbed at some point during its useful life, as it could be the case with locations, as probably in the future the power plant will become somebody's backyard as cities are expanding. Considering that generation assets are the type of infrastructure that cannot be relocated, at some point, if firms do not proactively manage their legitimacy during all the useful life of the asset, their investments will be at risk, independently, if firms comply with the different regulations and their assets are still needed by the electric system.

Energy activists and the global climate change debate are challenging fossil fuel-based technologies, while promoting renewables as an environmentally friendly solution. The before mentioned has put pressure on energy incumbents to invest in renewable energy, but the industry is still locked into conventional fossil fuel-based technologies. The current period is distinguished by conventional technologies losing legitimacy while new technologies gain legitimacy.

Eventually, this may lead to widespread illegitimacy which may become a real liability for energy incumbents, as has occurred with tobacco, fast food, and arms firms (Patala, et al. 2019).

The lessening legitimacy of fossil fuels energy technologies has been showed by the statement of the European coal industry representative to the Paris COP 21: “We will be hated and vilified, in the same way that slave traders were once hated and vilified” (Clark 2015). In reaction, energy incumbents are expanding their technology portfolio and investing more resources on new renewable technologies. However, simultaneously, many incumbents keep investing in conventional fossil fuel technologies that may be influenced by widespread illegitimacy judgment (Patala, et al. 2019).

When confronted with institutional change, incumbents may adopt an ambidextrous approach, simultaneously defending existing technologies while embracing new ones. Ambidextrous responses are often observed in incumbents who, despite benefiting from the current status, possess the capability to adopt new technologies for future success. Energy incumbents rhetorically legitimate their ambidextrous role when technology choices pose a value conflict. They construct dual yet interconnected narratives for stakeholders under the concept of clean energy. They align their strategy to the new technology, while simultaneously emphasizing the functional attributes of the older technology (Patala, et al. 2019).

Reflecting the before mentioned, during the last couple of years, the electric industry worldwide has seen examples of different acts related to legitimacy: i) parliament discussing to reduce the rate of return of some electric assets related to regulated services, ii) communities not allowing coal power plants to continue operations, iii) energy activist discussing to close fossil fuel power plants but at the same time firms justifying their investment in fossil fuels power plants to complement renewable intermittency.

HYPOTHESES

Technological Change and Performance in Electric Firms

For a firm to successfully adapt to a given technological change, it must be able to possess the new technological knowledge and at the same time the complementary assets and the capabilities to use and commercialize the new technology. There are three types of barriers to adapting the new technology in the firm: i) external barriers that hinder external acquisition of new knowledge and complementary resources, ii) internal barriers that hinder assimilation, and iii) internal barriers that hinder reconfiguration and integration. Overcoming these barriers is central to a firm's adaptation (Eggers and Park 2018).

Creating new business models create sustainable value, impacting firm's performance. This is one of the main ways for firms to create value. Other alternatives are i) creating more efficient business, as resources are used in a better way, ii) creating more effective business, as end customers are served in a better way (Van Heck 2019).

Utterback (1987: p.18) proposes that the conditions required for rapid innovation are extremely different from those required for high levels of output and productivity. "Under demands for rapid innovation, organizational structure will be fluid and flexible, whereas, under demands for high levels of output and productivity, organizational structure will be standardized and inflexible".

Performance during technological transitions is improved by experimentation, and the exploitive nature of process management hinders experimentation. Once process management is built into the operations, it acts as an inertial force (Eggers and Park 2018).

The tension is also seen in Christensen and Raynor (2003), who proposes that incumbent firms do need to respond to disruption if it is occurring. Still, they should not overreact by

dismantling a still-profitable business. Instead, they should continue to strengthen relationships with core customers by investing in sustaining innovations. In addition, they can create a new division focused solely on the growth opportunities that arise from the disruption. That means that for some time, firms will find themselves managing two very different operations (Christensen, Raynor, and McDonald 2015).

The literature has provided evidence of the important role of business models in firm performance, competitive advantage, and innovation at the firm and industry level. However, disruptions may affect the efficacy of existing business models. The new technologies disrupt the established trajectory of performance improvement and redefine what performance means. Disruptive technologies tend to come first and do not necessarily paralyze firms, but rather create opportunities. Disruptive business models tend to emerge when firms find ways to commercialize previous disruptive technologies, threatening firms' business models (Cozzolino, Verona, and Rothaermel 2018).

Firms are likely to invest and experiment early when disruptive technologies make new factors of production available. This exception to the common inertial prediction that firms do not allocate resources and efforts to disruptions (Cozzolino, Verona, and Rothaermel 2018). This could explain the reason firms have invested in renewable energy while cannibalizing their coal and diesel assets. The same is happening as firms try to exploit the data they generate from customers and assets operations which drive to replace their investments in information systems.

At the beginning of the study period, electric firms' generation assets were mainly fossil fuel sources, which meant that to generate electricity, firms had to buy raw materials, and

electricity had a variable cost³. Electricity from solar and wind technologies have zero variable cost, as sun and wind are free, so the question was to evaluate capital investment costs against electricity tariff. If the evaluation did not reach the investment point, generally, firms invested in learning the technology. While time passed and solar and wind technology costs decreased, the number of investments grew due to positive returns. As these new renewable energy assets were not relevant in the electric system, the projects based on these technologies were treated as new sources of electricity at zero variable costs and green, replacing new investments in fossil fuels power plants. However, still, fossil fuel plants were the base.

In the electricity industry, legitimacy has played a crucial role in facilitating technological change, especially in the focus to renewable energy sources. The traditional dependency on fossil fuels has been contested due to its environmental implications, challenging the industry legitimacy. Technological change is seen a pathway to regain or maintain legitimacy by aligning the industry with societal environmental expectations. By transitioning to renewable energy sources the industry navigates the pressures from multiple stakeholders advocating cleaner practices.(Clark 2015; Bergek, Jacobsson, and Sandén 2008)

H1 (baseline): Current technological change increases the performance of firms operating in the electricity industry.

The Moderating Effects of Inertia and Adaptability in Firms' Performance

Electric firms' business models depend on asset leverage (grid network, power plant, substations, etc). Firms treat them as sunk costs. When firms evaluate new investments, any

³ The variable operating cost of electric power generators is a key factor in determining which units a power system operates (or "dispatches") to meet the demand for electricity. Other things being equal, plants with the lowest variable operating costs are generally dispatched first, and plants with higher variable operating costs are brought on line sequentially as electricity demand increases.

project that brings new technology potentially will be underrated, as it will absorb the totality of the investment. A project based on the leveraged asset is considered marginal, absorbing only a part of the investment. From a managerial point of view, the before mentioned dilutes any effort of bringing new changes, as firms from the power sector move slow as they have their revenue stream "guaranteed", not having the internal incentives to take new risks maintaining the inertia.

As the electricity industry is capital intensive, there is intense pressure to optimize the operational process for increasing returns. The before mentioned and the long term assets' useful life generates inertia, not allowing a smooth process to adapt the firm's business model to current technological changes. The tension between those two forces constantly raises while firms fight for productivity improvement and, at the same time, are looking for growth opportunities.

The analysis of the condition of the electric generation sector and its large energy firms, shows that there is a serious tension and implementation difficulty between the goal of continuous, secure, efficient operations on short term, and the long-term research and development and innovation strategies and investments, "technological change" (Zavarkó, et al. 2017).

The tension between the inertia, related to short term efficient operations, and innovation strategies could be transformed to a virtuous wheel if change management can transform that pressure in energy (Zavarkó, et al. 2017). The inertia of energy systems is primarily attributed to their significant resistance to change, largely due to the lengthy investment cycles associated with energy infrastructures and production plants while at the same time acknowledging that the crucial nature of energy as a fundamental commodity often leads to competition being driven by costs, which put the focus in optimization process, making difficult any change (Lund 2006).

While renewable energy increased its penetration, they started displacing the dispatch of fossil fuel plants, causing those plants to be dispatched intermittently, increasing their operational

costs, and decreasing the number of generation hours. The economics that supported the investment changed. Anticipating the before mentioned on a bigger scale, firms with many fossil fuel assets delayed their increase in renewable investments due to a change in the way their current assets will operate and the expected decrease in returns. However, the trend in costs continues, increasing the pressure to adopt the technology at a big scale to maintain its competitiveness, even at the risk of writing off current fossil fuel investments.

Building legitimacy for new technologies in the electricity industry is tough, where incumbent technologies and actors have had extensively time to solidify their positions as socially accepted entities. This scenario is reflected in the historical inertia observed in the industry, where the established legitimacy around conventional models and fuels foster resistance to change, despite environmental and societal pressures. This resistance is further cemented by high investments in fixed assets, and the pressure for returns during their long term assets useful life (Bergek, Jacobsson, and Sandén 2008; Bitektine and Haack 2015; Johnson, Dowd, and Ridgeway 2006) .

H2: Inertia has a negative impact on the effect predicted in H1. Inertia reduces the increase in performance due to technological change.

As an empirical phenomenon, the declining performance of firms in the face of radical technological change has been observed repeatedly over the years in numerous studies. Scholars often attribute this decline to firms' failure to embrace the new technology. The reasons given to explain such failure include the differential economic incentives new entrants and incumbents confront, forces of inertia within incumbents firms, and the embeddedness of incumbents within an established industry network that does not initially value the new technology (Hill and Rothaermel 2003).

This research has provided a series of significant findings. First, it is disentangled two separate forces in the disruptive process coming in 2 phases: i) the first phase is the initial advent of disruptive technologies; and ii) the second phase is the subsequent entry of disruptors introducing new business models. The second major finding relates to how firms reconfigure their models after a disruption. Firms' adaptation in the second phase is driven mainly by reactions to threats (from entrants with disruptive business models), whereas the stand-alone experimentation of the first phase is consistent with opportunity perception (from available new technologies) (Cozzolino, Verona, and Rothaermel 2018). Energy technology diffusion and adoption are influenced by factors like information availability, cost and risk considerations, public support, firms' perceptions of new technologies, and volume/size effects (Lund 2006).

Disruptive technologies in factors of production generate 'external economies of scale' and incentivize firms to adopt the new technologies to exploit external benefits. Hence, the advent of disruptive technologies does not constitute an inertial force per se, as it can create opportunities and incentives to adopt superior technologies. In addition, the emergence of external economies diminishes the firm-specific advantages of previous 'internal economies of scale,' thus incentivizing firms to adopt the external disruptive technologies (Cozzolino and Rothaermel 2018; Cozzolino, Verona, and Rothaermel 2018).

The potential for future benefits for ecosystem members and perceptions of immediate disruption generates forces for cooperation and competition between disruptors and incumbents. How does a disruptor create a vision of the future compelling enough to persuade incumbents to support its innovation despite the clear and present threat of disruption? To navigate multilateral competition successfully, a firm must manage relationships across a set of interdependent stakeholders, with changes in one relationship affecting others (Ansari, Garud, and Kumaraswamy 2016).

As the number of firms that adopted the technology increased, there were system costs that appeared, especially those related to managing the intermittence of the renewable source. So, changes in the regulation were needed to incorporate clear rules about who should pay them. The larger the amount of firms with investments in renewable is, the larger is the understanding of changes required, so new regulation is easy to consensus among participants. In addition, external network effects as the increasing number of vendors, technical knowledge, and others decrease risk perception –causing more investments and attracting more participants.

In the early adoption phase of a technology, legitimacy seeks to endorse the technology as a viable alternative to existing options through experts' opinion and rational argument. As the new technology gains support, legitimacy shift to commitment and trust from accumulated actors. Legitimacy derives not only from performance expectations but also from the actor base of the technology, making legitimacy both a prerequisite and a result of a system formation process, which are the ones born from new renewable energy technologies (Bergek, Jacobsson, and Sandén 2008; Bitektine and Haack 2015).

H3: The adaptability of the firms operating in the industry has a positive impact on the effect predicted in H1. This adaptability magnifies the increase in performance due to technological change.

RESEARCH METHODS

Research Setting

The research setting is a database of electric firms worldwide built using Orbis, Irena, World Bank, and Lazard for the period 2012 – 2019. The original sample contained 80,640 firms worldwide, but due to missing data, some firms were dropped, and the final sample is 58,775 firms. For the regression, this number decreases to 504 firms from 63 different countries,

omitting those cases with missing data for the main variables. The following table summarizes the characteristics of the firms used in the study. Their market capitalization has an average USD 3,911 million. Fixed assets have an average of USD 9,338 million and their number of employees is 5,996 in average.

Insert Table 1 about here

Data:

I used Orbis firm database, filtering firms by primary industry classification 351. Specifically, the final codes used are i) 3511 Production of electricity, ii) 3512 Transmission of electricity, iii) 3513 Distribution of electricity, and iv) 3514 Trade of electricity. 80,640 firms belonged to these industry classifications. I used for these firms time series from 2012 to 2019. I selected the following variables: i) Market Capitalization, ii) Fixed assets, iii) EV/EBITDA, iv) Return on assets, v) Tobin's Q, and vi) Number of employees. In addition, for each firm I collected the firm name as well as its country of precedence.

Then the firm database decreased to 59,270 firms as I eliminated all the firms with no data. After eliminating duplicates (i.e., 495 firms), the sample was reduced to 58,775 firms. I considered all fixed assets registered with negative numbers as missing data as probably this is a typing error from the database. This affected 19 firms.

I obtained the information for technology prices from Lazard's Levelized Cost of Energy analysis – version 15.0 and specifically from the Historical Utility-Scale Generation graph (www.lazard.com/perspective), which I utilized for all firms as this is information at industry level. I converted this information to an excel file typing the data for Solar PV Crystalline as well as Wind.

For country data for the period 2012 -2019, I used Irena and World Bank databases. Irena was used for the country annual generation produced by Solar Photovoltaic and Wind onshore technologies (<https://pxweb.irena.org/pxweb/en/IRENASTAT>) while World Bank for country GDP and CPI (<https://databank.worldbank.org/home.aspx>). Finally I merged all the data using the country of residence of each firm.

Variables

Dependent Variable

Market Capitalization: As in previous studies (Weill, Malone, and Apel 2011; Zott and Amit 2002), our dependent variable is market capitalization as a performance measure for firms. The variable is measure in million of USD.

To account for possible endogeneity issues all independent and control variables are lagged by one year with respect to the dependent variable.

Independent Variables

Hypothesis 1 predicts that *Technological change in electric firms increases performance*. To test this baseline hypothesis, I used Levelized Cost of Energy⁴ (LCOE) for Solar Photovoltaics Crystalline⁵ Utility Scale. Levelized cost of energy is widely used as a comparative measure between different sources of electricity. Over recent years renewable energy has become competitive compared to fossil fuels because of technological and commercial innovation. The decline in renewable costs is expected to continue. (Aldersey-Williams and Rubert 2019). A decrease in the Levelized Cost of Energy, means that technology has become cheaper, then a

⁴ Levelized cost of energy is a metric that provides an indication of the unity energy cost over the life of a generation plant, including capital, operating and financing costs.

⁵ Solar Photovoltaics Crystalline is the dominant semiconducting material used in the production of solar cells, which are assembled into solar panels as part of photovoltaic system to generate electricity.

Technological Change has occurred, i.e. a negative sign on the technological change coefficient means a positive impact in business model performance as technological change is related to decrease in technology price

Hypothesis 2 foresees that *Inertia has a negative impact on the effect predicted in Hypothesis 1. Inertia reduces the increase in performance due to technological change.* For Hypothesis 2, I looked at the moderating effect of the multiplication between Levelized Cost of Energy for Solar Crystalline Utility Scale and Fixed Assets, the latter as a proxy for inertia (Josefy et al. 2015; Shimizu and Hitt 2005). The substitution of technologies implies the substitution of the current stock of old technology assets with new ones. The observed composition of the fixed assets is the result of technology dissemination and stock turnover, combined with its own source of inertia, impacting the proportion of replacement (Knapp 1999).

Hypothesis 3 predicts that Adaptability of the firms operating in the industry has a positive impact on the effect predicted in Hypothesis 1. Adaptability magnifies the increase in performance due to technological change. For Hypothesis 3, I looked at the moderating effect of the multiplication between Levelized Cost of Energy for Solar Crystalline Utility Scale and Solar Generation (photovoltaic) by country, this variable reflects how intensive the technology has been adopted. Adaptability refers to diffusion of a technology, that is the level to which the technology is adopted in the market. Diffusion is key in endogenous technological change, bringing together market opportunity and learning effects to invention and innovation (Kim, Heo, and Kim 2017).

Controls

I control for factors that together with technological change, inertia and adaptability may explain the change in a firm's performance: i) Year, ii) Firm, iii) Country GDP, iv) Country CPI, v) Firm's Fixed Assets and vi) Solar Generation by country.

The following provides a detailed exposition of each variable and its respective influence.

i) Year: Firm's performance may depend on worldwide economic cycles which are reflected through the years. Thus, I include year fixed effects in all models (Cannella Jr, Park, and Lee 2008). ii) Firm: Firm's performance may depend on unobservable firm's characteristics. Thus, I include firm fixed effects in all models (Agarwal et al. 2016). iii) Country Gross Domestic Product (GDP): Firm's performance may depend on the economic situation of the country, which generally is measured through its GDP. It is expected that higher GDP leads to better firm performance. (Abeberese 2017; Sun and Tong 2003). iv) Country Consumer Price Index (CPI): Firm's performance may be affected by the country's inflation, as this variable has a direct impact on revenues as well as local costs (Irani, Katircioglu, and Gokmenoglu 2021). v) Firm's Fixed Assets: Firm's performance may be affected by firm's size, as it generates several advantages (access to resources, economies of scale and scope, higher influence, and greater legitimacy) as well as disadvantages (such as complexity, bureaucracy, and inertia). (Josefy, et al. 2015). In this study firm size, and its proxy Fixed Assets relates to Inertia. vi) Solar Generation by Country: Firm's performance may be affected by the adoption of a technology in a country and its relation with Firm's energy matrix (Doblinger, Wales, and Zimmermann 2022).

RESULTS

I started by exploring some descriptive statistics in Table 2. Market Capitalization has an average value of USD 3,911 million, with a range value between USD 118,362 million and USD

0.1 million. Fixed Assets has an average value of USD 9,338 million with a range value between USD 253,874 million and less than 1 million. Number of employees by firm has an average value 5,996 with a range value between 165,790 and 1 person. Solar generation by country has an average value of 22,198 GWh-year with a range value of 177,546 GWh-year and 0 GWh-year.

The Table 3 reports the matrix of pairwise correlations between the variables used in the regression analysis. The correlation coefficient between Market Capitalization and the Levelized Cost of Solar Energy (LCOE Solar) is -0.015 but not statistically different than zero. However, Fixed Assets and Solar Generation have values of 0.790 and 0.150 and are statistically different than zero.

In the same table, we can observe that the correlation coefficient between LCOE Solar and Solar Generation is -0.410 and statistically different from zero, which is reasonable to expect as the lower the technology price the higher the implementation of the technology, then the higher the generation by it. A similar situation we can see with LCOE Wind and Wind Generation, which has a correlation coefficient of -0.305 and it is statistically different than zero.

Related to alternative measures for the dependent variable, in the table we can observe that the EBITDA Multiple and LCOE Solar have a correlation coefficient of 0.019 which it is not statistically different than zero. Similar situation that we can observe at the correlation coefficient between Tobins Q and LCOE Solar. However, we can observe that Return on Assets has a correlation coefficient with LCOE Solar of -0.028 and it is statistically different than zero.

In the same table we can observe that Employees, an alternative measure for Inertia, has a correlation coefficient with Market Capitalization of 0.502 and it is statistically different than zero. Obviously, these values need to be further examined in a full fledged regression analysis.

Insert Table 2 about here

Insert Table 3 about here

Main Results

Table 4 reports the results of the regression analyses. In Model 1, the dependent variable is Market Capitalization and I only included the control variables. In the subsequent models, I added the independent and moderating variables one by one. The following models in this table display the results of five different specifications. The first column (model 1) is the baseline model with control variables only. Fixed Assets is statistically significant ($p < 0.01$) and has a positive sign, which reflects a direct relationship with Market Capitalization. Solar Generation is statistically significant ($p < 0.01$) and has a negative sign reflecting an inverse relationship with Market Capitalization. GDP is statistically significant ($P < 0.01$), its coefficient is 0.001 meaning that an increase of 1 USD million in the GDP increases market capitalization by 1 USD thousand. CPI is statistically significant, but only at $p < 0.05$

The second column (model 2) has only LCOE Solar as the independent variable. It shows a negative coefficient which is statistically significant ($p < 0.01$). A negative sign on the technological change coefficient means a positive impact in business model performance as technological change is related to decrease in technology price. Hypothesis 1 predicts that a decrease in technology price will increase firm's Market Capitalization. In the third regression (model 3) I added the interaction between LCOE Solar and Fixed Assets to see how Inertia moderates the impact of Technology in Market Capitalization. This relationship shows a negative sign and it is statistically significant ($p < 0.01$) In the fourth regression (model 4) I added the

interaction between LCOE Solar and Solar Generation to analyze how Adaptability moderates the impact of Technology on Market Capitalization. This relationship shows a negative sign and it is statistically significant ($p < 0.01$)

Effects Size

Using the Model 2 of Table 4 and Table 5, I calculated the size of the predicted effects, the results indicate that the marginal effect of having a decrease of 1 USD/MWh in LCOE Solar increases a firm's market capitalization by 19.7 USD million, and this effect is statistically significant ($p < 0.01$). The effect increases to 52.2 million when the technology is wind, and its effect is statistically significant ($p < 0.01$). The size of these effects is not negligible, given that the average market capitalization of the firm in my sample is 3,911.3 USD million. The levelized cost of energy for solar photovoltaic decreased 82 USD/MWh over the observation period. This effect translates into a 40% increase in market capitalization (solar and wind alike).

Continuing with the analysis in Table 4, Model 3, I can see that the interaction term is negative and statistically significant at $p < 0,01$. This result indicates that inertia has a negative and significant impact on the effect of LCOE on performance. In other words, while I predicted that inertia would reduce this main effect, my results indicate that it magnifies it. This result could be due that the advantages of firm size, i.e. economy of scale and scope, are greater than the costs of inertia, being contrary to what it was expected in Hypothesis 2.

Model 4 in Table 4 shows that the interaction term is negative and statistically significant at $p < 0,01$. It reflects that the impact in Market Capitalization of having a decrease of 1 USD/MWh in LCOE Solar is amplified when the effect is moderated by Adaptability which is consistent with the Hypothesis 3. In the 5 models, the values of the R-squared range between 0.17 and 0.22.

Insert Table 4 about here

Robustness Tests

Different Operationalizations and Measures of the Dependent Variable

I tested the robustness of the results to different operationalizations and measures of the dependent and independent variables. I started by investigating whether the results may be dependent on a narrow definition of a firm's performance. For this investigation I used for dependent variable three different measures, i.e. EBITDA Multiple, Tobin's Q, and Return on Asset. The results of these additional analyses can be seen in Appendix Tables 1A, 2A and 3A.

First, I replaced performance for Enterprise Value / EBITDA, which is also known as "enterprise multiple or EBITDA Multiple". It is used to compare the value of one firm to the value of another firm within the same industry. It is a fundamental factor in explaining the EBITDA multiple expansion due to management skills (Mauboussin 2018; Achleitner, Braun, and Engel 2011). The results show a loss of significance compared with those of the main analysis. R squared is 0.035 for all models. Second, I used Tobin's Q (market value of a firm divided by its assets)(Weill, Malone, and Apel 2011). The results show a loss of significance and are not aligned with those of the main analysis. R squared is 0.007 for all models. Finally, I used Return on asset (Weill, Malone, and Apel 2011). The results show a loss of significance and are not aligned with those of the main analysis. R squared is a range between 0.007 and 0.009.

Different Operationalizations and Measures of the Independent Variables

In Table 5, I report the results of the main regressions using LCOE for onshore wind technology and onshore wind generation instead of solar photovoltaic, as the second-largest

renewable worldwide generation capacity after solar, not considering hydropower as this is old technology.

Insert Table 5 about here

The first column (model 1) is the baseline model with control variables only. Fixed Assets is statistically significant ($p < 0.01$) and has a positive sign, which reflects a direct relationship with Market Capitalization. Wind Generation is statistically significant ($p < 0.01$) and has a negative sign reflecting an inverse relationship with Market Capitalization. GDP is statistically significant ($P < 0.01$), its coefficient is 0.002 meaning that an increase of 1 USD million in the GDP increases market capitalization by 2 USD thousand. CPI is statistically significant, but only at $p < 0.1$. The second column (model 2) has only LCOE Wind as the independent variable. It shows a negative coefficient which is statistically significant ($p < 0.01$). Hypothesis 1 predicts that a decrease in technology price will increase firm's Market Capitalization. In the third regression (model 3) I added the interaction between LCOE Wind and Fixed Assets to see how Inertia moderates the impact of Technology in Market Capitalization. This relationship shows a negative sign and it is statistically significant ($p < 0.01$), being contrary to what it was expected in Hypothesis 2.

In the fourth regression (model 4) I added the interaction between LCOE Wind and Wind Generation to analyze how Adaptability moderates the impact of Technology on Market Capitalization. The result shows that the interaction term is negative and statistically significant. It reflects that the impact in Market Capitalization of having a decrease of 1 USD/MWh in LCOE Wind is amplified when the effect is moderated by Adaptability, being statistically significant at $p < 0.01$, which is consistent with the Hypothesis 3. In the 5 models, the values of the R-squared range between 0.17 and 0.22. These results are aligned with those of my main analyses.

In the appendix Table 4A I replaced Fixed Assets with the number of Employees for Inertia (Josefy, et al. 2015; Miller and Chen 1994). I used that replacement for solar as well as wind technologies. In models 1 and 2 we can observe that only at wind level the inertia interaction term with technology follow the qualitative result of the main analysis although it loses statistical significance. R-squared decreased for all models compared to the ones that used fixed assets, being on the range of 0.11-0.13.

EXPLORING THE CAUSAL MECHANISM

To corroborate my intuitions, test the soundness of the hypotheses and conceptual model and the meaningfulness of the expected theoretical mechanism, I interviewed 26 with work experience in the electric industry. Given that the relationship between inertia, investments in new technologies and performance may be subject to issues of endogeneity, I used the interviews also to tease out possible reverse causality concerns and presence of latent variables.

I reached them through alumni networks and industrial networks. The sample size considered for this qualitative research part is 26 interviews, as sample size guidelines suggests a range between 20 and 30 interviews to be adequate, as this is the number of interviews at which no new concepts emerge from subsequent interviews, thematic saturation (Vasileiou et al. 2018). I also used the interviews to explore the importance of legitimacy on electric firms' business models, and the way legitimacy is managed, considering that it needs to be dynamically run due to the long term useful life of the electric assets.

The Pilot

In a first, exploratory pilot I interviewed 2 senior executives from the industry. The pilot respondents were chosen to cover the entire period and provide information on key perspectives such as technology, strategy, and market. Findings were triangulated between the two

interviewees, public sources, and my own experience in the industry to confirm the major industry disruptions and validate the organizational responses from an external and unbiased perspective. Both interviewees have more than 15 years of experience in the industry, do not know each other, and have key positions in their own firms.

The interviews followed a semi-structured format: starting with an introduction, definition of the concepts related to the business model, inertia, and organizational change to have a common background to compare responses. The legitimacy part was incorporated after the pilots interviews were made.

Approval by the IE Research Committee

To proceed with the interviews, I obtained approval from the IE Research Committee. They reviewed a brief project description, the interview questionnaire, and the interview consent form, and authorized the interviews on May 19th, 2022. To comply with the protocols, each interviewee approved a consent form and agreed to have the interview recorded anonymously. These recordings are stored in a Google Drive provided by IE. To maintain anonymity, each interview is labeled as Interview 1, Interview 2, and so on, depending on the chronological order. Only by referring to the consent form is one able to access the name of the interviewee.

Interviews

I interviewed 26 people during the period between October 20th, 2022, and January 9th, 2023, all of whom had experience in the electricity industry, ranging from 4 to 35 years. Their work experience included executive positions such as C Suite, as well as founder, consultant, and government authority. They had market experience in Chile, as well as other countries in LATAM, North America, Europe, Oceania and Africa. In terms of demographics, 16 interviews

were Chilean, and 10 were Non-Chilean, with 3 Females and 23 Males. 5 of the interviews were in English and 21 in Spanish. A summary of the data is presented in the following table:

Insert Table 6 about here

Topic Modeling

To extract valuable information from large text corpora, various text mining approaches have been developed, with topic modeling being widely embraced as a prominent technique. In the field of social sciences, topic models have found numerous applications, including but not limited to identifying consumer preferences, uncovering semantic structures, enhancing recommendation systems, and supporting strategic management in business (Pröllochs and Feuerriegel 2020; Egger and Yu 2022).

To process the data, I used Python, which is a general-purpose, versatile, and powerful programming language. Python is commonly used for a variety of tasks, ranging from web development to machine learning to data science. Additionally, Python has many existing libraries for topic modeling, which allows users to access code for running models without the need to write everything from scratch. The interviews were transcript for coding using Descript, an artificial intelligence software. Then using Python to apply topic modeling methodology, and in conjunction with the researcher experience 5 topics were selected.

Topic 1 has the following terms as the 10 most relevant for topic composition: “company”, “energy”, “issue”, “model”, “business”, “change”, “contract”, “development”, “price” and “market”. This topic seems to deal with issues related to Business changes in the Energy Market.

Topic 2 has the following terms as the 10 most relevant for topic composition: “company”, “change”, “energy”, “business”, “model”, “legitimacy”, “car”, “electric”, “business model” and “industry”. So, topic 2 seems to deal with deals with Sustainability and Electromobility.

Topic 3 has the following terms: “company”, “change”, “energy”, “business”, “model”, “technological”, “business model”, “people”, “issue” and “legitimacy”. So, this topic seems to deal with Business Models and People in the Energy Business.

Topic 4 has the following terms: “company”, “energy”, “change”, “business”, “model”, “people”, “community”, “wind”, “legitimacy” and “time”. So, topic 4 seems to deal with Community Engagement and Legitimacy in the Energy Business.

Topic 5 has the following terms: “company”, “business”, “change”, “model”, “energy”, “people”, “business model”, “legitimacy”, “time” and “technological”. This topic seems to deal with Business Models and the Energy Transition.

In the following figure you are able to see a Topic Modeling output that reflects the distance map among topics.

Insert Figure 8 about here

Coding

The interview data was systematically coded in NVIVO, with a primary focus on the five pre-defined topics in alignment with the research theoretical frameworks. In addition to that, I coded based on the related hypothesis when possible as well as the concept of ambidexterity. The following were the codes used: i) Business changes in the energy market: The code refers to changes in regulations and market dynamics impacting the energy sector. ii) Sustainability and electromobility: the code relate to a) the practice of balancing resource use while meeting present

and future needs. Conducting activities in a way that meets the needs of the present generation without compromising the ability of future generations to meet their own needs and b) those activities related to use electricity in transportation. iii) Business model and the energy transition: The code addresses how the business model or its parts adapts or evolves due to the energy transition. iv) Business model and people in the energy business: The code highlights the significance of individuals in shaping business models and decision-making within the energy industry. v) Community Engagement and Legitimacy in the Energy Business: the code relates to drivers and consequences of firm's legitimacy during the asset useful life as well as the interaction of the firm with all its stakeholders during the lifespan of its assets. vi) Technological Change: The code concerns to the drivers and consequences of technological change. vii) Performance: The code pertains to any references or activities related to measuring or evaluating performance in the energy business. viii) Inertia: The code relates to any activity or mention from the interview to the ability of the organization to adapt or not to adapt to any change triggered by external or internal factors. ix) Adaptability: The codes related to the adoption or acceptance of any new technology. x) Ambidexterity: The code encompasses activities that enable a firm to effectively balance exploration and exploitation, incorporating both innovation and efficiency. It also includes the outcomes or consequences of ambidexterity.

It is interesting to see the results of the coding similarity cluster analysis using the Jaccard coefficient⁶, which quantifies the overlap between two coding references. The following chart shows the relationships using a Jaccard coefficient between 0,7 and 1 as it was the default provided by NVIVO. The diagram show a strong relationship between technological change and

⁶ It is calculated as the ratio of the number of coding references that are coded to both sources to the number of coding references coded to either source. The Jaccard coefficient ranges from 0 to 1, with 0 indicating no overlap and 1 indicating complete overlap.

i) Business Changes in the Energy Market, ii) Business Models and Energy Transition, iii) Business Models and People, iv) Community Engagement and Legitimacy, v) Inertia, and vi) Sustainability and Electromobility. On the other side Performance and Adaptability do not show any strong relationship while Ambidexterity show strong relationship only with Business Models and People.

Insert Figure 9 about here

Findings about the Underlying Causal Mechanisms

This study investigated the impact of current technological change on the performance of firms operating in the electricity industry, and how factors such as inertia and adaptability influence this relationship. I utilized a mixed-methods approach, combining quantitative statistical results with qualitative insights from in-depth interviews with industry executives.

Technological change in electric firms increases performance: Rise in electricity demand dependence.

The quantitative results supported the baseline hypothesis (H1) that current technological change increases the performance of firms in the electricity industry. To enrich this understanding, I turned to the qualitative data from the industry executive interviews.

Technological change is increasing the relevance of electricity in the society, mainly due to decrease in its cost followed by widespread digitalization and electrification of process, which could be part of the reasons for increasing in firm's performance. The before mentioned is reflected in the following quotes:

“Major technological changes are related to process electrification, aiming for changes in generation itself. In other words, solar panels are becoming increasingly efficient, generating power from both sides nowadays. This leads to cheaper energy each day. The price has dropped by half,

which is a massive change. What you used to do with gas or diesel, you will now start electrifying processes as an end customer because electricity is cheaper.” (Interview 7)

“Another significant change is the digitization of everything. Before, we probably used to say, “the power went out,” but nowadays, the last thing you care about is the electricity itself. If you think about it, nowadays everything, even education, depends on electricity. During the pandemic, if you experienced a power outage, your child would be left unable to access school and many other things. Additionally, we now have home office. Just imagine, if the power goes out, it's like the office has closed. I believe that's what has changed—the digitization. It has altered customer habits and the level of dependence we have on electricity today.” (Interview 5).

Inertia: The tension between Scale, technology choices, and executive decision making in the electricity industry.

In line with hypothesis H2, interviews revealed that inertia, measured by fixed assets, often hindered capital-intensive firms, like those in the electricity industry, from capitalizing on technological advancements. Larger firms could afford technological risks, but also exhibited more entrenched routines and legacy systems due that they have to make profitable their existing assets, increasing inertia. This presents a tension: larger firms have the resources to invest in new technologies, but their size and legacy systems can also increase resistance to change. These insights suggest a complex interplay of forces, all influencing the impact of technological change on performance.

“There was an inertia to maintain that business model, and the justification was precisely that significant investments were being made in a certain technology, which was coal, and therefore they had to make profits from it for the next 20 years, and so on. So, rather, I got the impression that the vision was to monetize these assets rather than jump on the bandwagon of renewable technologies”. (Interview 15)

“They had a very biased mentality due to their own development or the technology they operated, given that the technology they operated had implications for the business model, given the regulatory framework in place”.(Interview 17)

However, although small firms tend to be flexible, in a capital intensive industry a bad move can be lethal. The before mentioned amplifies its effect while considering the board and executives behavior.

“The large firms are big and rigid, but they also have a more solid structure. Therefore, they can handle changes of that kind when they make mistakes. On the other hand, a small or medium-sized firm, if it makes a mistake, can end up bankrupt, as sometimes happens in the electrical sector.”
“(Interview 10)

“I haven't seen a great concern among Chileans to innovate or to move out of their comfort zone if the business is functioning. I believe there is a certain tendency to view it as just another financial asset rather than as a firm that can lead and progress with the evolution of society.”
(Interview 17)

“No executive wants to stand out for being the one driving innovation because if they make a mistake, they can be fired or see their career deteriorate.”(Interview 2)

“I have always said that one of the main enemies or risks that firms face is their own executives because they have a business model that has worked for them, they are well-known, and therefore, they are in a comfort zone that is difficult for them to break out of.”(Interview 7)

“I believe that generally, in the boards, especially if they are boards of traditional firms, traditionally composed of white men of a certain age, there is a lot of resistance to change.” (Interview 20)

Adaptability magnifies the increase in performance due to technological change.

The third hypothesis (H3) proposed that the adoption of technology, which we refer to as adaptability, would enhance the positive impact of technological change on performance. This was corroborated by the interviews, where executives often emphasized a culture of technological adaptability. They highlighted practices such as continuous learning about new technologies, and proactive responses to technological trends as key drivers of their successful technology adoption, both critical to maintain or increase their competitiveness. Furthermore, if a new technology proved successful, firms were willing to replicate it. While doing so, they often organized themselves to lobby for regulations that would facilitate faster and more efficient incorporation of that technology, further enhancing their adaptability and performance.

“In my opinion, technological innovation doesn't really come from the firm itself; it's an adoption based on observation. When it is considered that a certain technology can be part of a technological mix that corresponds to a commodity sector, the sector adopts it as a whole. For example, lithium batteries are widely used today, even though we all know that there might be another solution in 5 or 10 years. But I won't spend money on technology development thinking that I will revolutionize the sector. I prefer to see what works elsewhere, adopt it for my firm, and deploy it just like everyone else does. There is a "follower effect" in the energy sector.”(Interview 14)

Legitimacy: Balancing exploration and exploitation while adapting to technological change.

This study also explores how legitimacy influences how firms balance exploration and exploitation while adapting to technological change during the asset's lifespan. This challenge is dynamic because of three main factors: i) the asset's long lifespan, ii) the need to interact with multiple stakeholders due to its relation to the exploitation of natural resources and its status as an essential good, and iii) the extended period required for investment recovery.

The interviews help us to see the mechanisms through which legitimacy evolves within the firm's relationships with diverse stakeholders, and how it impacts the adaptability of the firm to technological change over the asset's useful life. The relevance of legitimacy is spreading through industry.

“If business models want to be sustainable in the long term, they must have a high degree of legitimacy both in society and in regulatory bodies, as well as in the different firms the firm interacts with.” (Interview 3)

“What happens is that legitimacy is constantly evolving, especially in terms of what is considered legitimate. In the past, a firm could claim to focus on a certain value, but things have changed over time, and now the environment cannot be ignored. The environment was not previously part of the equation.” (Interview 5)

However, there are still some firms that use legitimacy as synonym of legality.

“Within the environmental framework, we interact with various stakeholders such as the community, municipality, and environmental organizations. We go through the permitting process. I believe that the legitimacy of the project is established as you obtain the necessary permits. Once you have them, you can commence with the construction phase.” (Interview 1)

Legitimacy serves as both a facilitator and a constraint in the effective implementation of ambidextrous strategies, making it a critical element for understanding how organizations adapt to multi-logic institutional environments (Zhong, Zhao, and Song 2023; Reast et al. 2013; Hahn, et al. 2015; Patala, et al. 2019; Greenwood et al. 2011) .

“Legitimacy provides protection for your brand and operation. When you install infrastructure in a certain location and operate it for 20 years, you need to not only engage with the community at the beginning, during the construction phase or when obtaining permits but also maintain a continuous relationship with the community until the operation eventually comes to a close. This ensures a harmonious coexistence throughout the project's lifespan.” (Interview 10)

“When one or both parameters deviate from society's expectations, it starts to generate illegitimacy for an energy firm. For instance, if you are unable to guarantee a certain level of supply availability or if the energy becomes too expensive and begins to impact the profitability or quality of life of your customers, your legitimacy decreases, and they may start seeking someone else to replace you.” (Interview 14)

Legitimacy as a valuable resource

Legitimacy becomes key for investment decision, attracting new investors as well as for human capital. Legitimacy is viewed as a political resource that must be established and maintained to pursue economic goals (Shaffer 1995; Bucheli and Salvaj 2013; Bucheli and Salvaj 2018).

“I believe that in order to sustain a business model in front of an investor or a financier, you need to have a robust business model. And if it is not robust from the perspective of social legitimacy, it is worthless.” (Interview 10)

“What a firm requires is to generate value and financial profitability in line with the risks it takes. In this logic, there is a crucial component: regulatory risks, environmental legislation, and societal expectations. As I mentioned earlier, it's the social license. Put another way, if I were to participate in a project for a new transmission line, which is clearly part of our business, the first thing I would consider is whether it is feasible to carry out before looking at financial profitability. I mean, is it viable to develop it? If you don't have the social license, which means that the community allows you to proceed with the project, it doesn't matter if your project is environmentally perfect, financially profitable, and technically necessary. If the community doesn't want it, it won't matter. I would say that the main drivers are the social license, regulatory and environmental issues, and the financial aspect. Without any of these components, the matter won't progress.” (Interview 7)

“Fundamentally, our business model for Africa is an impact-driven business model. We are capable of raising capital to deploy it in our projects, with the main objective being energy access. The specific sector I work in is called "Energy Access," which involves providing affordable, sustainable energy for non-electrified areas. Therefore, I believe there is no sector more legitimate than ours because we strive to minimize negative externalities while maximizing positive externalities and impact. When investors consider investing, they not only look at the target IRR (Internal Rate of Return) but also the quantification of impacts. These impacts include the number of people connected, job creation, gender equality, and low emission levels. We have a list of impact indicators to attract capital to our project” (Interview 14).

Legitimacy allows the firm to attract skilled workers. When a firm is seen legitimate, talent is more likely to join and remain in the firm. This makes it easier for the firm to hire and maintain good people, which in turn makes the firm more profitable.

“For me, the most important stakeholders alongside my clients are the people who work in my firm. Firstly, they are young people who genuinely believe, along with me, that what we are doing is good, right, and beneficial for the environment, etc. In this sense, they are stakeholders but also critical of what we do. Imagine if we have a project and we mistreat people. It would be our own staff who would say, "This is not right. We are not doing things correctly." (Interview 19)

Legitimacy: the relevance of diversity.

Firms legitimacy impact and is impacted by all the ecosystem, as such diversity becomes crucial due to the multiple voices that the ecosystem has.

“I agree. I also don't believe that firms are separate from society. They are a part of society. They are an entity within society, just like other organizations and individuals. They provide a reason for people to be happy. They give individuals the ability to be creative, to learn, to earn money, and to support other endeavors. I believe that a firm is much more than just providing employment; it has a broader impact and significance.” (Interview 11)

“Everyone must be satisfied with what you are doing, and society must feel that it is a contribution rather than exploitation. They should feel that it will protect the environment and that it is beneficial for employees, investors, and the entire business ecosystem. All stakeholders should feel that I have a contribution and that we are contributing in all aspects through this.” (Interview 18)

In a world in constant evolution, diversity equips the firm with the ability to tackle problems from multiple perspectives, thereby enhancing its adaptability. This is especially relevant for industries with long life assets as it is the electricity as it increases or at least maintain its performance.

“Being exposed to very different situations also allows you to have very different responses to new difficulties or challenges. Without diversity, you will have the same response as always to problems that change.” (Interview 14)

“That demonstrates that the more diverse your workforce is, the more profitable your firm becomes. So, I don't think it's just social pressure. I believe it's a fact that leaders in our industry realize that having a diverse workforce will help us with the bottom line. So why wouldn't we want to be diverse? It's the right thing to do socially. It's the right thing to do from a profitability perspective. It's the right thing to do from a legitimacy perspective because it adds to a firm's value proposition. When a firm can say, "We are diverse. We have a higher level of diversity," it adds to their ability to attract talent and shareholders. So, I think the benefits are what drive the industry to want diversity, not social pressure.” (Interview 23)

“Diversity within an organization. I believe that on many levels, not just for social acceptance, it is truly important because you gain different viewpoints and perspectives. Whether it's gender, cultural, or other forms of diversity, people bring different perspectives, and sometimes, through diversity, you get the most surprising ideas. Instead of having groupthink, diversity allows you to think outside the box and explore different perspectives. I believe that is truly important in any organization, both for social acceptance and for all other activities.” (Interview 24)

Moreover, keeping ties with an elite group perceived as a relic and a representation of an illegitimate past can be detrimental. Visible connections are particularly susceptible to becoming liabilities during periods of political and social transformation compared to less conspicuous associations (Bucheli and Salvaj 2018).

“I believe that generally, in the boards, especially if they are boards of traditional firms, traditionally composed of white men of a certain age, there is a lot of resistance to change”. (Interview 20)

Conclusion

This study researched the impact of current technological change on the performance of firms in the electricity industry, considering moderating factors of inertia and adaptability. The quantitative analysis confirmed the hypothesis that technological change increases performance, while the interviews showed us that the mechanism could be related to the trend of the increasing relevance of electricity triggered by the fact of gaining competitive advantage due to decrease in costs. Related to the effect of inertia qualitative insights from interviews revealed that inertia in larger firms, driven by fixed assets and entrenched routines, could hinder them from fully capitalizing on technological advancements. On the other hand, adaptability, as proactive

responses to technological trends, was found to enhance the positive impact of technological change on performance. Overall, the study highlights the complex interplay of forces influencing the relationship between technological change and firm performance in the electricity industry.

The interviews confirmed that legitimacy is at the same time a facilitator and a constraint in the effective implementation of ambidextrous strategies as well as an essential resource for achieving economic goals. It influences the adaptability of the business model throughout the asset's life and is vital for investment decisions, attracting investors, and acquiring and maintaining talent. Legitimacy serves as a social license, protecting a firm's brand and operations, and is essential for sustainable businesses seeking for positive social and environmental impacts. Embracing diversity in the organization increases responses to challenges and profitability. Legitimacy is fundamental for success, social acceptance, and succeeding in a dynamic business environment.

DISCUSSION

Contributing to literature on technological change and firm's performance

Building on research on ambidexterity, this paper set out to examine in electric firms how technological change influences firm's performance, specifically depending on their inertia and ability to adapt. I argue that technological change impacts on firm's performance but paradoxically a firm may be unable to adapt to technological change even if it possesses all the core knowledge related to the innovation. However, a firm can improve its performance through an early adaptation of its business model.

I examined the linkage between technological change and firm's performance, using levelized cost of energy for solar photovoltaic crystalline utility scale and firm's market capitalization as their respectively proxy. I undertook an empirical analysis of 504 electricity

firms during the period 2012-2019, located in 63 countries worldwide. The study focused on the technological change on solar photovoltaic, and as a robustness test on onshore wind, the 2 most relevant new sources of renewable energy worldwide. These new technologies have been under fast expansion during the period of study.

I argue and empirically show that technological changes are consequential for firm's performance in the electricity industry. Specifically, I argue that i) current technological change in electric firms increases performance. A potential explanation is that current technological change frees productive factors for electric generation firms and also that renewable energy sources are energy flows more than stock while compared with fossil fuels technologies (Cozzolino, Verona, and Rothaermel 2018; Moriarty and Honnery 2016) and ii) testing the boundary conditions of this main prediction, and building on ambidexterity literature, I examine specifically the effect of two competing forces, i.e. inertia and early adaptability. I hypothesize that a) Inertia has a negative impact on increases in firm's performance. A potential explanation relates to the fact that electric generation firms have largely depend on high asset utilization business model (Vorbach, Wipfler, and Schimpf 2017; Konig, Schoberl, and Graf-Vlachy 2020; Zavarkó, et al. 2017); however the results show the contrary, which could be explained due to 1) higher advantages than disadvantages of firm size, the construct used for inertia, 2) the relevance of business model or 3) large firms tend to lead, at least in the electric industry in adopting technological innovation, then capturing first its results in market capitalization (Rose and Joskow 1988) and that b) the higher the adoption of a new technology in the industry has a positive impact on the effect predicted. A potential explanation is that the higher the use of a technology, the higher the number of electric firms that have adopted technological change, the higher the consensus of what the regulation needs to accelerate its penetration and expand it to the relevant network agents (Ansari, Garud, and Kumaraswamy 2016).

To corroborate my intuitions, test the soundness of the hypotheses and conceptual model and the meaningfulness of the expected theoretical mechanism, I interviewed 26 individuals with work experience in the electric industry. I also used the interviews to explore the importance of legitimacy on electric firms' business models, and the way legitimacy is managed, considering that it needs to be dynamically run due to the long term useful life of the electric assets. The results obtained from the interviews are consistent with Suchman (1995), that maintain legitimacy is vital but also problematic due mainly to i) third parties are often heterogeneous, ii) stability often entails rigidity, and iii) institutionalization often generates its own opposition.

In the longer term, evolving social practices and regulations, frequently supported by social movements, modify the standards to assess legitimacy. This shift presents challenges to organizations that are slow to adapt.

This study seeks to contribute to two main conversations in management, i.e. firm's performance in the face of technological change and firms' ambidexterity in industries characterized by investments in big assets. First, this study suggests that firms can adapt their business model in the face of technological change, and that this adaptation is consequential for their performance. Current technological change in electric firms increases performance. A potential explanation is that current technological change frees productive factors for electric generation firms and also that renewable energy sources are energy flows more than stocks while compared with fossil fuels technologies (Cozzolino, Verona, and Rothaermel 2018; Moriarty and Honnery 2016).

Scholars in management often attribute the decline in performance to firms' failure to embrace the new technology to inertia. Zavarko attributed the firm's inertia to operations of big assets and thus argued inertia would be more predominant in the electricity industry (Zavarkó, et al. 2017). However, as mentioned previously, the results of this study shows the benefits of firm

size are higher than the costs, as it could be the case of inertia (Josefy, et al. 2015) . Another explanation is that large firms lead in the electricity industry in adopting technological innovation, then capturing first its result in market capitalization, counterbalancing the disadvantages produced by Inertia (Rose and Joskow 1988).

Contributing to literature on ambidexterity

Second, this study also advances the extant conversation on firms' ambidexterity, specifically in industries characterized by investments in big assets. Building on prior research on ambidexterity and the idea of an intrinsic tension between inertia and adaptability specifically in industries, such as the electricity one, characterized by investments in big assets, and yet the need to adapt to the current technological disruption, I propose that firms have to be able to develop an ambidextrous business model. Some authors have argued that in this change of business models, ambidexterity should be sought through organizational separation (O'Reilly, Harreld, and Tushman 2009); in contrast, others have argued that it can be achieved by building processes or systems that support individuals to overcome the tensions associated with ambidexterity (Birkinshaw and Gibson 2004); and finally, ambidexterity might also be achieved through externalization, such as promoting exploration through venturing schemes (Raisch, et al. 2009). Some of the firms where the before mentioned is reflected are ENEL, the Italian utility, with ENEL X, ENGIE, the French energy group, though acquisitions broaden its capabilities, ALPIQ, the swiss energy group, with JUICAR. Yet, it is challenging for technological change to permeate inside the organization's business model, as the organization focuses on continuous, secure, efficient operations, favoring short-term performance, which implies a sustaining technological change, as Zavarko suggested (Zavarkó, et al. 2017). I propose and offer evidence that, given the current technological shift in the industry, like for example: solar photovoltaic and wind turbines,

firms in the electricity industry need to and can change their business models so as to explore new business opportunities while continuing to explore and capitalize on its existing businesses, to survive the energy transition, and that those who manage this business model change will experience an increase in performance (Winterhalter, Zeschky, and Gassmann 2016; Raisch, et al. 2009). Specifically, I expected that electric firms would incorporate technological change, either incorporating new technology in their energy matrix or diversifying through new business models, not adapting the current business model. They will avoid a direct confrontation inside the organization when incorporating the changes, which is consistent with firms not managing multiple business models and accepting (partial) cannibalization as they build new ones (Kaulio, Thorén, and Rohrbeck 2017). Which is consistent with the idea that resistance to new knowledge is more likely if the company has been successful, as it emerged in the interviews (Alänge and Steiber 2018).

LIMITATION OF THE STUDY AND AVENUES FOR FUTURE RESEARCH

The strengths of this research include its cross-sectional time series firms samples matched with relevant technology prices and generation by country. Additionally, the isolation through fixed effects of the impact of local regulation on firm's performance, so important for electric firms which are highly regulated. Nevertheless, this research is not without limitations. First, the study will include only firms with public information, mainly listed firms. Thus, one direction for further research is expanding the sample to include private and smaller firms. Second, the study relies mainly on the Orbis database, which produces some distortion compared to countries as the sample size between them changes dramatically. Third, the analysis include the period 2012-2019 as representatives of dramatic technological change. Expanding the period could provide a deeper inside into the speed that business model adaptation took place. Fourth,

the interaction did not reflect the expected results in the case of Inertia, which could be because fixed assets do not reflect directly how much each firm has already invested in renewable resources, or firm size advantages are greater than disadvantages in the energy industry, however future research needs to be developed. Although size is typically convenient to measure, its theoretical impact is difficult to articulate –and I hope that this study will offer a steady ground for future scholars to investigate further the electricity industry and its dynamics.

Other areas of improvement for the study include are a high dispersion on database firm size, either measure at market capitalization, fixed assets or employees (their coefficient of variation is 2.34, 2.44 and 2.23 respectively), which could lead to further research based on firm's size. Relying on country level statistics for solar and wind generation may not accurately represent firms primarily invested in fossil fuels. Also, increasing the number of non Chilean executives interviewed would enhance the research diversity. A deeper analysis of the impact of local regulations is also advisable as they could be more influential than initially anticipated. Finally, expanding the research to other capital intensive industries could offer a more comprehensive view.

NORMATIVE IMPLICATIONS

Many challenges are reaping the benefits of emerging technologies. If it were easy, every business would do it, and competitive advantage would easily fade away. It is, in fact, extremely difficult and challenging for firms to create value with emerging technologies.

The electricity market and the current business models of its incumbent utilities sit at a precarious point in history – attempting to manage the increasing disruption to the market. On the one hand, firms are trying to leverage the opportunities created by their current assets and operations, including, in some cases having the Government acting as both a large energy

consumer as well as a relevant shareholder. On the other hand, the need to move into new energy market structures with more agile and entrepreneurial firms because of the incapacity of the current large and risk-averse firms to transform their business models effectively.

The electric industry is going into a similar process as the telecommunication industry experienced before. Both industries were utility industries, they had natural monopolies characteristics, and they were capital intensive. However, the telecommunication industry started its technological revolution in the '80s with the deregulation and introduction of the first mobile phones. Today, telecommunication as an industry can seem contradictory. On the one hand, it is mature with fierce competition among existing players based mainly on price and performance; on the other hand, it is an emerging industry in which new technologies and new business logics emerge and converge (Kaulio, Thorén, and Rohrbeck 2017).

Thus, this research begins to contribute to a better understanding of the electric firms' technological change adaptation and its impact on performance. This study also has interesting implications for managers, especially from the perspective of upgrading manager mental models. The process of business model adaptation imposes significant challenges to managers who rely on incomplete cognitive representations while attempting to understand the environmental dynamics that determine a business model's future performance (Moellers, et al. 2019). Exploratory results from the interviews showed that i) a large majority of organizational transformations were accomplished via a rapid and discontinuous change over most or all domains of organizational activity, ii) small changes in strategies, structures, and power distributions did not accumulate to produce fundamental transformations, and iii) major environmental changes and chief executive officer succession influenced transformations, which is consistent with Romanelli and Tushman.

In light of this analysis, the pivotal road of the CEO in the transformation of the firm's performance is critical, as it could trigger the conditions to develop an ambidexterity business model. If this is not happening, the change of the CEO itself could influence the transformation of firm's business model. Some of the Chilean firms that have seen a change in the CEO that support this model are Engie and Gasco.

The diminishing legitimacy of traditional energy technologies was demonstrated through the statement made by the representative of the European coal industry at the Paris COP 21 agreement: "We will be hated and vilified, in the same way that slave traders were once hated and vilified" (Clark 2015). As a reaction, energy incumbents are expanding their technology matrix and allocating more resources on new renewable technologies. However, at the same time, numerous incumbents persist in investing in conventional fossil fuel technologies which might ultimately face a broad judgement of illegitimacy.

Three aspects of legitimacy make its maintenance intermittently problematic: i) third parties are often heterogeneous, ii) stability often entails rigidity, and iii) institutionalization often generates its own opposition (Suchman 1995). In the longer term, shifts in social habits and regulations, frequently supported by social movements, transform the criteria by which legitimacy is evaluated, challenging those organizations that are slow to adapt or are not able to listen the different demands that the business ecosystem constantly raises.

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FIGURES

Figure 1 Worldwide investment in the power sector by technology, 2005-2018 period

(IEA, 2019a)

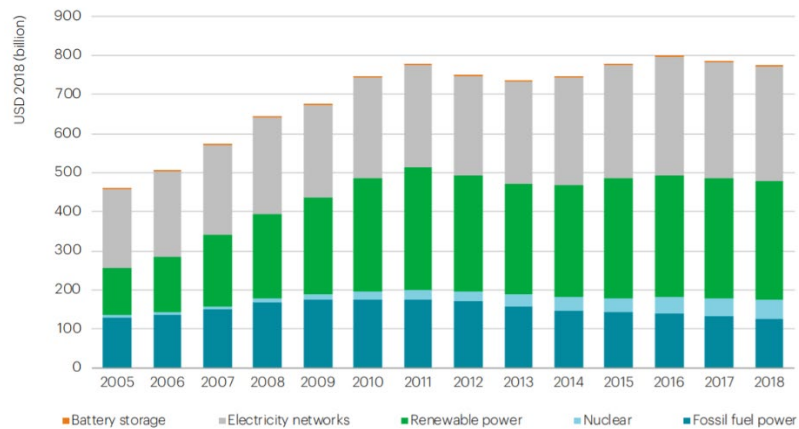


Figure 2 Worldwide Installed power generation capacity by source, 2000-2040 period

(IEA, 2019b)

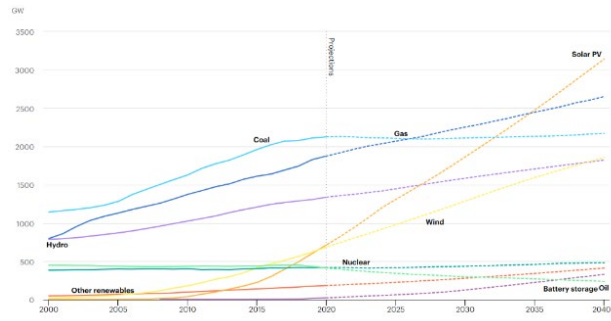


Figure 3: Worldwide Employment in the generation electricity sector.

Period 2000-2014, million jobs (Montt, Maître, and Amo-Agyei 2018)

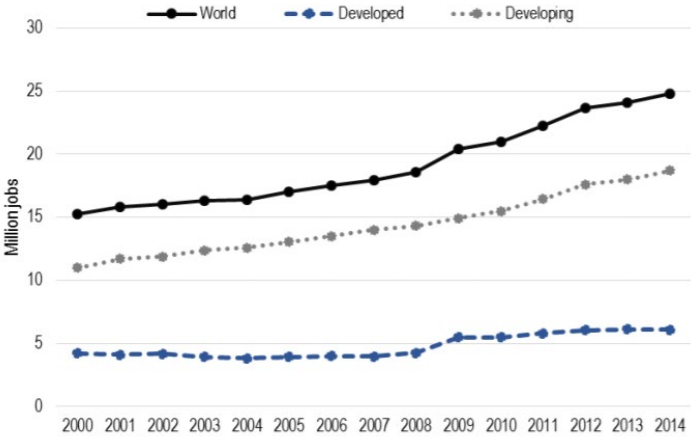


Figure 4 Financial comparison among different Electric Firms 2019

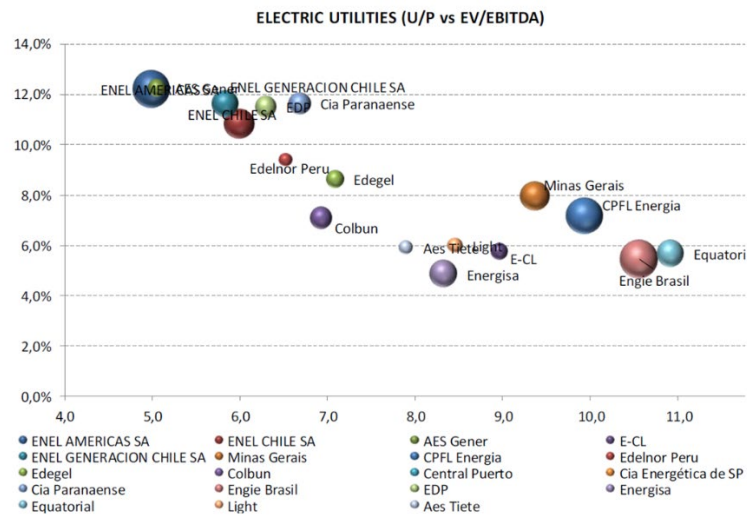


Figure 5 Worldwide weighted average levelized cost of electricity from utility scale.

Renewable power generation technologies for the 2010-2019 period MUSD(2019) (IRENA 2020)

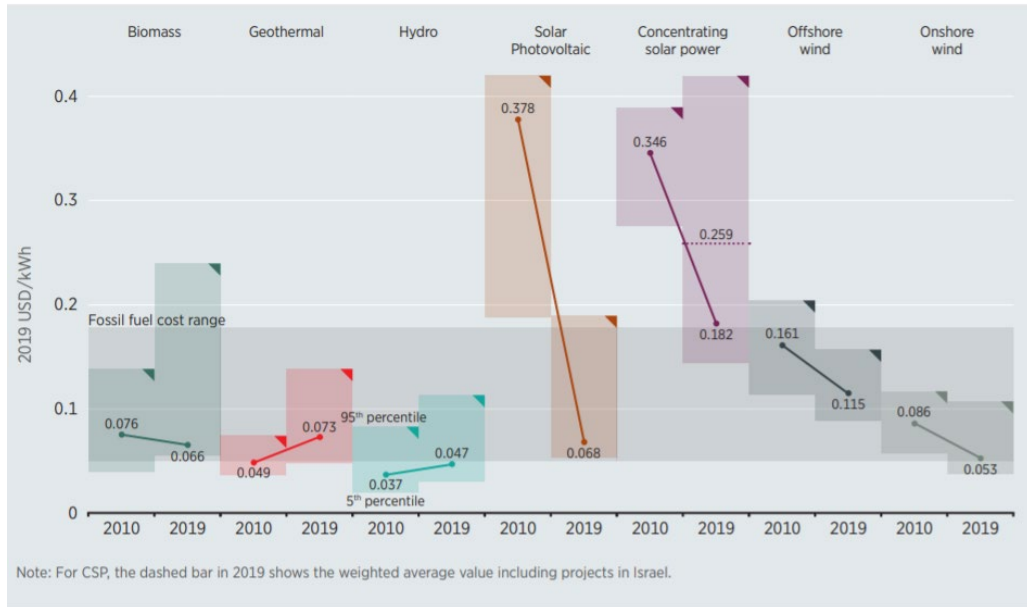


Figure 6 Worldwide Lithium-Ion Battery Pack Price for the 2010-2018 period.

USD(2018)/Kwh (Goldie-Scot 2019)

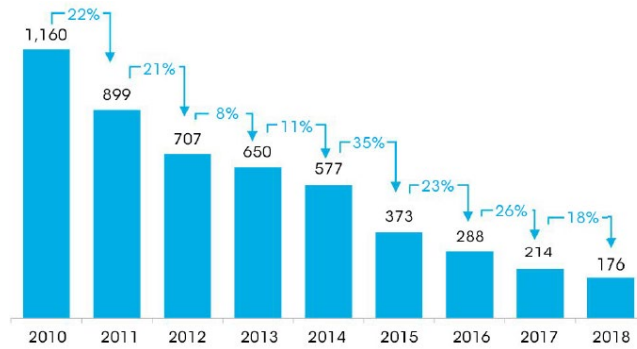


Figure 7 Worldwide average prices resulting from auctions, 2010-18 period

IRENA 2019

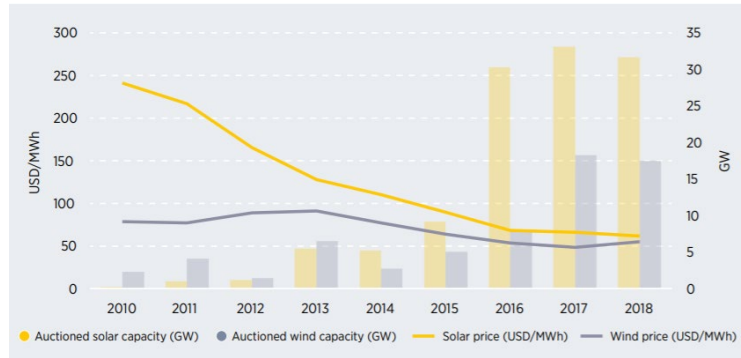


Table 1 Descriptive Statistics

		Sample	
Period		2012-2019	
Number of Firms		504	
Number of Countries		63	
Market Capitalization by firm (million USD)	N: 2.498	Mean:3,911.3	SD:9,180.1
Fixed Assets by firm (million USD)	N: 2.498	Mean:9,338.2	SD:22,809.6
Number of Employees	N: 2.498	Mean: 5,996.6	SD: 13,421.8
Solar Generation by country (GWh-year)	N: 2.4.98	Mean:22,198,5	SD: 38,479.9

Table 2 Summary Statistics

	Unit	Mean	Max	Min
Market Capitalization by Firm	Million USD	3911.3	118362	0.1
LCOE Solar	USD/MWh	69.9	125	43.0
Fixed Assets by Firm	Million USD	9338.3	253874.4	0.0
Solar Generation by Country	GWh-year	22198.5	177546.7	0.0
GDP by Country	Million USD	5212159.3	20611860	4291.2
CPI by Country	Index 2010=100	122.6	261.1	97.7
LCOE Wind	USD/MWh	54.2	72	42.0
Wind Generation by Country	GWh-year	75885.8	356848.2	0.0
Employees by Firm	Employee	5996.6	165790	1.0
EBITDA Multiple	Times	10.3	98	-5.3
Return on Assets	%	1.4	93.4	-95.6
Tobins Q	Times	.7	81.6	0.0

Table 3 Pairwise Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Market Capitalization	1.000											
(2) LCOE Solar	-0.015	1.000										
(3) Fixed Assets	0.790***	0.001	1.000									
(4) Solar Generation	0.150***	-0.410***	0.095***	1.000								
(5) GDP	0.316***	-0.122***	0.180***	0.740***	1.000							
(6) CPI	-0.180***	-0.299***	-0.006***	0.069***	-0.030***	1.000						
(7) LCOE Wind	-0.016	0.974***	0.001	-0.434***	-0.123***	-0.305***	1.000					
(8) Wind Generation	0.243***	-0.294***	0.140***	0.908***	0.931***	0.035***	-0.305***	1.000				
(9) Employees	0.502***	0.014***	0.623***	0.017***	0.069***	0.006**	0.017***	0.038***	1.000			
(10) EBITDA Multiple	0.012	0.019	-0.029*	0.077***	0.089***	-0.088***	0.019	0.105***	-0.110***	1.000		
(11) Return on Assets	0.065***	-0.028***	0.002	0.001	0.005**	0.041***	-0.032***	0.009***	-0.008**	-0.118***	1.000	
(12) Tobins Q	-0.013	0.016	-0.012	0.010	0.079***	-0.025*	0.021	0.047***	-0.064***	0.283***	-0.072***	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4 Regression model results: Market Capitalization and LCOE Solar

VARIABLES	(1) Base Line with CV and FEs only	(2) H1 LCOE Solar Technology	(3) H2 LCOE Solar x Fixed Assets Technology x Inertia	(4) H3 LCOE Solar x Solar Generation Technology x Adaptability	(5) Full Model Solar
H1: Technology: LCOE Solar		-19.741*** (3.714)	-8.055** (3.845)	-11.296*** (3.852)	-3.251 (3.925)
H2: Technology x Inertia: LCOE Solar x Fixed Assets			-0.001*** (0.000)		-0.001*** (0.000)
H3: Technology x Adaptability: LCOE Solar x Solar Generation				-0.002*** (0.000)	-0.002*** (0.000)
Fixed Assets	0.184*** (0.014)	0.184*** (0.014)	0.249*** (0.016)	0.197*** (0.014)	0.251*** (0.016)
Solar Generation	-0.035*** (0.005)	-0.035*** (0.005)	-0.033*** (0.004)	0.048*** (0.012)	0.028** (0.012)
GDP	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
CPI	-16.505** (7.005)	-16.505** (7.005)	-6.555 (6.940)	-6.335 (7.062)	-0.234 (6.995)
Constant	-2,056.463* (1,077.055)	411.143 (1,355.930)	-1,559.424 (1,344.090)	-1,596.069 (1,367.964)	-2,806.059** (1,355.414)
Observations	2,498	2,498	2,498	2,498	2,498
R-squared	0.177	0.177	0.212	0.198	0.223
Number of Firm	504	504	504	504	504
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 Regression model results: Market Capitalization and LCOE Wind

VARIABLES	(1) Base Line with CV and FEs only	(2) H1 LCOE Wind Technology	(3) H2 LCOE Wind x Fixed Assets Technology x Inertia	(4) H3 LCOE Wind x Wind Generation Technology x Adaptability	(5) Full Model Wind
H1: Technology: LCOE Wind		-52.266*** (10.157)	-18.995* (10.366)	-43.300*** (10.146)	-16.794 (10.341)
H2: Technology x Inertia: LCOE Wind x Fixed Assets			-0.002*** (0.000)		-0.002*** (0.000)
H3: Technology x Adaptability: LCOE Wind x Wind Generation				-0.001*** (0.000)	-0.001*** (0.000)
Fixed Assets	0.183*** (0.015)	0.183*** (0.015)	0.313*** (0.019)	0.179*** (0.014)	0.297*** (0.019)
Wind Generation	-0.030*** (0.004)	-0.030*** (0.004)	-0.025*** (0.004)	0.016** (0.008)	0.003 (0.008)
GDP	0.002*** (0.000)	0.002*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
CPI	-13.557* (7.031)	-13.557* (7.031)	-2.183 (6.924)	-7.357 (7.023)	0.522 (6.931)
Constant	-2,648.498** (1,139.934)	1,114.689 (1,603.156)	-1,537.135 (1,579.586)	4,670.171*** (1,677.914)	946.724 (1,691.850)
Observations	2,498	2,498	2,498	2,498	2,498
R-squared	0.174	0.174	0.219	0.192	0.225
Number of Firm	504	504	504	504	504
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

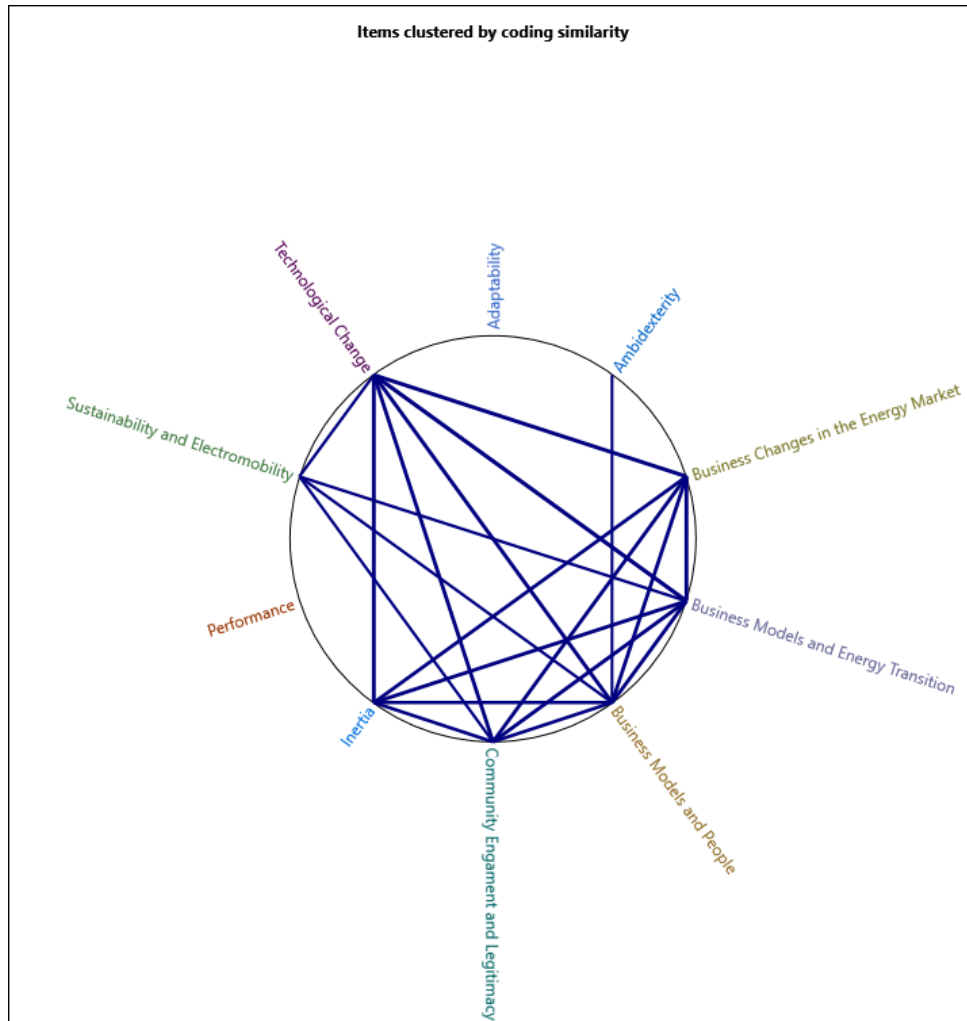
Table 6 Demographics of the Interviewees

Sample				
Relevant Position	Amount	Years of Experience in the industry	Nationality	Market
CEO - Founder	6	10 -28	Chilean - European	Chile – Latam – Africa
Executives	16	4 - 35	Chilean – Latam -European - North American - Oceania	Chile – Latam - Europe - North America - Oceania
Government Authority	1	30	Chilean	Chile
Consultants	3	15 - 20	Chilean - Latam - European	Chile – Latam - Europe

Figure 8 Topic Modeling Distance Map



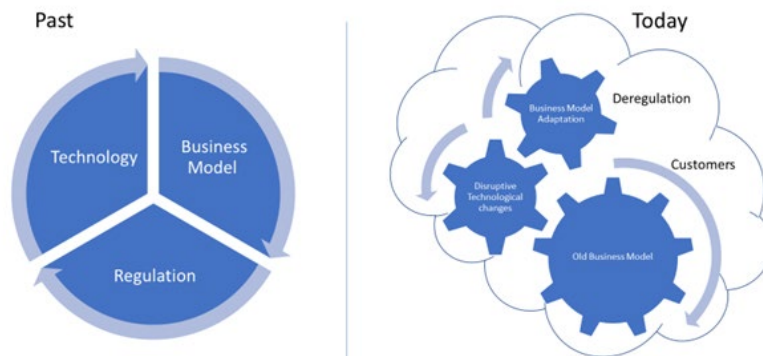
Figure 9 NVIVO Items clustered by coding similarity



APPENDIX

Figure 1A Comparison between business model

Electric Industry – Business Model Evolution



Source: Own elaboration, interviews

Figure 2A Worldwide Electricity generation by source, for the 1990-2017 period (IEA 2019)

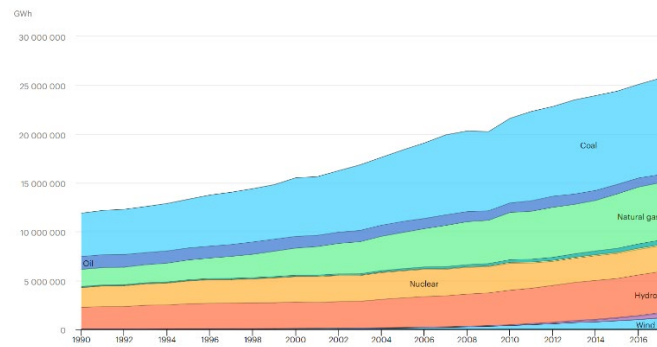


Figure 3A Worldwide CO2 emissions from electricity and heat by energy source.

For the 1990-2018E period (IEA 2019)

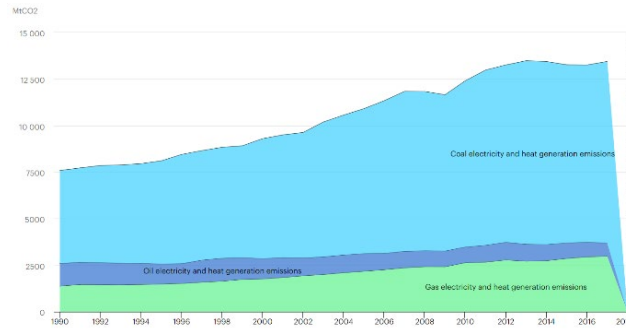


Figure 4A Competitive Procurement process design criteria

Global Record Breaking Solar Bids since 2016(Attia 2018)

Project	Capacity	Contract Price	Expected Operation
Location	MWdc	USD per MW	Year
Wilsona, United States	34	\$36.8	2021
Al Maktoum, UAE	800	\$29.9	2018-2020
Tarapaca, Chile	125	\$29.1	2019
Sweihan, UAE	350	\$24.2	2019
Sakaka, Saudi Arabia	300	\$23.6	2019
Antofagasta, Chile	116	\$21.5	2024
Aguascalientes, Mexico	377	\$19.2	2020

Figure 5A Innovation v/s Productivity and cost decrease

(Christensen and Bower 1996; Utterback 1987; Romanelli and Tushman 1994)



Source: Own elaboration

Figure 6 A The importance of change management based on the situation of the energy sector

(Zavarkó, et al. 2017)

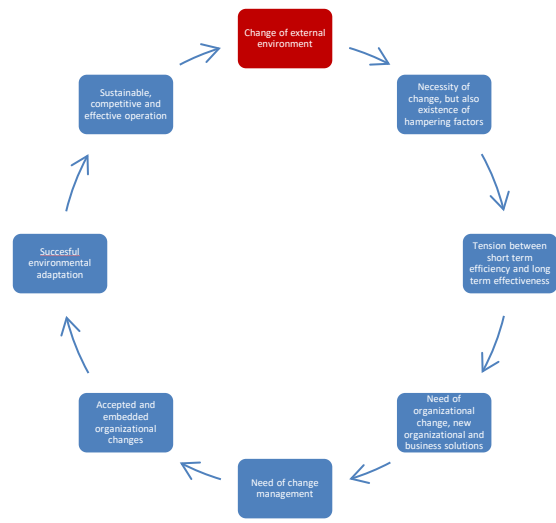


Table 1A Robustness Test using EBITDA Multiple as the firm's performance measure

VARIABLES	(1) Base Line with CV and FEs only	(2) H1 LCOE Solar Technology	(3) H2 LCOE Solar x Fixed Assets Technology x Inertia	(4) H3 LCOE Solar x Solar Generation Technology x Adaptability	(5) Full Model Solar
H1: Technology: LCOE Solar		-0.001 (0.010)	0.001 (0.010)	0.002 (0.010)	0.003 (0.011)
H2: Technology x Inertia: LCOE Solar x Fixed Assets			-0.000 (0.000)		-0.000 (0.000)
H3: Technology x Adaptability: LCOE Solar x Solar Generation				-0.000 (0.000)	-0.000 (0.000)
Fixed Aseets	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Solar Generation	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)	-0.000 (0.000)	-0.000 (0.000)
GDP	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
CPI	-0.029 (0.019)	-0.029 (0.019)	-0.027 (0.019)	-0.026 (0.019)	-0.025 (0.019)
Constant	3.490 (2.831)	3.629 (3.549)	3.216 (3.605)	2.958 (3.634)	2.733 (3.665)
Observations	2,186	2,186	2,186	2,186	2,186
R-squared	0.035	0.035	0.035	0.035	0.035
Number of Firm	456	456	456	456	456
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2A Robustness Test using Tobins Q as the firm's performance measure

VARIABLES	(1) Base Line with CV and FEs only	(2) H1 LCOE Solar Technology	(3) H2 LCOE Solar x Fixed Assets Technology x Inertia	(4) H3 LCOE Solar x Solar Generation Technology x Adaptability	(5) Full Model Solar
H1: Technology: LCOE Solar		-0.003 (0.003)	-0.004 (0.003)	-0.004 (0.003)	-0.004 (0.003)
H2: Technology x Inertia: LCOE Solar x Fixed Assets			0.000 (0.000)		0.000 (0.000)
H3: Technology x Adaptability: LCOE Solar x Solar Generation				0.000 (0.000)	0.000 (0.000)
Fixed Assets	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Solar Generation	-0.000** (0.000)	-0.000** (0.000)	-0.000** (0.000)	-0.000 (0.000)	-0.000 (0.000)
GDP	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
CPI	0.000 (0.005)	0.000 (0.005)	-0.000 (0.006)	0.000 (0.006)	-0.000 (0.006)
Constant	36.943*** (0.839)	37.369*** (1.056)	37.411*** (1.069)	37.393*** (1.078)	37.421*** (1.086)
Observations	2,470	2,470	2,470	2,470	2,470
R-squared	0.007	0.007	0.007	0.007	0.007
Number of Firm	497	497	497	497	497
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3A Robustness Test using ROA as the firm's performance measure

VARIABLES	(1) Base Line with CV and FEs only	(2) H1 LCOE Solar Technology	(3) H2 LCOE Solar x Fixed Assets Technology x Inertia	(4) H3 LCOE Solar x Solar Generation Technology x Adaptability	(5) Full Model Solar
H1: Technology: LCOE Solar		0.009 (0.009)	0.010 (0.010)	0.015 (0.010)	0.014 (0.010)
H2: Technology x Inertia: LCOE Solar x Fixed Assets			-0.000 (0.000)		0.000 (0.000)
H3: Technology x Adaptability: LCOE Solar x Solar Generation				-0.000** (0.000)	-0.000** (0.000)
Fixed Assets	-0.000** (0.000)	-0.000** (0.000)	-0.000* (0.000)	-0.000* (0.000)	-0.000* (0.000)
Solar Generation	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000* (0.000)	0.000* (0.000)
GDP	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
CPI	-0.012 (0.018)	-0.012 (0.018)	-0.012 (0.018)	-0.005 (0.018)	-0.005 (0.018)
Constant	2.479 (2.711)	1.379 (3.413)	1.260 (3.456)	-0.049 (3.483)	0.044 (3.506)
Observations	2,481	2,481	2,481	2,481	2,481
R-squared	0.007	0.007	0.007	0.009	0.009
Number of Firm	501	501	501	501	501
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

Table 4A Numbers of Employees as Inertia construct

VARIABLES	(1) H2 LCOE Solar x Employees Technology x Inertia	(2) H2 LCOE Wind x Employees Technology x Inertia	(3) Full Model Solar	(4) Full Model Wind
H1: Technology: LCOE Solar	-17.808*** (4.103)		-11.844*** (4.194)	
H1: Technology: LCOE Wind		-42.025*** (11.094)		-35.680*** (10.999)
H2: Technology x Inertia: LCOE Solar x Employees	0.000 (0.000)		0.000* (0.000)	
H2: Technology x Inertia: LCOE Wind x Employees		-0.000 (0.000)		0.000 (0.000)
H3: Technology x Adaptability: LCOE Solar x Solar Generation			-0.002*** (0.000)	
H3: Technology x Adaptability: LCOE Wind x Wind Generation				-0.001*** (0.000)
Employees	0.049 (0.039)	0.072 (0.044)	0.070* (0.039)	0.062 (0.044)
Solar Generation	-0.045*** (0.005)		0.026** (0.013)	
Wind Generation		-0.040*** (0.004)		0.012 (0.009)
GDP	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.001*** (0.000)
CPI	-12.795* (7.309)	-7.873 (7.332)	-4.399 (7.389)	-1.771 (7.297)
Constant	-1,159.113 (1,439.178)	-1,449.426 (1,696.747)	-2,889.553** (1,457.411)	2,889.811 (1,786.933)
Observations	2,498	2,498	2,498	2,498
R-squared	0.112	0.110	0.128	0.131
Number of Firm	504	504	504	504
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

Interview Analysis

Introduction

To corroborate my intuitions, test the soundness of the hypotheses and conceptual model and the meaningfulness of the expected theoretical mechanism, I interviewed 26 executives with work experience in the electric industry. Given that the relationship between inertia, investments in new technologies and performance may be subject to issues of endogeneity, I used the interviews also to tease out possible reverse causality concerns and presence of latent variables.

I reached them through alumni networks and industrial networks. The sample size considered for this qualitative research part is 26 interviews, as sample size guidelines suggests a range between 20 and 30 interviews to be adequate, as this is the number of interviews at which no new concepts emerge from subsequent interviews, thematic saturation. (Vasileiou et al. 2018).

I also used the interviews to explore the importance of legitimacy on electric firms' business models, and the way legitimacy is managed, considering that it needs to be dynamically run due to the long term useful life of the electric assets.

The pilot

In a first, exploratory pilot I interviewed 2 senior executives from the industry. The pilot respondents were chosen to provide information on key perspectives such as technology, strategy, and market. Findings were triangulated between the two interviewees, public sources, and my own experience in the industry to confirm the major industry disruptions and validate the organizational responses from an external and unbiased perspective. Both interviewees have more than 15 years of experience in the industry, do not know each other, and have key positions in their own firms.

The interviews followed a semi-structured format: starting with an introduction, definition of the concepts related to the business model, inertia, and organizational change to

have a common background to compare responses. The legitimacy part was incorporated after the pilots' interviews were conducted.

Once the introduction had been finished, they were asked about years of experience in the industry and their thoughts about if the industry is living a revolution.

The questions about discontinuities and organizational responses were posed as open questions, however the one related to discontinuities provided a list of examples that they could consider in their answer. The respondents were asked to sort chronologically, starting from the present day and backtracking events until the respondent had entered to work in the industry. This approach can be compared with the critical incident techniques in which respondents are asked to recall critical events. Recall of critical incidents is considered to be valid, as it often contains important and emotionally engaging events, and it helps respondents remember the events in more detail (Kaulio, Thorén, and Rohrbeck 2017). The weakness of this approach is that it alone does not guarantee comprehensiveness.

Based on the pilot interview feedback the interview was slightly updated to mainly focus in i) the relationship between technological change and firm's performance, ii) the tension between business model innovation because of technological change and the organization's inertia, and iii) explore how legitimacy is considered in a firm's business model

Approval by the IE Research Committee

To proceed with the interviews, I obtained approval from the IE Research Committee. They reviewed a brief project description, the interview questionnaire, and the interview consent form, and authorized the interviews on May 19th, 2022.

To comply with the protocols, each interviewee approved a consent form and agreed to have the interview recorded anonymously. These recordings are stored in a Google Drive provided by IE. To maintain anonymity, each interview is labeled as Interview 1, Interview 2,

and so on, depending on the chronological order. Only by referring to the consent form is one able to access the name of the interviewee.

Interviewed

I interviewed 26 people during the period between October 20th, 2022, and January 9th, 2023, all of whom had experience in the electricity industry, ranging from 4 to 35 years. Their work experience included executive positions such as C Suite, as well as founder, consultant and government authority.

They had market experience in Chile, as well as other countries in LATAM, North America, Europe, Oceania and Africa

In terms of demographics, 16 interviews were Chilean, and 10 were Non-Chilean, with 3 Females and 23 Males.

5 of the interviews were in English and 21 in Spanish.

A summary of the data is presented in the following table:

Relevant Position	Amount	Years of Experience in the industry	Nationality	Market
CEO – Founder	6	10 -28	Chilean - European	Chile – Latam – Africa
Executives	16	4 - 35	Chilean – Latam -European - North American - Oceania	Chile – Latam - Europe - North America - Oceania
Government Authority	1	30	Chilean	Chile
Consultants	3	15 - 20	Chilean - Latam - European	Chile – Latam - Europe

Interview

The total duration of the interviews was 22 hours and 27 minutes, with an average duration of 51 minutes each. The interviews were transcribed in their original language using the Descript software. Each transcription was then compared to its recording to correct any mistakes, such as misspellings or incorrect transcriptions of words or concepts. For seven interviews, a

business administration undergraduate student from Pontificia Universidad Católica de Valparaíso provided assistance with this task. Afterward, I reviewed each transcription.

For understanding the theoretical mechanism analysis, the transcriptions were also translated into Spanish.

To facilitate Topic Modeling analysis, each transcription was translated into English using Google Translate. The English words in the transcriptions totaled 142,145, with an average of 5,467 words per interview.

Topic Modeling

To extract valuable information from large text corpora, various text mining approaches have been developed, with topic modeling being widely embraced as a prominent technique. In the field of social sciences, topic models have found numerous applications, including but not limited to identifying consumer preferences, uncovering semantic structures, enhancing recommendation systems, and supporting strategic management in business analytics (Pröllochs and Feuerriegel 2020; Egger and Yu 2022).

Topic modeling is a probabilistic model. This model relies on the statistical associations of words within a text to create topics—clusters of words that jointly represent higher-order concepts—without relying on pre-established dictionaries or interpretive guidelines. The most distinctive characteristic of topic models is that they reflect an automated procedure for coding the content of a corpus of texts into a set of substantively meaningful coding categories called “topics”. The algorithms do this with a minimum of human intervention. (Storopoli 2019; Mohr and Bogdanov 2013)

Latent Dirichlet Allocation, LDA, is the most popular topic modeling technique, is a generative probabilistic model for discrete datasets such as text corpora. In LDA, each topic can be viewed as a theme because they are a set of distribution over all observed words in the texts; in

other words, a bag-of-words that frequently appear together across documents. Hence, as the number of topics need not be pre-defined, applying LDA provides researchers with an efficient resource to obtain an explicit representation of a document. (Mohr and Bogdanov 2013; Egger and Yu 2022; Storopoli 2019)

LDA posits that comparisons of similarity are probabilistic in nature and models each word in a text as a sample from a combination model. In this model the components are multinomial random variables, which can be interpreted as representations of various topics (Storopoli 2019).

Instead of commencing with pre-defined codes of concepts (similar those researchers create when they start hand code a text), the scholar details the number of topics for the algorithm to find. The program then identifies that number of topics and returns the likelihoods of words being used in a topic as well as the distribution of those topics across the body of the texts. (Mohr and Bogdanov 2013)

The main benefits of Topic Modeling are:

a.- They do not enforce the researcher dictionaries or interpretative rules regarding the data, allowing recognition of important subjects that readers are not capable to discern. Also, topics are not mutually exclusive. Individual words appear through topics with differing probabilities, and topics themselves may intersect or cluster (DiMaggio, Nag, and Blei 2013).

b.- When dealing with a large size of textual data, it provides a way for researchers to acquire reasonable automated content coding, that we could not have previously been able to do (Mohr and Bogdanov 2013).

c.- It eliminates the burden on the study from manually coding text data to interpret and validate the results of topic models, generating a shift from people interpretive methods to disciplining the results through statistical validation (Storopoli 2019).

Topic Modeling Methodology and Python

To process the data, I used Python, which is a general-purpose, versatile, and powerful programming language. Python is commonly used for a variety of tasks, ranging from web development to machine learning to data science. Additionally, Python has many existing libraries for topic modeling, which allows users to access code for running models without the need to write everything from scratch.

Steps:

Step 1: To have each document as an individual text in a sample, in this case we refer to each interview transcription.

Step 2: Once the researcher has the data, it needs to be pre-processed. This entails executing basic transformation on the data, in order to have it more suitable for conducting, more meaningful analysis.

a.- The initial step in pre-processing is text normalization, involving a series of transformations aimed at making textual data quantifiable and comparable within itself. This process includes: (1) converting all text to an uniform case, either lower or upper; (2) transforming numbers into words or deleting them; (3) removing punctuations, accent marks, and other diacritics; (4) eliminating white spaces, leading and ending spaces in a text; and (5) expanding abbreviations into their full forms.

b.- The next step in pre-processing procedure is the elimination of "stop words", defined as the most popular words in a language like for example: the, a, on, is, all. These words do not have substantial meaning and are usually eliminated from texts.

c.- The last final pre- processing procedure is named stemming or lemmatization.

Stemming is reducing inflected (or sometimes derived) words to their word stem, base, or root form, generally a written word form.

Step 3: After the text is pre-processed, the scholar can run the Topic Modeling by applying an algorithm. The algorithm used in this research is Latent Dirichlet Allocation and the library in Python is Gensim.

Researchers seeking to perform topic modeling in a Python environment are recommended to utilize the ‘gensim’ library, ‘gensim’ stands out for its frequent updates and widespread adoption by firms such as Amazon, Cisco, and Capital One. Although ‘gensim’ is limited to performing Latent Dirichlet Allocation (LDA), it offers several advantages. Firstly, it exhibits excellent scalability, allowing it to handle large datasets and process substantial amounts of data efficiently. Secondly, ‘gensim’ excels in text parsing, enabling researchers to work with various types and sources of textual data. Additionally, ‘gensim’ seamlessly integrates with popular Python machine learning libraries, further enhancing its appeal to both computer scientists and social scientists (Storopoli 2019).

As LDA request the researcher to estimate the number of topics to include as input. There is no agreement on the number of topics that a scholar should choose for their analysis. Some scholars debate that it is based on the level of detail a social researcher wants to obtain. While others argue that it depends on the performance metrics of the model: such as perplexity (measure of how well the topic model predicts new or unseen data) or coherence (measure of how well the words in a topic relate to each other). The point is to identify the lens through which one can see the data most clearly (Storopoli 2019). I run the model with 10, 8, 6, 5 and 4 topics to analyze which model provides the best congruence of data.

Step 4: The LDA outputs are a i) topic-word matrix and ii) topic-document matrix. Both matrices are vectors of influences, with the topic- word being the weight of words in each topic and the topic-document the wight of topics in each document.

Step 5: Identify the topics based on the LDA outputs. In a typical scenario of content classification and coding, researchers usually are looking for shared structures of meaning that are not formally materialized. Topic modeling serves a similar purpose in uncovering common structures but it does so without introducing researcher bias. The sole human inputs required are selecting the number of topics that the model should generate, and conceptualize the topics.

If one applies topic modeling strictly, one may skip important particularities on how to capture an important meaning and meaning structures in the data to generate relevant theoretical discussions and contributions (Storopoli 2019).

Step 6: Based on the topics chosen by the researcher code the interviews.

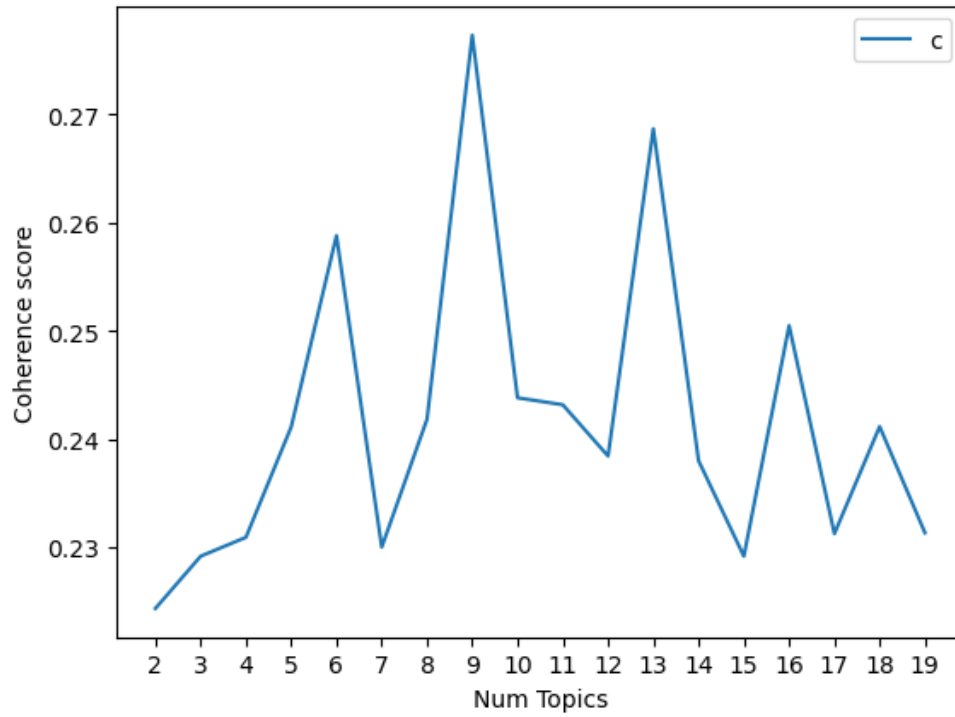
Steps 2 to 4 involve programming in Python. The program structure was derived from a combination of online resources, specifically:

- i) "Python Tutorial - Python Full Course for Beginners" by Mosh Hamedani, and
- ii) "Topic Modeling in Python" by Dr. W.J.B. Mattingly.

These resources were adapted and modified to suit the specific needs of this research project. The programming process was facilitated by the assistance of a Master's student from Pontificia Universidad Católica de Valparaíso and the support of ChatGPT.

Topic Modeling Results

Based on the results of the model in conjunction with the researcher experience, and contrasted with the coherence test results, the number of topics defined is 5



The following table provide an output of words and its respective weight by topic, highlighted in color those words that repeat through all topics:

Topic Table	Topic: 1	Topic: 2	Topic: 3	Topic: 4	Topic: 5
Word 1 (coeficient)	"company" (0.017)	"company" (0.020)	"company" (0.024)	"company" (0.017)	"company" (0.019)
Word 2 (coeficient)	"energy" (0.010)	"change" (0.010)	"change" (0.016)	"energy" (0.011)	"business" (0.014)
Word 3 (coeficient)	"issue" (0.009)	"energy" (0.009)	"energy" (0.012)	"change" (0.009)	"change" (0.012)
Word 4 (coeficient)	"model" (0.008)	"business" (0.009)	"business" (0.011)	"business" (0.007)	"model" (0.011)
Word 5 (coeficient)	"business" (0.008)	"model" (0.008)	"model" (0.009)	"model" (0.006)	"energy" (0.010)
Word 6 (coeficient)	"change" (0.008)	"legitimacy" (0.008)	"technological" (0.008)	"people" (0.006)	"people" (0.008)
Word 7 (coeficient)	"contract" (0.006)	"car" (0.007)	"business_model" (0.007)	"community" (0.006)	"business_model" (0.008)
Word 8 (coeficient)	"development" (0.006)	"electric" (0.007)	"people" (0.005)	"wind" (0.006)	"legitimacy" (0.008)
Word 9 (coeficient)	"price" (0.005)	"business_model" (0.006)	"issue" (0.005)	"legitimacy" (0.005)	"time" (0.007)
Word 10 (coeficient)	"market" (0.005)	"industry" (0.005)	"legitimacy" (0.005)	"time" (0.005)	"technological" (0.007)

Topic 1 has the following terms as the 10 most relevant for topic composition: “company”, “energy”, “issue”, “model”, “business”, “change”, “contract”, “development”, “price” and “market”. This topic seems to deal with issues related to Business changes in the Energy Market.

Topic 2 has the following terms as the 10 most relevant for topic composition: “company”, “change”, “energy”, “business”, “model”, “legitimacy”, “car”, “electric”, “business_model” and “industry”. So, topic 2 seems to deal with deals with Sustainability and Electromobility.

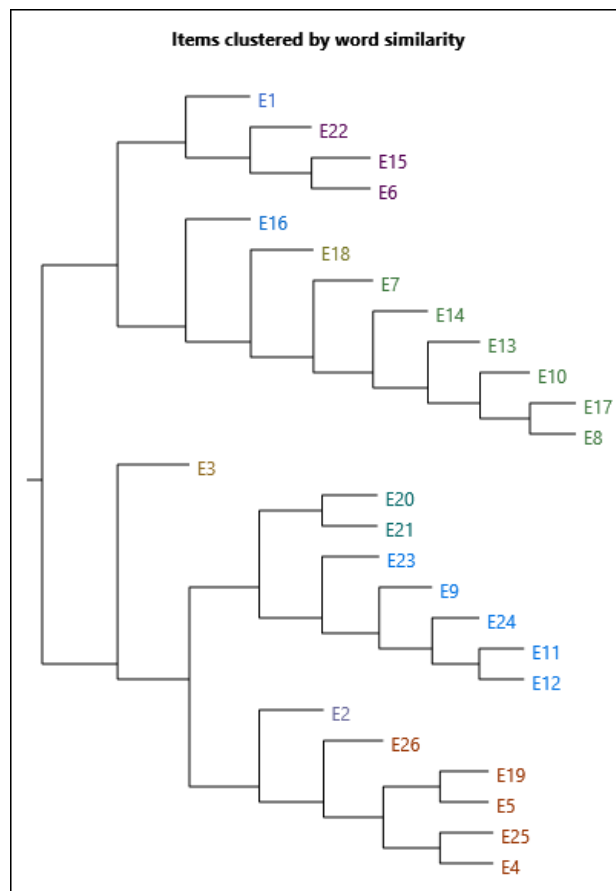
Topic 3 has the following terms: “company”, “change”, “energy”, “business”, “model”, “technological”, “business model”, “people”, “issue” and “legitimacy”. So, this topic seems to deal with Business Models and People in the Energy Business.

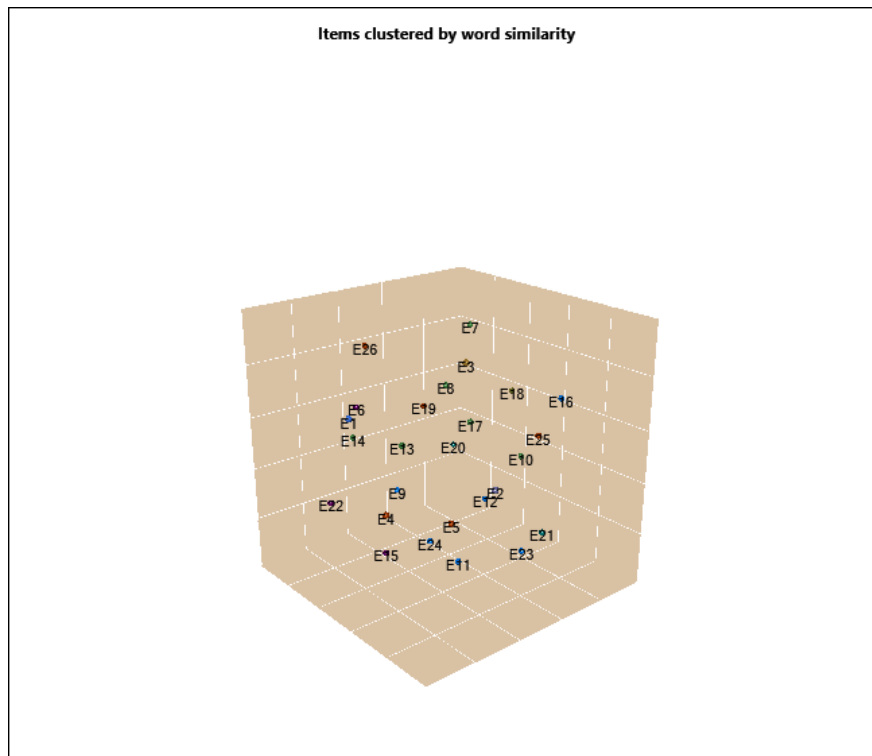
Topic 4 has the following terms: “company”, “energy”, “change”, “business”, “model”, “people”, “community”, “wind”, “legitimacy” and “time”. So, topic 4 seems to deal with Community Engagement and Legitimacy in the Energy Business.

Topic 5 has the following terms: “company”, “business”, “change”, “model”, “energy”, “people”, “business_model”, “legitimacy”, “time” and “technological”. This topic seems to deal with Business Models and the Energy Transition.

Coding the Interviews

For the coding process the software NVIVO was used. The 26 interviews were uploaded to NVIVO in Spanish for comparison purposes. The following charts show the cluster of the interviews based on word similarity. The language setting was Spanish to use the stop words that the software brings.





The interviews were coded looking for information that allow me to corroborate my intuitions, test the soundness of the hypotheses and conceptual model and the meaningfulness of the expected theoretical mechanism based on the topics previously described. In addition to that, I coded based on the related hypothesis when possible as well as the concept of ambidexterity.

Business changes in the energy market: The code refers to changes in regulations and market dynamics impacting the energy sector.

Sustainability and electromobility: the code relates to i) the practice of balancing resource use while meeting present and future needs. Conducting activities in a way that meets the needs of the present generation without compromising the ability of future generations to meet their own needs and ii) those activities related to using electricity in transportation.

Business model and the energy transition: The code addresses how the business model or its parts adapts or evolves due to the energy transition.

Business model and people in the energy business: The code highlights the significance of individuals in shaping business models and decision-making within the energy industry.

Community Engagement and Legitimacy in the Energy Business: the code relates to drivers and consequences of firm's legitimacy during the asset useful life as well as the interaction of the firm with all its stakeholders during the lifespan of its assets.

Technological Change: The code concerns to the drivers and consequences of technological change

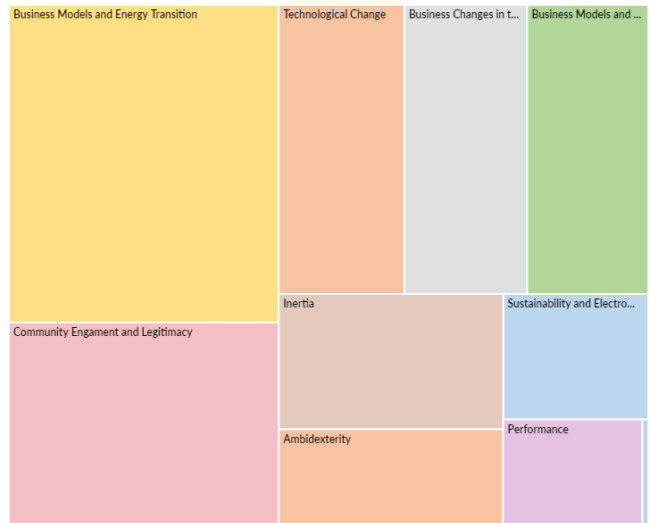
Performance: The code pertains to any references or activities related to measuring or evaluating performance in the energy business.

Inertia: The code relates to any activity or mention from the interview to the ability of the organization to adapt or not to adapt to any change triggered by external or internal factors.

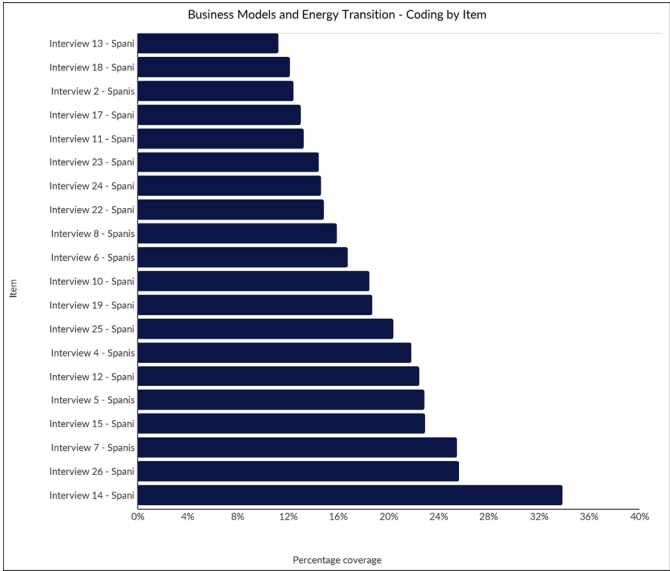
Adaptability: The codes related to the adoption or acceptance of any new technology

Ambidexterity: The code encompasses activities that enable a firm to effectively balance exploration and exploitation, incorporating both innovation and efficiency. It also includes the outcomes or consequences of ambidexterity.

The following chart summarizes how the coding references were applied to the total of the interviews.



Taking the code Business Models and Energy Transition in the following chart we see how relevant the topic is for each one of the interviewees.



Results

The 10 most relevant words, considering for NVIVO purposes stemmed words and words of at least 6 characters, for each one of the codes translated from Spanish into English are:

Adaptability: company, sector, technology, adoption, adopts, fast, changes, energy, innovation, small. It is interesting to note that the code seems to cover the concept of technology and its speed.

Ambidexterity: company, technology, changes, development, business, energy, projects, big, enterprise, electric. The code seems to include the changes in companies and business models due to technology.

Business Changes in the Energy Market: energy, changes, generate, electric, technology, renewable, market, company, price, coal. It appears the code incorporates the idea of changing market dynamics, including energy price, due to the penetration of renewable energy and its impact on coal related technology.

Business Models and Energy Transition: business, models, company, energy, technology, changes, clients, generate, electric, projects. It seems that the code incorporates the concept of changes in business models and how they relate to technology as well as clients.

Business Models and People: company, changes, job, people, model, business, gender, organization, decisions, different. The code seems to reflect the relevance of people, diversity and engagement for the changes in business models.

Community Engagement and Legitimacy: legitimacy, company, business, clients, community, changes, models, social, diversity, enterprise. The interesting concept of this code is how relates the legitimacy to community as well as the clients as its source. It also shows the relevance of diversity and the relationship with the business model.

Inertia: company, changes, big, technology, business, small, organization, models, projects, generated. The code seems to relate to the size of the organization, and its relationship with its adaptation to technology and business models innovation.

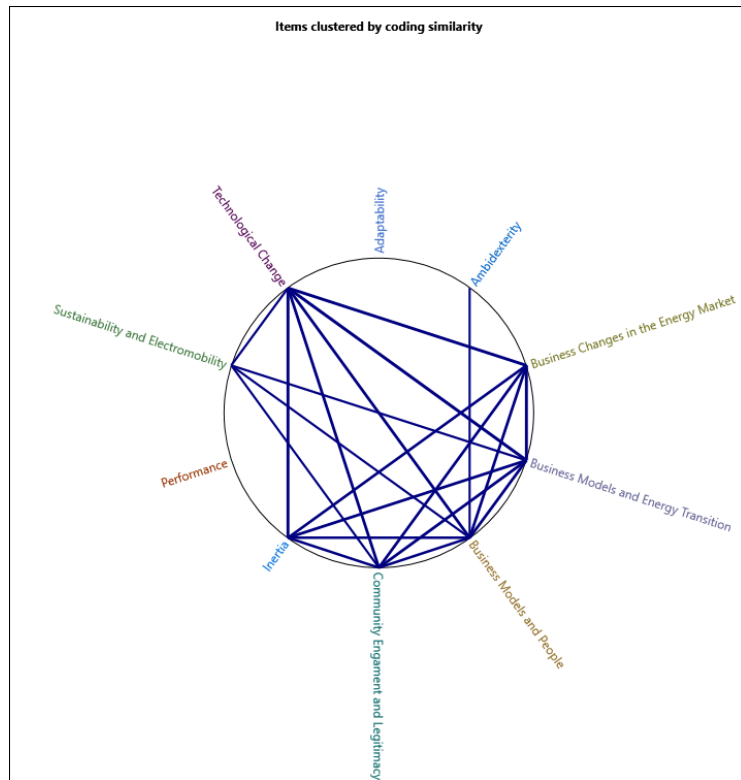
Performance: company, business, investment, projects, assets, distribution, profitability, energy, renewable, tariff. The code appears to relate to financial indicators as well as its relationship with the penetration of renewable energy and the impact of regulations, through tariffs for example.

Sustainability and Electromobility: electric, energy, changes, social, climate, environmental, technology, price, business, renewable. The code seems to include the impact of climate change in the environment and the society, and how this impact relates to renewable energy and energy price.

Technological Change: technology, changes, energy, electric, generate, revolution, battery, industry, development. It seems to include the concept of the impact in the industry due to the development of new technology, which in some cases could be disruptive or cause a “revolution”.

Additionally, is interesting to see the results of the coding similarity cluster analysis using the Jaccard coefficient⁷, which quantifies the overlap between two coding references. The chart shows the relationships using a Jaccard coefficient between 0,7 and 1 as it was the default provided by NVIVO.

⁷ It is calculated as the ratio of the number of coding references that are coded to both sources to the number of coding references coded to either source. The Jaccard coefficient ranges from 0 to 1, with 0 indicating no overlap and 1 indicating complete overlap.



The diagram shows a strong relationship between technological change and i) Business Changes in the Energy Market, ii) Business Models and Energy Transition, iii) Business Models and People, iv) Community Engagement and Legitimacy, v) Inertia, and vi) Sustainability and Electromobility. On the other side Performance and Adaptability do not show any strong relationship while Ambidexterity show strong relationship only with Business Models and People.