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Online Supplementary Material
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Induced Innovation, Inventors, and the Energy Transition

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A Data Cleaning and Construction

A.1 Overview of Patent Data Cleaning and Construction

We used the Spring 2022 Edition of PATSTAT from the European Patent Office (2022). There's a time lag between when patents are filed and when they appear in the database. As a result, data after 2019 is incomplete, with many patent applications missing.

We group patents by DOCDB simple patent families to prevent counting the same invention multiple times. Sometimes, multiple patents are filed for the same invention. This can happen if the patents have slightly different details about the same invention or if identical patents are filed in different countries.

PATSTAT provides the names and identifiers of the inventors and applicants listed on patent applications. However, only a subset of the identifiers is disambiguated. For this reason, we further process inventor names and improve inventor disambiguation (see next section for details). For applicants, we leverage Orbis Intellectual Property (Orbis IP), a database from Bureau van Dijk that contains links between private organizations and their patent applications. We match data from Orbis IP with PATSTAT using patent application numbers. In the end, this allows us to link DOCDB families in PATSTAT to BvD ids of Orbis establishments associated with these families.

Furthermore, PATSTAT provides extensive information about each patent family, especially where each application was filed. Since our data on natural gas prices only covers OECD countries, we concentrate on inventors who have submitted at least one energy patent in an OECD country. When categorizing inventors (like clean, grey/dirty, or non-energy), we consider their entire patent history in PATSTAT, no matter where the patent was filed.

A.2 Summary of Inventor Disambiguation and Cleaning

This section provides a summary of cleaning steps on inventor names. For more details, see Section B.

We standardize inventor names by starting with the PATSTAT Standard Name identifier and then removing special characters, changing all middle names to middle initials, and keeping only the first middle initial for people with multiple middle names.

We then use granted patent applications from the USPTO to compare the performance of our approach with the disambiguation effort done by Li et al. (2014). We find that for the subsample of inventors listed on USPTO patent grants between 1975 and 2010, our approach yields 92.1% of correct matches.

One concern is that our approach is susceptible to a "John Smith" problem, whereby we wrongly tag two identifiers as being the same inventor. Here, we adopt a conservative approach to limit the potential for false positives. We count the number of countries and the number of PATSTAT Standardized Name identifiers associated with each unique name that remains after our standardization procedure. For unique names for which either the number of countries or the number of PATSTAT identifiers is above the 99th percentile, we revert back to identifying unique inventors based solely on their PATSTAT identifiers. To be conservative, when inventors have patenting gaps of more than 15 years, we ignore observations before the gap. We also drop inventors whose patent history spans more than 60 years.

A.3 Clean, Grey, and Dirty Classification using Patent Technological Codes

To study the type of energy technologies in patent applications, we use the codes given on the patent filings. These codes tell us if the patent is about clean, grey, or dirty energy technologies. We use codes from both the Cooperative Patent Classification (CPC) and the International Patent Classification (IPC). This way, we can include many patent families. Specifically, we need IPC codes to include patents from China and Japan, as they don't use the CPC.

We make a list of energy codes that are relevant to electricity generation based on previous studies (Johnstone et al. 2010; Lanzi et al. 2011; Dechezleprêtre et al. 2014; Popp et al. 2022). These codes are shown in Tables A.1, A.2, and A.3. Note that we do not include codes related to fracking in "dirty" since this would introduce endogeneity with respect to changes in natural gas prices. We also do not include patents related to carbon capture and storage in "clean" since such technologies are complementary to fossil fuels.

In our main method, we say a patent family is "clean" if it has at least one code about renewable or nuclear energy. With this method, even if a patent has grey or dirty codes, it's still "clean" if it has a renewable or nuclear code.

We also use another, broader, method to define "clean." This method is different in two ways. First, it includes more than just renewables and nuclear; it also includes other enabling technologies related to electricity (see Table A.1). Second, it does not consider patents "clean" if they have any grey or dirty codes. Robustness results using this broader definition are contained throughout this Online Appendix.

A "dirty" patent family is one that has at least one "dirty" code and no "clean" or "grey" codes. "Grey" patent families are those that: 1) have at least one "grey" code, irrespective of whether they also have "clean" or "dirty" codes; or 2) have both "clean" and "dirty" codes.

Table A.1: CPC and IPC Codes for Clean Electricity Generation Technologies

Sub-sector	Code	Description
Wind Energy	F03D	Wind motors
	H01L27/142	Devices consisting of a plurality of semiconductor components sensitive to infra-red radiation, light - specially adapted for the conversion of the energy of such radiation into electrical energy
	Y02E10/70	Wind energy
Solar Energy	E04D13/18	Aspects of roofing for energy collecting devices - e.g. incl. solar panels
	F03G6	Devices for producing mechanical power from solar energy
	F24J2	Use of solar heat e.g. solar heat collectors
	F26B3/28	Drying solid materials or objects by processes involving the application of heat by radiation e.g. from the sun
	H01L31/04	Semiconductor devices sensitive to infra-red radiation, light - adapted as conversion devices
	H02N6	Generators in which light radiation is directly converted into electrical energy
	Y02E10/40	Solar thermal energy, e.g. solar towers
	Y02E10/50	Photovoltaic [PV] energy
	Y02E10/60	Thermal-PV hybrids
Renewables	Y02B10	Integration of renewable energy sources in buildings
	Y02E10	Energy generation through renewable energy sources
Nuclear Energy	Y02E30	Energy generation of nuclear origin
Marine Energy	E02B9/08	Tide or wave power plants
	F03B13/10	Submerged units incorporating electric generators or motors characterized by using wave or tide energy
	F03B13/12	Submerged units incorporating electric generators or motors characterized by using wave or tide energy
	F03G7/05	Ocean thermal energy conversion
	Y02E10/30	Energy from the sea, e.g. using wave energy or salinity gradient
Hydro Energy	Y02E10/20	Hydro energy
Geothermal Energy	F03G4	Devices for producing mechanical power from geothermal energy
	F03G7/04	Mechanical-power-producing mechanisms - using pressure differences or thermal differences occurring in nature
	F24J3	Production or use of heat, not derived from combustion - using natural or geothermal heat
	Y02E10/10	Geothermal energy
Enabling Technologies	Y02B70/30	Systems integrating technologies related to power network operation and ICT for improving the carbon footprint of the management of residential or tertiary loads, i.e. smart grids as CCMT in the buildings sector or as enabling technology in buildings sector.
	Y02B90/20	Systems integrating technologies related to power network operation and communication or information technologies mediating in the improvement of the carbon footprint of the management of residential or tertiary loads, i.e. smart grids as enabling technology in buildings sector
	Y02E40/70	Smart grids as climate change mitigation technology in the energy generation sector
	Y02E60	Enabling technologies (storage, hydrogen. . .)
	Y02E60/10	Energy storage using batteries, capacitors, Mechanical energy storage, e.g. flywheels or pressurised fluids
	Y02E60/30	Hydrogen Technology
	Y02E60/50	Fuel Cells
	Y02E60/70	Systems integrating technologies related to power network operation and communication or information technologies mediating in the improvement of the carbon footprint of electrical power generation, transmission or distribution, i.e. smart grids as enabling technology in the energy generation sector
	Y04S	Systems integrating technologies related to power network operation, communication or information technologies for improving the electrical power generation, transmission, distribution, management or usage, i.e. smart grids.

Table A.2: CPC and IPC Codes for Grey Electricity Generation Technologies

Sub-sector	Code	Description
Energy Efficiency	B01J8/20	Chemical or physical processes (and apparatus therefor) conducted in the presence of fluidised particles, with liquid as a fluidising medium
	B01J8/24	Chemical or physical processes (and apparatus therefor) conducted in the presence of fluidised particles, according to fluidised bed furnaces
	C10J3	Production of combustible gases containing carbon monoxide from solid carbonaceous fuels
	F01K17/06	Use of steam or condensate extracted or exhausted from steam engine plant; Returning energy of steam, in exchanged form, to process, e.g. use of exhaust steam for drying solid fuel of plant
	F01K23	Plants characterised by more than one engine delivering power external to the plant, the engines being driven by different fluids
	F01K27	Plants for converting heat or fluid energy into mechanical energy; use of waste heat;
	F01K3	Plants characterised by the use of steam or heat accumulators, or intermediate steam heaters, therein
	F01K5	Plants characterised by use of means for storing steam in an alkali to increase steam pressure, e.g. of Honigmann or Koenemann type
	F02B1/12	Engines characterised by fuel-air mixture compression ignition
	F02B11	Engines characterised by both fuel-air mixture compression and air compression, or characterised by both positive ignition and compression ignition, e.g. in different cylinders
	F02B13/02	Engines characterised by the introduction of liquid fuel into cylinders by use of auxiliary fluid; Compression ignition engines using air or gas for blowing fuel into compressed air in cylinder
	F02B3/06	Engines characterised by air compression and subsequent fuel addition; with compression ignition
	F02B49	Methods of operating air - compressing compression - ignition engines involving introduction of small
	F02B7	Engines characterised by the fuel-air charge being ignited by compression ignition of an additional fuel
	F02C3/20	Gas turbine plants characterised by the use of combustion products as the working fuel
	F02C3/32	Gas turbine plants characterised by the use of combustion products as the working fuel
	F02C3/34	Gas turbine plants characterised by the use of combustion products as the working fuel
	F02C3/36	Gas turbine plants characterised by the use of combustion products as the working fuel
	F02C6/10	Combinations of gas-turbine plants with other apparatus; Supplying working fluid to a user, e.g. a chemical process, which returns working fluid to a turbine of the plant
	F02C7/30	Gas turbine plants - Preventing corrosion in gas-swept spaces
	F02G5	Profiting from waste heat of combustion engines;
	F22B31	Modifications of boiler construction, or of tube systems, dependent on installation of combustion apparatus; Arrangements or dispositions of combustion apparatus
	F22B33/14	Steam generation plants, e.g. comprising steam boilers of different types in mutual association; Combinations of low- and high-pressure boilers
	F22G	Superheating of steam (steam separating arrangements in boilers)
	F23B10	Combustion apparatus characterized by the combination of two or more combustion chambers (using only solid fuel)
	F23B30	Combustion apparatus with driven means for agitating the burning fuel; Combustion apparatus with driven means for advancing the burning fuel through the combustion chamber
	F23B70	Combustion apparatus characterized by means for returning solid combustion residues to the combustion chamber
	F23B80	Combustion apparatus characterized by means creating a distinct flow path for flue gases or for non-combusted gases given off by the fuel
	F23C1	Combustion apparatus specially adapted for combustion of two or more kinds of fuel simultaneously or alternately, at least one kind of fuel being fluent
	F23C10	Apparatus in which combustion takes place in a fluidised bed of fuel or other particles
	F23C5/24	Combustion apparatus characterized by the arrangement or mounting of burners; Disposition of burners to obtain a loop flame.
	F23C6	Combustion apparatus characterized by the combination of two or more combustion chambers (using fluent fuel)
	F23D1	Burners for combustion of pulverulent fuel
	F23D17	Burners for combustion simultaneously or alternatively of gaseous or liquid or pulverulent fuel
	F23D7	Burners in which drops of liquid fuel impinge on a surface
	F27B15	Fluidised-bed furnaces; Other furnaces using or treating finely-divided materials in dispersion
	Y02E20/10	Combined combustion
	Y02E20/30	Technologies for a more efficient combustion or heat usage
	Y02E40	Technologies For An Efficient Electrical Power Generation, Transmission Or Distribution
Biomass and Waste	C10L5/40	Solid fuels essentially based on materials of non-mineral origin - animal or vegetable substances; sewage, town, or house refuse; industrial residues or waste materials
	F01K25/14	Plants or engines characterized by use of industrial or other waste gases
	F02B43/08	Engines or plants operating on gaseous fuel generated from solid fuel, e.g. wood
	Y02E20	Combustion Technologies With Mitigation Potential (E.G. Using Fossil Fuels, Biomass, Waste, Etc.)
	Y02E50	Technologies for the production of fuel of non-fossil origin (Biofuels, e.g. bio-diesel, Fuel from waste, e.g. synthetic alcohol or diesel)

Table A.3: CPC and IPC Codes for Dirty Electricity Generation Technologies

Sub-sector	Code	Description
Traditional Fossil Fuels	C10J	Production of fuel gases by carburetting air or other gases
	C10L1	Liquid carbonaceous fuels; Gaseous fuels; Solid fuels
	C10L3	Gaseous fuels; Natural gas; Synthetic natural gas obtained by processes not covered by subclass C10G, C10K; Liquefied petroleum gas
	C10L5	Solid fuels
	F01K	Steam engine plans; steam accumulators; engine plants not otherwise provided for engines using special working fluids or cycles
	F02C	Gas-turbine plants; air intakes for jet-propulsion plants; controlling fuel supply in air-breathing jet-propulsion plants
	F22	Steam generation
	F23	Combustion apparatus; combustion processes
	F24J	Production or use of heat not otherwise provided for
	F27	Furnaces; kilns; ovens; retorts
	F28	Heat exchange in general

A.4 Inventor-Level Patenting Outcomes

To determine how often an inventor patents, we look at the number of patent families of different types (e.g., clean) that are connected to inventor i in year t. We use the first application in that family where the inventor's name is mentioned to assign a year for the family for that inventor.

Imagine an inventor applied for a patent that is classified both as "renewable energy" and as "grey" (this is a rare but possible case concerning only 3.6% of renewable energy families). Using our basic definition of "clean", this inventor would be noted as having one "clean" patent and one "grey" patent. However, using the broader definition of "clean", the inventor would only have one "grey" patent and zero "clean" ones.

Note that, with our baseline definition, the patent is therefore counted twice, once as "clean" and once as "grey." While this has no bearing on our regression analyses, which center on clean patenting, it does mean that in Section 2, the inventor is labeled as "Clean and Grey/Dirty." If we adopt the broader definition of "clean", the entire patent family is then classified as "grey", and consequently, so is the inventor.

We construct an alternative count of inventor-level clean families by weighting families by the number of citations they received. The number of citations received is often used as a proxy of patent quality (Jaffe et al. 2000; Jaffe and Rassenfosse 2017). Our weighting procedure lets us give more weight to families that may be of higher quality. Specifically, for a family filed in year t, the weight is equal to the ratio of the number of citations the family received within three years over the number of citations that the average energy family filed in year t received.

This weighting approach presents two defining features: 1) it uses a particular time window (three years in our baseline measure) and 2) it makes the weight relative to the citation count of the average energy family filed in that *same year* (as opposed to the average energy family filed in any year). We provide further explanations regarding these features below.

First, we use a particular time window because the older a patent family is, the more chances there are for others to cite it. Comparing old and new patents directly on their number of citations wouldn't be inappropriate since newer ones haven't had as much time to get cited. For this reason, we count citations that occur within a particular time window. We use three years in our baseline measure but, as an extra check, we also look at citations from the first five years.

In fact, since we're using citations from a fixed time frame to compare patents, the exact time frame shouldn't change much as long as citations happen at about the same rate over time for all patents. In our sample, citations peak on average after four years, and so our robustness check using citations received within five years ensure that our measure covers the majority of citations.

Second, we use the citation count of the average energy family filed in the same year in the denominator which makes the weight relative to the citation behavior of a contemporaneous family. This is useful because citation patterns may change significantly over time without necessarily indicating a change in quality. For example, the average family filed in 2000 may have a lower number of citations received within three years compared to a family filed in 2014, simply because the overall inventors and firms in the economy, and thereby a citing pool of patents, was much larger in 2014. But this does not necessarily mean the 2000 families are of lower value.

Another issue may arise since the 2022 version of PATSTAT provides good coverage of applications only up to 2019, and the number of citations that occurred within 3 or 5 years for a family filed in, e.g., 2017, may be incomplete. Constructing citation weights based on the average behavior of the energy families filed in the same year circumvents these potential problems.

We also construct an alternative count of inventor-level clean families by weighting families by the number of coinventors that are listed on the patent. In this case, the weight equals $1/n$ where n is the total number of coinventors on the patent. So if two inventors worked on a "clean" patent together, each would get credit for half a patent. We use this approach to avoid double-counting and to facilitate comparisons to extensive margin responses in Section 5.

Finally, while we can easily observe when inventors produce their first patent, it is more difficult to ascertain when they exit. For this reason, if an inventor didn't patent in a year but did later on, we impute that they produced zero patents that year. But after the last year we observe a patent from an inventor, we do not impute any more data. That means the record for each inventor stops the last year in which they produced a patent family.

A.5 Natural Gas Price Data

We use data on natural gas prices from the International Energy Agency (2020). Prices are available for three sectors: electricity generation, industry, and households. Our baseline prices use industrial prices because the coverage of prices for electricity is much poorer, and the industrial prices are highly correlated with electricity sector prices. The International Energy Agency (2020) natural gas prices are in nominal U.S. dollars per megawatt-hour. As discussed in the text, all econometric analysis in the paper includes time fixed effects, which absorb common time-varying factors including changes in the value of U.S. dollars due to inflation, so the results are invariant to using prices in real terms.

A.6 Ancillary Data for Regressions

We use country-year level data from the International Energy Agency (2019) on government spending on energy RD&D, both in aggregate and specifically for low-carbon technologies. Country-year level data on GDP and GDP per capita in 2017 U.S. dollars purchasing power parity terms come from the World Bank (2020a, 2020b).

A.7 Construction of Exposure Measures

As explained in the main manuscript, our baseline inventor-specific prices take the following form:

$$\ln P_{it} = \sum_j s_{ij} \sum_c \frac{s_{jc} GDP_c}{\sum_c s_{jc} GDP_c} \ln P_{ct},$$

where

- P_{ct} represents the average tax-inclusive natural gas price in country c during year t. Our baseline approach uses industry prices. However, for robustness checks, we introduce alternative measures based on prices in the electricity generation and household sectors. Furthermore, price data might be incomplete for some countries. In our primary approach, we construct prices only for countries with data consistently available from 2000 to 2017 or with at most one year missing. This approach yields what we term a "balanced" panel of prices. For further robustness, we also formulate an "unbalanced" version, incorporating all available country-year price data, irrespective of its duration or consistency.

- GDP_c represents the average GDP of country c from 1990 to 2018, expressed in PPP terms using constant 2017 international dollars. For added robustness, we also consider measures without GDP-weighting the prices.

- s_{jc} quantifies firm j's exposure to country c. In our primary approach, this is determined by the proportion of firm j's energy patents in country c spanning 1990 to 2015. To enhance robustness, we consider three alternative methods to compute this weight: 1) Based on the proportion of *all* of firm j's patents in country c from 1990 to 2015. 2) Using the proportion of firm j's *energy* patents in country c during a pre-defined period from 1990 to 2000. 3) Reflecting the proportion of *all* of firm j's patents in country c within the same pre-defined period from 1990 to 2000. Firms lacking patent activity during the pre-period are allocated uniform weights across all countries.

- s_{ij} measures the association between inventor i and firm j. Specifically, it's determined by the fraction of patent families of inventor i linked with firm j. This weight is constructed using the full time series of each inventor's activities. Inventors who file independently, often termed "garage" inventors, are presumed to be influenced by the price in their country of residence.

B Inventor Disambiguation

B.1 Background

The challenge of accurately distinguishing authors and institutions is a significant concern in patent data. The same entity, be it an organization or an individual, can be represented with variations in their names, depending on the channels they've used for patent applications over time. Such inconsistencies arise from spelling errors, typographical mistakes, and different name variants, among others. While the initial PATSTAT data provided names and addresses of inventors, it lacked a system to uniquely identify inventors chronologically. For our study, creating a consistent and unique identifier for each inventor is crucial as we aim to monitor patents registered by individual inventors over time. Patent data frequently suffers from name misspellings, leading to multiple variants for a single inventor's name (e.g., JONSSON, NILS-AKE might also appear as JONSSON, NILS A.). The primary difficulty in disambiguation lies in associating all variants of an inventor's name without inadvertently merging distinct inventors with similar names.

Numerous studies have endeavored to disambiguate names and establish trustworthy inventor identifiers within patent databases, predominantly within the USPTO and EPO repositories. For instance, Li et al. (2014) (hereforth LLDD) undertook a disambiguation exercise on patents registered with the USPTO between 1975 and 2010, yielding unique identifiers for each inventor within their sample timeframe. A parallel initiative on European patent data was carried out by Coffano and Tarasconi (2014), crafting distinct inventor identifiers for the EPO database spanning 1970 to 2010. Research endeavors focusing on tracking activities at the inventor level typically lean on such disambiguated databases.

For our current study, given the absence of previous disambiguation work on the most recent PATSTAT dataset, our aim is to design straightforward disambiguation rules for the PATSTAT database. This will facilitate the efficient identification of unique inventors over time, while significantly alleviating issues related to name misspelling.

B.2 Harmonized Names in PATSTAT Data

PATSTAT provides multiple name versions for a single inventor: the nonharmonized inventor name (person name), the name in its original language, and several harmonized renditions.

The initial harmonized version in PATSTAT is the DOCDB standardized name, designated for applicant and inventor names set for inclusion in DOCDB. An issue with the DOCDB standardized name is its occasional misalignment with accurate person names. For instance, an inventor named "Charquet, Daniel" might be erroneously linked with "MARDON JEAN-PAUL", a clear mismatch. Such errors are particularly prevalent in USPTO patents.

Another available harmonized version is the HAN name, formulated primarily by the OECD HAN (Harmonized Applicant Name) project of the OECD. However, this applies solely to patent applicants and excludes inventors. ' The final harmonized version is the PATSTAT standardized name (PSN name), derived through automation and manual refinements, with non-harmonized names being directly lifted from the person name variable[1]. This standardization aims to rectify spelling variations, typographical errors, and acronym inconsistencies.

1. Details on PSN name and PSN ID construction in PATSTAT can be found in Magerman et al. (2006)

While PSN name harmonization undoubtedly reduces data discrepancies, it can fall short. A number of issues arise in particular related to presence of special characters (e.g., "TAKAHASHI, YUKIO" and "TAKAHASHI YUKIO") or the treatment of middle names (e.g., "JONSSON NILS AKE" vs. "JONSSON NILS A." or "SCHULZ, JOHANN G." vs. "SCHULZ, JOHANN G. D.").

Such issues are widespread, necessitating further refinement to the harmonized name variables for more accurate inventor identification. In addition, existing IDs anchored solely to harmonized name spellings disregard the locational/address data, potentially misidentifying distinct inventors with identical names.

B.3 Simple Rules for Further Name Disambiguation

As outlined in the previous section, two primary challenges arise when directly utilizing the PATSTAT standardized name ID (PSN ID) as a singular inventor identifier: 1) Variations in the spelling or format of an inventor's name lead to multiple identifiers for the same individual. 2) Conversely, distinct inventors sharing identical names may be erroneously grouped under one identifier.

For our analysis, we devised three straightforward rules to clean PATSTAT standardized names (PSN name) and forge unique inventor identifiers based on these refined names. We then examine the efficacy of these rules by comparing our approach to the disambiguated USPTO inventor data from LLDD.

We implemented the series of different rules:

- Rule 0: No modification (i.e., keeping the PSN name as provided by PATSTAT)
- Rule 1: Character cleaning and punctuation cleaning
- Rule 2: Rule 1 + changing all the middle names to middle initials
- Rule 3: Rule 1 + Rule 2 + keeping only 1 middle initial for people with multiple middle names

We also created two new inventor identifiers:

- Inventor ID 1: unique disambiguated PSN names as inventor identifier (without using any address information)
- Inventor ID 2: unique combinations of disambiguated PSN names and reported country of residence as inventor identifier

B.4 Comparing to Li et al. (2014)

To assess the efficacy of our disambiguation rules and the resultant inventor IDs for PSN names in PATSTAT, we compare our approach to the disambiguated inventor IDs of LLDD. To do so, we first narrow our PATSTAT sample to inventors that filed granted energy-related patents through the USPTO between 1975 and 2010. This data subset is then integrated with the OECD triadic patent family database via PATSTAT IDs, allowing us to retrieve the original USPTO IDs for these patents. Using these USPTO IDs, we extract an identical subset of patent grants from LLDD.

Table B.1 displays our data summary. We found more unique inventors using the original PSN names (38,853) than in LLDD (36,546). This suggests that the PSN IDs might be mixing up some inventors, seeing them as different people when they're actually the same. Consequently, we also find a higher average patent applications per inventor in LLDD.

Table B.1: Summary Statistics of Comparable Sample Used for Analysis

	PATSTAT subsample	Li et al. (2014) subsample
Number of Unique Inventors	38,853	36,546
Number of Patent Grants	26,018	26,018
Number of OECD Triadic Families	20,257	20,257
Number of DOCDB Families	22,135	-
Number of Inventors w/ Reported Address in 2 Countries	199	252
Number of Inventors w/ Reported Address in 3 Countries	3	6
Average Number of Patent Applications Per Inventor	0.670	0.712

Note: The number of unique inventors from PATSTAT sample is identified by the number of unique PSN IDs (hence unique PSN names).

Next, we match the inventor IDs from LLDD with our various cleaned-up versions of PATSTAT inventor IDs. We start by pairing inventors in each patent record using their cleaned-up last names. If a patent record has more than one inventor with the same last name, we use both their first and last names to match them. This ensures that each name from PATSTAT is checked against all its versions in the LLDD data.

Table B.2 gives an overview of how well each method works.[2] Row 1 displays the total number of unique inventors in LLDD. Row 2 the total number of unique inventors in PATSTAT with the original PSN ID. These totals stay the same, no matter which rules we use. They're there to help compare results. Row 3 reports the number of unique inventors in PATSTAT based on the rule used in each column.

Rows 4 and 5 provide information on mismatches between the two sets of data. Row 4 shows instances where an inventor has a unique ID in LLDD but gets multiple IDs in PATSTAT. For example, using Rule 1 with inventor ID 1, 1,298 inventors from LLDD get treated as different people in PATSTAT when they should be the same. Row 5 is the opposite: it lists cases where PATSTAT thinks inventors are the same person, but LLDD treats them as different people. There are 760 such instances.

Rows 6 and 7 tell us the number of inventors we are not able to match between the two datasets. These are less informative because as long as these inventors show up only one time in the data, this will not lead to over or under disambiguation. As a result, the numbers in Row 6 and 7 are simply an indication of the matched sample size.

Finally, Row 8 shows the number of correctly matched inventors. This is calculated by taking the unique inventors in PATSTAT and subtracting the ones with matching problems (multiple match in either way and unable to match). The percentage of these correctly matched inventors (Row 9) is then the correctly matched number divided by PATSTAT's total unique inventors based on the particular rule used in each column.

2. We do not include results for Rule 0 (which doesn't change the PSN names) because very few matches were found using this rule.

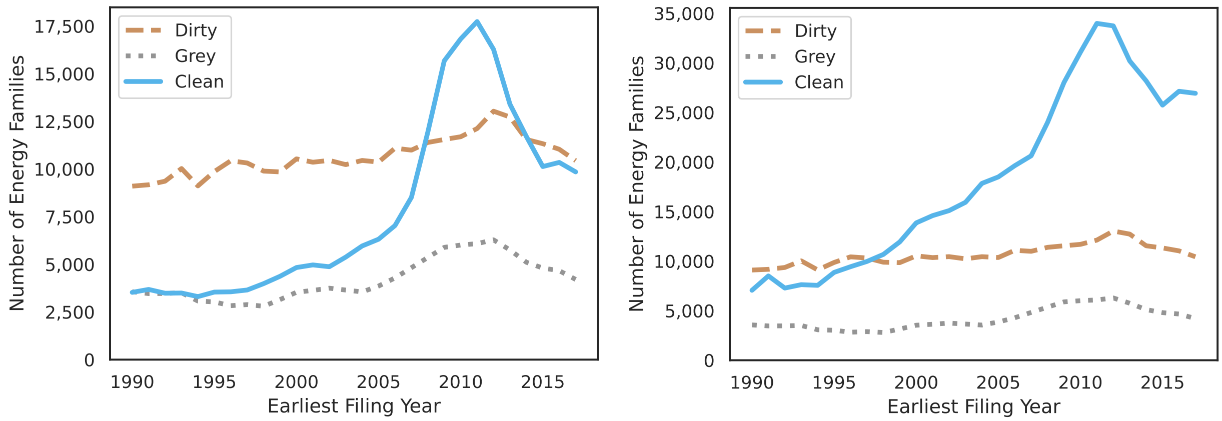
The fraction of correctly matched inventors is largest for Column 5 with 92.1%. This corresponds to using Rule 3 with inventor ID 1.

Table B.2: Summary of Performance of Different Disambiguation Rules

	Rule 1& INV ID 1	Rule 1& INV ID 2	Rule 2& INV ID 1	Rule 2& INV ID 2	Rule 3& INV ID 1	Rule 3& INV ID 2
Number of unique inventors in LLDD	**36,546**	**36,546**	**36,546**	**36,546**	**36,546**	**36,546**
Number of unique inventors in PATSTAT (by PSN ID)	38,853	38,853	38,853	38,853	38,853	38,853
Number of unique inventors in PATSTAT	37,170	37,440	36,147	36,472	36,257	36,565
Inventors with non-unique IDs in PATSTAT but unique ID in LLDD	1,298	1,395	522	628	572	668
Inventors with non-unique IDs in LLDD but unique ID in PATSTAT	760	619	894	726	754	699
Number of inventors in LLDD we cannot match to PATSTAT	1,417	1,417	1,416	1,417	1,417	1,417
Number of inventors in PATSTAT we cannot match to LLDD	1,591	1,601	1,530	1,546	1,550	1,570
Number of correctly matched inventors	33,521	33,825	33,201	33,572	33,381	33,628
Fraction of correctly matched inventors	0.902	0.903	0.918	0.920	0.921	0.920

C Descriptives

C.1 Trends in Families Over Time

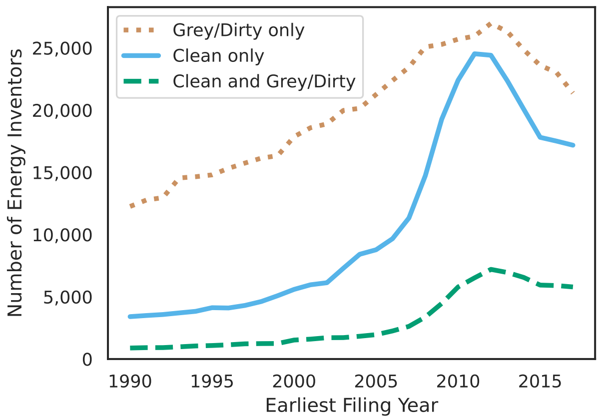


(a) Baseline Definition of Clean (b) Broader Definition of Clean

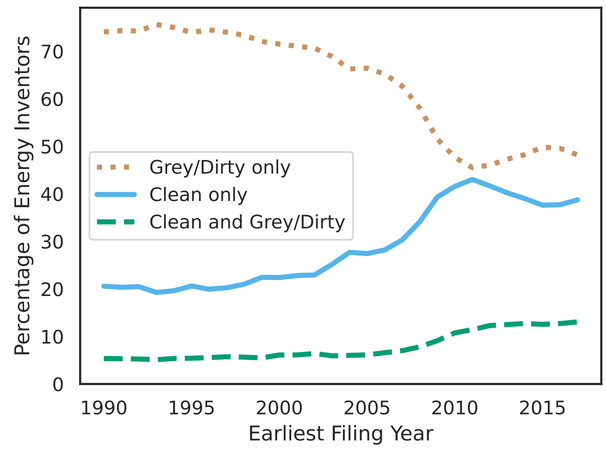
Figure C.1: Patent Families by Type Over Time

Note: The figures plot the number of patent families classified as clean, grey, and dirty over time. Panel a uses the baseline definition of clean and Panel b uses the broader definition.

C.2 Inventor Types

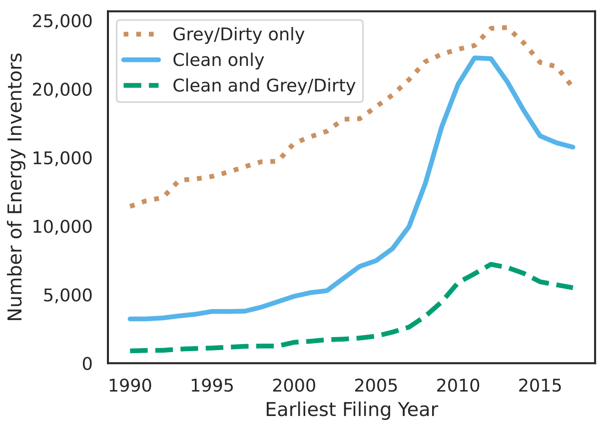


Levels

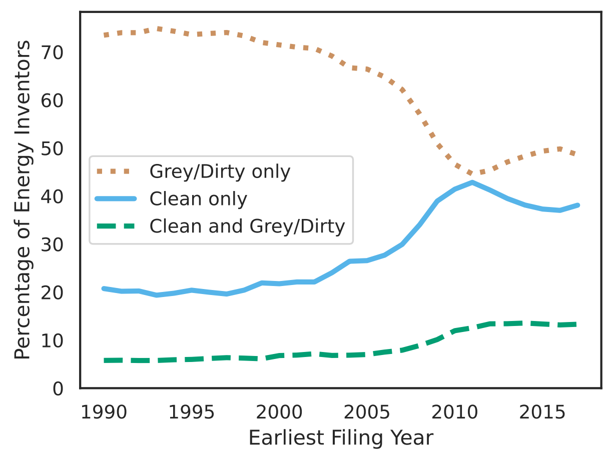


Percentage

(a) Energy Inventors with Energy Patents in at least Two Different Years



Levels



Percentage

(b) Energy Inventors with at least Two Energy Patents

Figure C.2: Trends in the Number and Composition of Energy Iventors over Time

Note: These figures are alternative versions of Figures 1a and 1b from the main text. The figures illustrate the extent to which energy inventors specialize in either clean, grey, or dirty patenting. We focus on inventors' global patent portfolios for inventors with at least one energy patent in an OECD country after 1990. To construct the graphs, we first identify inventors with at least one energy family filed in year t, and then classify them according to their last three years of patenting activity.

Table C.1: Energy Inventors by Type

(a) Using the Baseline Definition of Clean

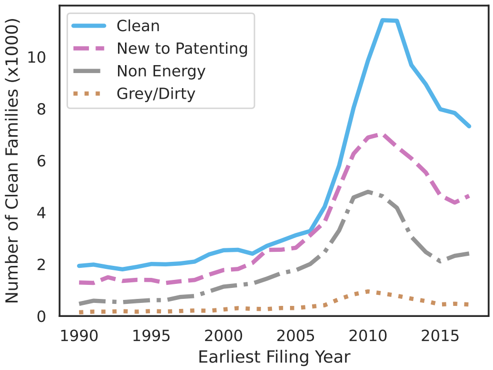
Inventor Type	All Inventors	Serial Inventors	Serial Inventors (2 years +)	Energy Serial Inventors	Top 10th Inventors
Grey/Dirty only	60%	55%	52%	50%	28%
Clean only	30%	30%	30%	29%	25%
Clean and Grey/Dirty	10%	15%	17%	21%	47%
Total Number of Energy Inventors	873,256	525,652	442,405	324,310	91,848

(b) Using the Broader Definition of Clean

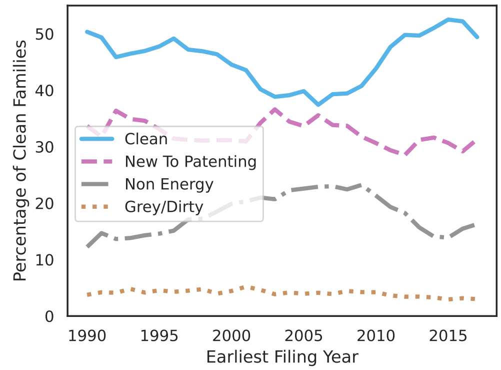
Inventor Type	All Inventors	Serial Inventors	Serial Inventors (2 years +)	Energy Serial Inventors	Top 10th Inventors
Grey/Dirty only	45%	40%	38%	36%	20%
Clean only	45%	44%	43%	40%	33%
Clean and Grey/Dirty	10%	16%	19%	23%	47%
Total Number of Energy Inventors	1,188,768	733,534	619,120	459,086	128,395

Note: These tables show the average share of energy inventors by type for different definitions of clean. These shares correspond to the average of the trends shown on Figures 1a, 1b and C.2. Details about the different definitions of clean are provided in Subsection A.3.

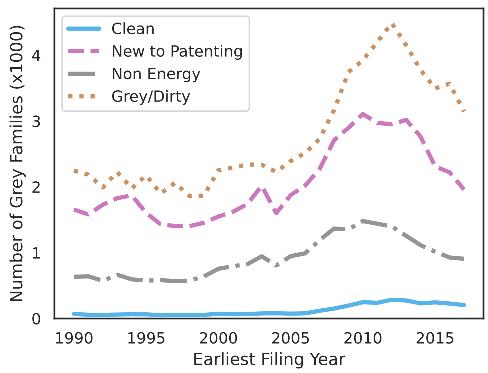
C.3 Clean, Grey, and Dirty Patent Families by Origin of Inventors



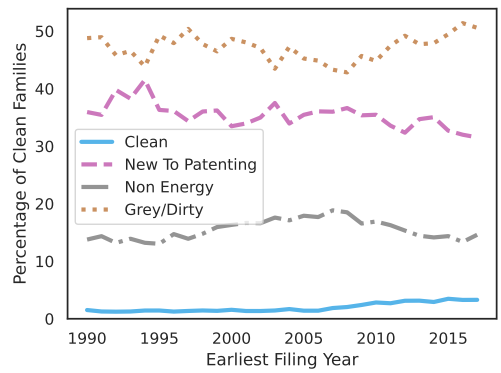
(a) Clean - Levels



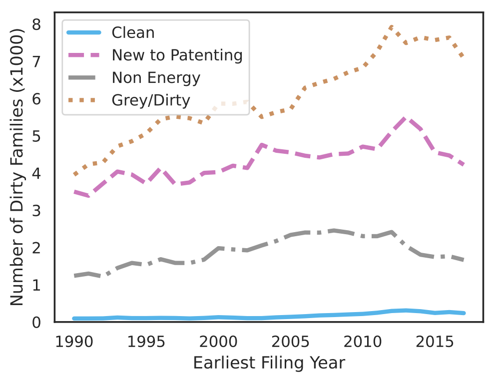
(b) Clean - Percentage



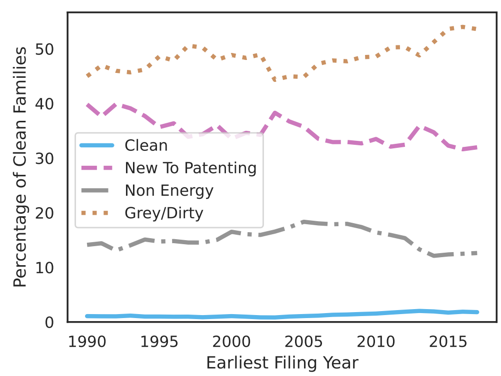
(c) Grey - Levels



(d) Grey - Percentage



(e) Dirty - Levels

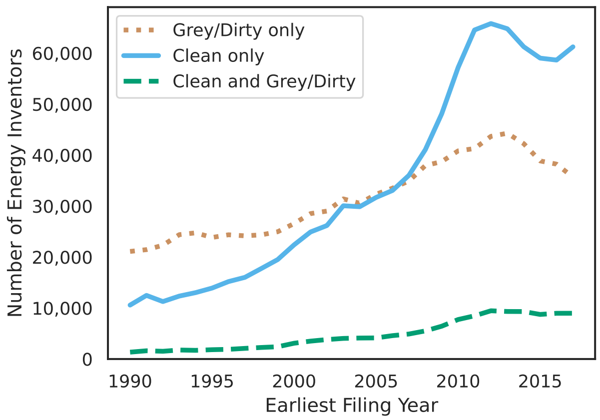


(f) Dirty - Percentage

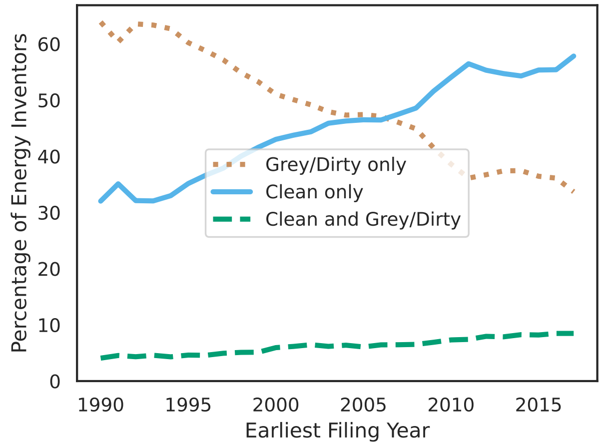
Figure C.3: Clean, Grey, and Dirty Patent Families by Origin of Inventor

Note: These figures illustrate the types of inventors that produce clean, grey, and dirty patent families over time. They plot the trend over time in the number and share of families connected to incumbents, inventors new to patenting, inventors with previous patents outside the set of energy technologies under study, and inventors with previous energy technology patents. Families with multiple inventors are fractionally attributed to the inventors to avoid double-counting. Figures C.3a and C.3b are reproductions of Figures 1c and 1d from the main text for convenience.

C.4 Descriptives using a Broader Definition of Clean



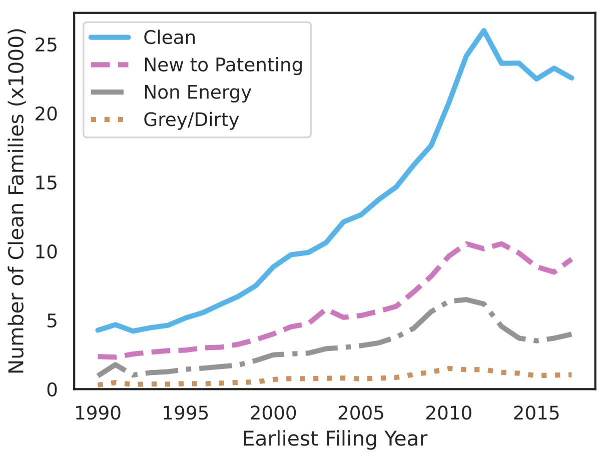
(a) Levels



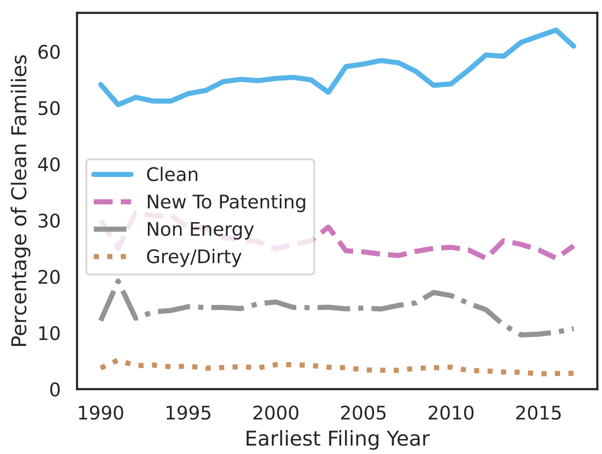
(b) Percentage

Figure C.4: Energy Inventors By Type (All Inventors)

Note: These figures are alternative versions of Figures 1a and 1b from the main text using a broader definition of clean as described in Subsection A.3.



(a) Clean Broader - Levels



(b) Clean Broader - Percentage

Figure C.5: Clean Patent Families by Origin of Inventor

Note: These figures are alternative versions of Figures 1c and 1d from the main text using a broader definition of clean as described in Subsection A.3.

C.5 Other Information about Patent Codes

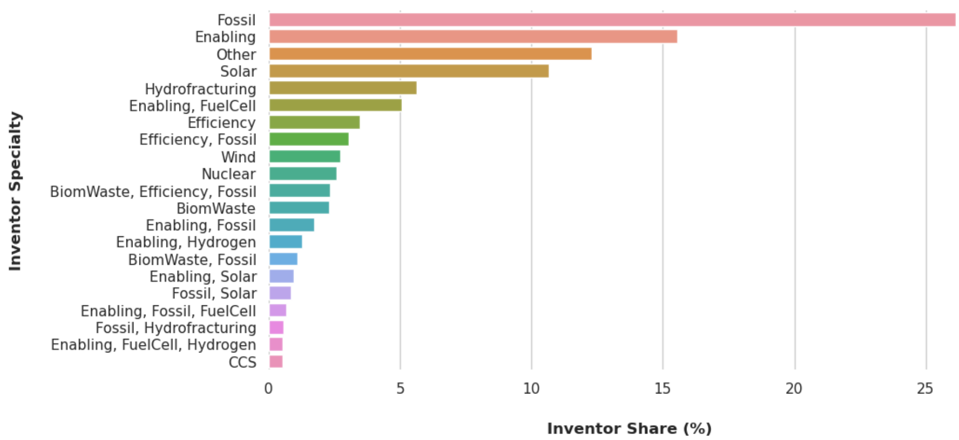


Figure C.6: Technological Areas Most Often Combined by Energy Inventors

Note: This bar plot depicts the specific technology areas that energy inventors focus on. The highest bar shows that over 25% of the energy inventors in our sample have patents exclusively in fossil-related technologies, while just over 15% specialize in enabling technologies. The most frequent other clean area is solar with about 10%. The label "Other" corresponds to all other combinations of technologies that are not listed.

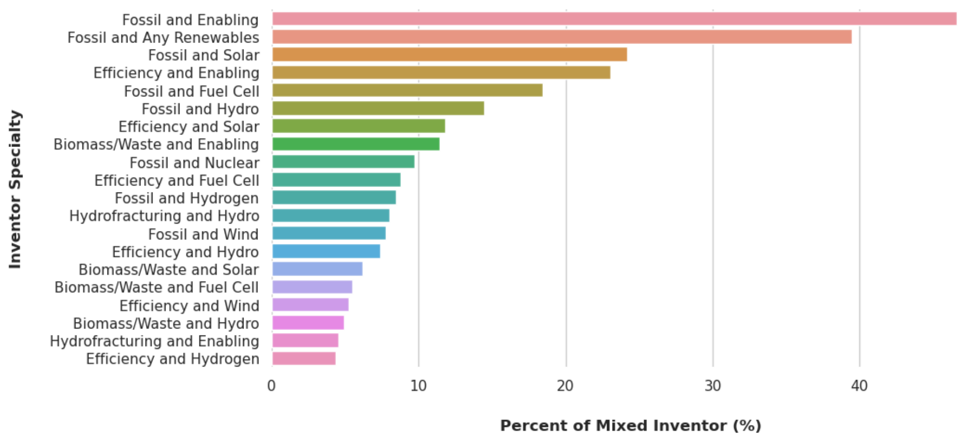


Figure C.7: Clean and Grey/Dirty Technological Areas Most Often Combined by Inventors

Note: This graph shows the 20 most common combinations of clean and grey/dirty areas. The highest bar indicates that about 45% of mixed-type inventors combine technologies related to fossil and enabling. 40% also combine fossil and any renewables. The percentages are calculated such that an inventor that combines fossil, enabling, and renewable technologies will count towards both the first and the second bars, as well as one or more other bars for the specific renewable technologies they combine.

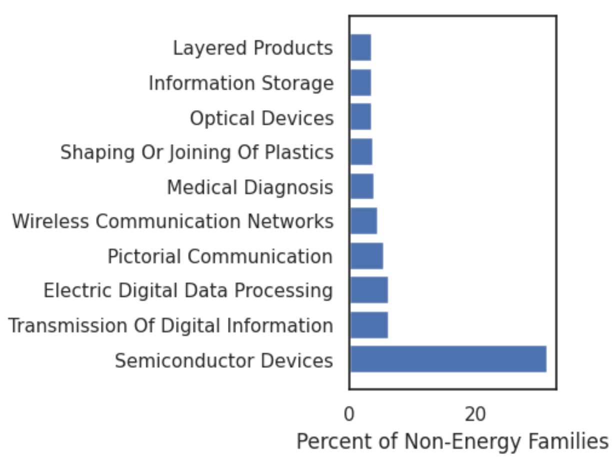


Figure C.8: CPC Codes of Non-Energy Patents of Clean Entrants

D Summary Statistics

D.1 Inventor-Level Summary Statistics

Table D.1: Summary Statistics for Patenting Variables - Baseline Definition of Clean

	count	mean	sd	min	p50	p90	p95	p99	max
Simple Count	1190738	0.51	1.06	0.00	0.00	1.00	2.00	4.00	113.00
Coinventor-Weighted	1190738	0.21	0.52	0.00	0.00	0.58	1.00	2.00	76.50
Citation-Weighted (3 years)	1190738	0.53	1.62	0.00	0.00	1.47	2.47	6.52	164.76
Citation-Weighted (5 years)	1190738	0.53	1.71	0.00	0.00	1.44	2.56	6.84	161.74
Triadic	1190738	0.11	0.42	0.00	0.00	0.00	1.00	2.00	30.00
Triadic (Coinventor-Weighted)	1190738	0.04	0.19	0.00	0.00	0.00	0.25	1.00	31.50
Granted	1190738	0.37	0.83	0.00	0.00	1.00	2.00	3.00	45.00
Granted (Coinventor-Weighted)	1190738	0.14	0.39	0.00	0.00	0.50	1.00	1.75	49.00
Triadic Granted	1190738	0.10	0.39	0.00	0.00	0.00	1.00	2.00	30.00
Triadic Granted (Coinventor-Weighted)	1190738	0.03	0.18	0.00	0.00	0.00	0.25	0.83	31.50
More than 2 countries	1190738	0.27	0.67	0.00	0.00	1.00	1.00	3.00	37.00
More than 2 countries (Coinventor-Weighted)	1190738	0.10	0.31	0.00	0.00	0.33	0.50	1.20	38.00
More than 2 OECD	1190738	0.23	0.61	0.00	0.00	1.00	1.00	3.00	36.00
More than 2 OECD (Coinventor-Weighted)	1190738	0.09	0.28	0.00	0.00	0.33	0.50	1.00	37.00

Note: These summary statistics are for the sample of clean incumbent inventors used in the incumbent regressions.

Table D.2: Summary Statistics for Patenting Variables - Broader Definition of Clean

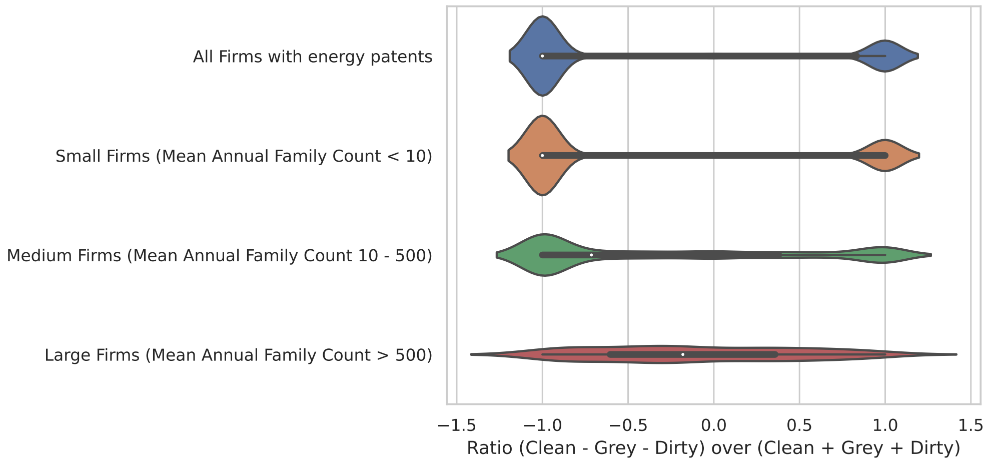
	count	mean	sd	min	p50	p90	p95	p99	max
Simple Count	2290321	0.66	1.49	0.00	0.00	2.00	3.00	6.00	98.00
Coinventor-Weighted	2290321	0.23	0.58	0.00	0.00	0.67	1.00	2.40	50.50
Citation-Weighted (3 years)	2290321	0.66	2.31	0.00	0.00	1.72	2.97	7.63	368.52
Citation-Weighted (5 years)	2290321	0.66	2.37	0.00	0.00	1.73	2.98	7.89	337.94
Triadic	2290321	0.14	0.52	0.00	0.00	1.00	1.00	2.00	50.00
Triadic (Coinventor-Weighted)	2290321	0.04	0.19	0.00	0.00	0.12	0.33	1.00	28.50
Granted	2290321	0.48	1.12	0.00	0.00	1.00	2.00	5.00	75.00
Granted (Coinventor-Weighted)	2290321	0.16	0.42	0.00	0.00	0.50	1.00	1.83	37.00
Triadic Granted	2290321	0.13	0.49	0.00	0.00	1.00	1.00	2.00	39.00
Triadic Granted (Coinventor-Weighted)	2290321	0.04	0.18	0.00	0.00	0.07	0.29	1.00	28.50
More than 2 countries	2290321	0.35	0.85	0.00	0.00	1.00	2.00	4.00	52.00
More than 2 countries (Coinventor-Weighted)	2290321	0.11	0.32	0.00	0.00	0.33	0.53	1.33	36.33
More than 2 OECD	2290321	0.31	0.80	0.00	0.00	1.00	1.00	3.00	52.00
More than 2 OECD (Coinventor-Weighted)	2290321	0.10	0.30	0.00	0.00	0.33	0.50	1.18	36.33

Note: These summary statistics are for the sample of clean incumbent inventors used in the incumbent regressions, based on the broader definition of clean as described in Subsection A.3.

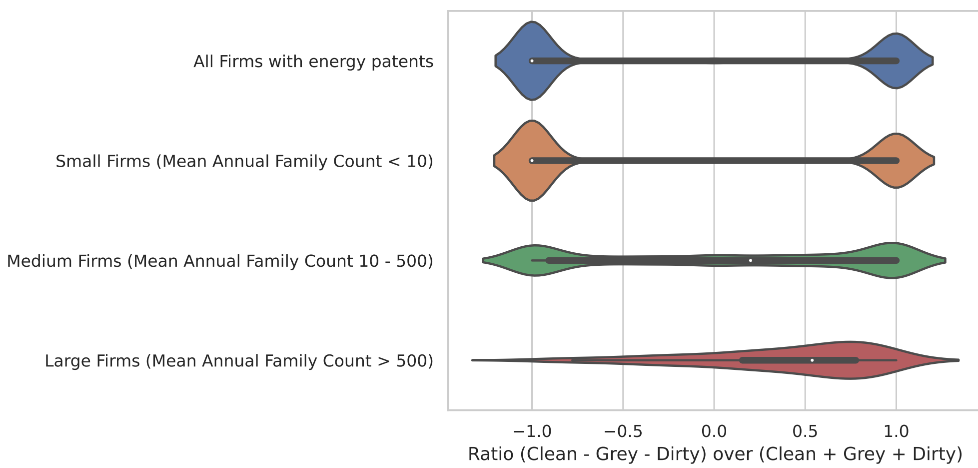
Table D.3: Summary Statistics for Different Measures of Natural Gas Prices - Incumbents Sample

	count	mean	sd	min	max
Prices GDP-Weighted Balanced (log, t-1)	1,164,850	31.2	11.5	5.51	73.5
Prices GDP-Weighted Unbalanced (log, t-1)	1,166,456	31.3	11.4	5.51	73.5
Prices Not GDP-Weighted Balanced (log, t-1)	1,164,850	36.9	13	5.51	73.5
Prices Not GDP-Weighted Unbalanced (log, t-1)	1,166,456	37.1	12.9	5.51	73.5

D.2 Firm-Level Summary Statistics



(a) Baseline Definition of Clean



(b) Broader Definition of Clean

Note: The graphs depict the distribution of firms based on their specialization degree. The x-axis consists of the following ratio: $\frac{FamilyCountClean - FamilyCountGrey - FamilyCountDirty}{FamilyCountClean + FamilyCountGrey + FamilyCountDirty}$, where $FamilyCountClean$ is the average number of clean patent families firm j filed annually between 1990 and 2014. This ratio holds a value of 0 when a firm files an equal number of clean and grey/dirty patent families. It registers a value of 1 when a firm exclusively specializes in clean patents and -1 when it focuses purely on grey or dirty patents. The graphs suggest that most firms in our sample are specialized in either clean or dirty. However, larger firms exhibit greater diversification, combining clean and grey/dirty patents. Notably, Figure D.1b emphasizes that when adopting the broader definition of clean, many larger firms focus predominantly on clean energy. This tendency can be attributed to sizeable conglomerates like Panasonic, which patent extensively on battery-related technologies and little on grey or dirty technologies.

Figure D.1: Density Plots for the Degree of Specialization

Table D.4: Firm-Level Summary Statistics

(a) Mean

Row	Sample Description	Family Count Total	Percent Energy	Family Count Energy	Percent in Energy				If Diversified	If Specialized in		Row
					ReNu	Clean	Grey	Dirty		Clean	Grey/Dirty	
		1	2	3	4	5	6	7	8	9	10	
1	Firms with energy patents	11.2	45	1.2	25	43	16	41	0.1	0.4	0.5	1
2	Firms with Re/Nu patents	25.9	44	2.1	79	83	8	9	0.2	0.7	0.1	2
3	Firms with clean patents	19.7	41	1.7	49	87	5	8	0.2	0.8	0.0	3
4	Firms connected to energy inventors	11.2	45	1.2	25	43	16	41	0.1	0.4	0.5	4
5	Firms connected to Re/Nu inventors	17.9	36	1.5	38	56	14	31	0.2	0.5	0.4	5
6	Firms connected to clean inventors	15.8	38	1.4	32	57	13	30	0.2	0.5	0.4	6
7	Firms connected to non-energy entrants before the year of entry	51.8	10	2.8	28	54	13	34	0.3	0.4	0.3	7
8	New Firms connected to non-energy entrants the year of entry	52.4	32	3.4	59	73	9	17	0.3	0.5	0.1	8
9	All Firms connected to non-energy entrants the year of entry	43.5	27	2.8	59	73	9	18	0.3	0.6	0.1	9
10	Firms connected to grey/dirty inventors	18.6	38	1.5	11	23	23	54	0.2	0.1	0.7	10
11	Firms connected to grey/dirty entrants before the year of entry	45.4	19	2.7	21	41	17	42	0.3	0.2	0.4	11
12	New Firms connected to grey/dirty entrants the year of entry	85.2	25	5.2	46	64	12	24	0.4	0.4	0.2	12
13	All Firms connected to grey/dirty entrants the year of entry	69.3	23	4.2	42	59	13	27	0.4	0.4	0.2	13
14	Firms connected to new to patenting entrants the year of entry	59.7	12	3.3	40	62	11	27	0.4	0.4	0.2	14

(b) Median

Row	Sample Description	Family Count Total	Percent Energy	Family Count Energy	Percent in Energy				If Diversified	If Specialized in		Row
					ReNu	Clean	Grey	Dirty		Clean	Grey/Dirty	
		1	2	3	4	5	6	7	8	9	10	
1	Firms with energy patents	2.0	33	0.7	0	0	0	0	0.0	0.0	1.0	1
2	Firms with Re/Nu patents	2.1	30	1.0	100	100	0	0	0.0	1.0	0.0	2
3	Firms with clean patents	2.2	25	0.7	44	100	0	0	0.0	1.0	0.0	3
4	Firms connected to energy inventors	2.0	33	0.7	0	0	0	0	0.0	0.0	1.0	4
5	Firms connected to Re/Nu inventors	2.6	19	0.5	0	75	0	0	0.0	0.0	0.0	5
6	Firms connected to clean inventors	2.3	20	0.5	0	83	0	0	0.0	0.0	0.0	6
7	Firms connected to non-energy entrants before the year of entry	8.2	4	0.3	1	60	0	13	0.0	0.0	0.0	7
8	New Firms connected to non-energy entrants the year of entry	4.3	13	0.9	67	100	0	0	0.0	1.0	0.0	8
9	All Firms connected to non-energy entrants the year of entry	4.2	11	0.6	67	100	0	0	0.0	1.0	0.0	9
10	Firms connected to grey/dirty inventors	2.1	21	0.5	0	0	0	63	0.0	0.0	1.0	10
11	Firms connected to grey/dirty entrants before the year of entry	6.1	7	0.5	0	27	0	31	0.0	0.0	0.0	11
12	New Firms connected to grey/dirty entrants the year of entry	9.5	8	1.0	36	79	0	5	0.0	0.0	0.0	12
13	All Firms connected to grey/dirty entrants the year of entry	8.5	8	0.8	29	71	0	9	0.0	0.0	0.0	13
14	Firms connected to new to patenting entrants the year of entry	8.8	5	0.4	25	77	0	5	0.0	0.0	0.0	14

Note: The tables present summary statistics of various firm samples. For instance, the first row examines firms that filed at least one energy patent between 1990 and 2014. In contrast, the 8th row delves into a specific subsample: firms that connected with a non-energy entrant in their year of clean entry but had no prior connection with them. Table D.4a reports values for the mean firm while Table D.4b reports values for the median firm.
Below is more information about each variable in the columns. All variables are calculated using firm-level patent data for the period between 1990 and 2014.

- "Family Count Total" (Column 1) is the average number of patent families filed annually, irrespective of type.
- "Percent Energy" is the proportion of energy-related patent families out of the total count.
- "Family Count Energy" is the average number of energy-related patent families, filed annually.
- The section labeled "Percent in Energy" breaks down firms' energy patent portfolio into the following categories: Renewables and Nuclear ("ReNu"), Clean (our broad definition of "Clean" that include enabling technologies), Grey, and Dirty.
- Columns "If Diversified" and "If Specialized in" show the mean or median values of binary variables that indicate whether a firm is diversified and if not, whether it i specialized in Clean or in Grey/Dirty. This classification relies on the following ratio:
  $\frac{FamilyCountClean - FamilyCountGrey - FamilyCountDirty}{FamilyCountClean + FamilyCountGrey + FamilyCountDirty}$.
  Where $FamilyCountType$ represents the average yearly count of patent families of type k filed by firm j between 1990 and 2014. The binary variables are constructed as follows:
  - Firms with a ratio greater than 0.8 are classified as specialized in Clean.
  - Firms with a ratio less than -0.8 are seen as specialized in Grey or Dirty.
  - Firms with a ratio between -0.8 and 0.8 are termed diversified.

Take-Aways from Table D.4

- Regarding firms that have at least one energy patent:

  From Row 1, we learn that, on average, these firms file 11.2 patents annually (Column 1), with 45% of these patents being energy-related (Column 2). In contrast, the median value for the total patent family count is significantly lower at 2.0 (Table D.4b Column 1). This suggests a skewed distribution with a long right tail, meaning that while the typical firm patents only two families per year, some firms patent extensively. Most firms specialize in clean or grey/dirty; about 10% only are diversified (Column 8).

- Regarding inventors that enter clean from non-energy:
  - Row 7: Before patenting in clean energy, non-energy entrants typically are connected with firms that: 1) patent more frequently than the average energy-patenting firm (51.8 in Column 1 vs 11.2 in Row 1 Column 1); 2) focus less on energy, with only 10% of their patents being related to energy (Column 2); 3) are more likely to be diversified (0.3 in Column 8 vs. 0.1 in Row 1).
  - Row 8: When non-energy inventors enter and file their first clean patent, we typically observe that they file patents with firms they have never patented with. The newly associated firms have a greater focus on energy (32% in Column 2 vs. 10% in Row 7) compared to the firms these inventors were previously patenting with (32% in Column 2 vs. 10% in Row 7). They are also considerably less likely to specialize in grey/dirty (0.1 in Column 10 vs. 0.3 in Row 7).

- Regarding inventors that enter clean from grey and/or dirty:
  - Row 11: Before patenting in clean, grey/dirty entrants are connected with firms that: 1) patent more frequently than the average grey/dirty firm (45.4 in Column 1 vs 18.6 in Row 10); 2) are not as heavily focused on energy, with their energy-related patents constituting only 19% of their portfolio (Column 2), compared to 38% for the average grey/dirty firm (Column 2 Row 10); 3) exhibit greater diversification between clean and grey/dirty technologies (reflected by a value of 0.3 in Column 8); 4) are less inclined to specialize solely in the grey/dirty sector (0.4 in Column 10 vs 0.7 in Row 10).
  - Row 12: When grey/dirty inventors enter clean, we observe that they tend to file patents with firms they have never patented with before. These newly associated firms patent significantly more than the firms these inventors were previously patenting with (85.2 in Column 1 vs 45.4 in Row 11). Additionally, these firms are more likely to be diversified (0.4 in Column 8 vs. 0.3 in Row 11) and less likely to specialize in grey/dirty technologies (0.2 in Column 10 vs. 0.4 in Row 11).

E Instrumental Variable Estimation

As described in Section 3, some estimates come from an instrumental variable strategy that utilizes variation in natural gas prices caused by the shale gas revolution. Since the model in equation 1 is nonlinear and contains inventor fixed effects, we use a control function approach to implement the instrumental variable strategy. Our approach is based on the control function method outlined in Lin and Wooldridge (2019). We start by estimating a first-stage linear regression of prices on the shale revolution instrument, as well as all other covariates used in estimating equation 1:

$$\ln P_{it-1} = \tilde{\beta}_z z_{it-1} + \tilde{\beta}_X X_{it-1} + \tilde{\gamma}_{t-1} + \tilde{\eta}_i + \tilde{u}_{it-1}, \tag{E.1}$$

where z_{it} is an inventor-specific measure of the binary instrument for the shale gas revolution.

The shale gas revolution instrument is determined at the country level. It takes on a value of one for the United States and Canada starting in 2009 (when the shale revolution began to take effect), and is zero in all other countries and time periods. To construct the inventor-specific instrument z_{it}, we take the same approach described in Section 3 for constructing inventor-specific natural gas prices: First, we compute firm-specific values of the instrument as a weighted average of the country-specific instrument, where the weights for each firm depend on the location of their patenting activity. Then, we use these firm-specific values of the instrument to compute the inventor-specific instrument. Here, the weights depend on the share of each inventor's patents that are associated with each firm.

The first-stage estimating equation is identical to the first stage of two-stage least-squares. However, it is not appropriate to use predicted values in place of the potentially endogenous regressor in equation 1 because the model is nonlinear. Instead, we recover the residuals from estimating E.1, $\hat{\tilde{u}}_{it}$, and modify equation 1 to include those residuals:

$$PAT_{it}^{C} = \exp(\beta_P \ln P_{it-1} + \beta_{\tilde{u}} \hat{\tilde{u}}_{it-1} + \beta_X X_{it-1} + \gamma_t + \eta_i) + u_{it}. \tag{E.2}$$

We estimate this augmented model via Poisson pseudo maximum likelihood. To conduct inference, we use a block bootstrap of this two-step procedure at the inventor level, sampling inventors 250 times with replacement.

F Robustness of Incumbent Patenting Results

F.1 Main Results Showing All Controls

Table F.1: Baseline estimates showing all controls

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.548***	0.463***	0.635***	0.533***	0.468***	0.389***
	(0.037)	(0.037)	(0.047)	(0.048)	(0.047)	(0.047)
GDP per capita (log, t-1)	2.999***	3.565***	6.716***	6.802***	1.582**	2.254***
	(0.503)	(0.470)	(0.465)	(0.435)	(0.620)	(0.570)
Energy RD&D (log, t-1)	-0.108*	-0.210***	0.018	-0.193**	-0.077	-0.139**
	(0.057)	(0.061)	(0.071)	(0.084)	(0.062)	(0.064)
Low-Carbon RD&D (log, t-1)	0.004	0.258***	-0.635***	-0.078	0.020	0.193**
	(0.074)	(0.077)	(0.098)	(0.107)	(0.074)	(0.075)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	110,454	110,454	110,454	110,454	110,454	110,454
Observations	763,630	763,630	763,630	763,630	763,630	763,630
Pseudo-R2	0.285	0.286	0.369	0.371	0.261	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.2: IV estimates showing all controls

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.512***	0.299***	0.963***	0.703***	0.360***	0.162*
	(0.069)	(0.071)	(0.081)	(0.084)	(0.085)	(0.087)
GDP per capita (log, t-1)	3.06***	3.85***	6.00***	6.44***	1.77***	2.66***
	(0.153)	(0.154)	(0.195)	(0.193)	(0.205)	(0.206)
Energy RD&D (log, t-1)	-0.111***	-0.228***	0.066	-0.161***	-0.085*	-0.162***
	(0.040)	(0.043)	(0.048)	(0.053)	(0.051)	(0.055)
Low-Carbon RD&D (log, t-1)	-0.006	0.225***	-0.502***	-0.031	0.001	0.167***
	(0.045)	(0.048)	(0.056)	(0.061)	(0.056)	(0.060)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Inventor Clusters (SEs)	110,454	110,454	110,454	110,454	110,454	110,454
Observations	763,630	763,630	763,630	763,630	763,630	763,630
First-stage F-statistic	163	163	163	163	163	163

Dependent variable: Number of Renewable/Nuclear docdb patent families .

Poisson pseudo-maximum likelihood. Bootstrapped (N=250) standard errors in parentheses.

Table F.3: Distributed lags estimates showing all controls

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.282***	0.279***	0.304***	0.327***	0.297***	0.278***
	(0.044)	(0.044)	(0.061)	(0.061)	(0.054)	(0.054)
Prices (log, t-2)	0.180***	0.107**	0.215***	0.132**	0.296***	0.221***
	(0.045)	(0.045)	(0.064)	(0.064)	(0.053)	(0.053)
Prices (log, t-3)	0.180***	0.160***	0.134**	0.107**	0.029	0.011
	(0.047)	(0.046)	(0.053)	(0.054)	(0.056)	(0.055)
L.GDP per capita (log, k$)	3.820***	4.116***	5.380***	5.543***	4.032**	4.440***
	(1.437)	(1.328)	(0.864)	(0.817)	(1.757)	(1.596)
L2.GDP per capita (log, k$)	-0.036	0.382	2.206***	2.572***	-0.963	-0.401
	(0.862)	(0.812)	(0.580)	(0.565)	(1.133)	(1.044)
L3.GDP per capita (log, k$)	-0.988**	-1.054***	1.323***	1.051**	-2.371***	-2.400***
	(0.413)	(0.393)	(0.421)	(0.418)	(0.472)	(0.460)
L.Energy RD&D (log, m$)	-0.431***	-0.487***	-0.396***	-0.505***	-0.297***	-0.344***
	(0.088)	(0.091)	(0.108)	(0.114)	(0.089)	(0.092)
L2.Energy RD&D (log, m$)	-0.441***	-0.459***	-0.272***	-0.294***	-0.287***	-0.300***
	(0.076)	(0.076)	(0.103)	(0.107)	(0.085)	(0.085)
L3.Energy RD&D (log, m$)	-0.161***	-0.174***	-0.045	-0.063	-0.163***	-0.174***
	(0.058)	(0.058)	(0.087)	(0.089)	(0.062)	(0.062)
L.Low-Carbon RD&D (log, m$)	0.304***	0.567***	-0.252*	0.200	0.173	0.402***
	(0.110)	(0.113)	(0.136)	(0.144)	(0.112)	(0.113)
L2.Low-Carbon RD&D (log, m$)	0.363***	0.473***	0.007	0.204*	0.370***	0.453***
	(0.082)	(0.084)	(0.116)	(0.121)	(0.091)	(0.093)
L3.Low-Carbon RD&D (log, m$)	0.156*	0.223***	0.058	0.173	0.165**	0.233***
	(0.081)	(0.081)	(0.110)	(0.112)	(0.080)	(0.079)
Cumulative Effect	0.642***	0.546***	0.652***	0.565***	0.622***	0.511***
	(0.050)	(0.052)	(0.069)	(0.070)	(0.057)	(0.061)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	85,905	85,905	85,905	85,905	85,905	85,905
Observations	590,767	590,767	590,767	590,767	590,767	590,767
Pseudo-R2	0.289	0.290	0.366	0.367	0.264	0.265

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.2 Alternative Outcome: Broader Definition of Clean Patenting

Table F.4: Main Results with Clean Patenting as Outcome

	Count of Clean Patent Families					
	Simple Count		Citation-Weighted		Coinventor-Weighted	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Baseline Poisson estimates						
Prices (log, t-1)	0.417***	0.375***	0.448***	0.392***	0.373***	0.328***
	(0.024)	(0.024)	(0.037)	(0.037)	(0.026)	(0.027)
Inventors	211,411	211,411	211,411	211,411	211,411	211,411
Observations	1,541,861	1,541,861	1,541,861	1,541,861	1,541,861	1,541,861
Pseudo-R2	0.330	0.331	0.386	0.387	0.278	0.279
Panel B: Instrumental variable estimates						
Prices (log, t-1)	0.438***	0.287***	0.751***	0.552***	0.381***	0.227***
	(0.042)	(0.041)	(0.055)	(0.054)	(0.044)	(0.044)
Inventors	211,411	211,411	211,411	211,411	211,411	211,411
Observations	1,541,861	1,541,861	1,541,861	1,541,861	1,541,861	1,541,861
First-stage F-statistic	163	163	163	163	163	163
Panel C: Distributed lag estimates						
Cumulative effect (3 lags)	0.419***	0.399***	0.305***	0.285***	0.476***	0.446***
	(0.036)	(0.037)	(0.058)	(0.058)	(0.039)	(0.039)
Inventors	161,990	161,990	161,990	161,990	161,990	161,990
Observations	1,178,924	1,178,924	1,178,924	1,178,924	1,178,924	1,178,924
Pseudo-R2	0.337	0.337	0.389	0.389	0.284	0.284
Year fixed effects	X	X	X	X	X	X
Inventor fixed effects	X	X	X	X	X	X
Tenure fixed effects		X		X		X
Country-year covariates	X	X	X	X	X	X

Note: The dependent variables are the number of clean patent families, either unweighted, weighted by citations, or inversely weighted by the number of inventors, depending on the column. Panels A, B, and C contain estimates of the same parameters using different estimation strategies. Panel A presents estimates of equation 1 estimated via Poisson pseudo-maximum likelihood. Standard errors are clustered by inventor and reported in parentheses. Panel B presents estimates of equation E.2 estimated via the control function approach described in the text, using the shale gas revolution as an instrument for natural gas prices. Standard errors are constructed via block bootstrap of the two-step control function approach, sampling inventors 250 times with replacement. The first-stage F-statistic for the instrumental variable estimates is from estimating equation E.1 at the country-year level rather than the inventor-year level, since the instrument varies at the country level and it thus provides a more conservative assessment of the instrument's strength. Panel C is analogous to Panel A except that the models include three lags of natural gas prices and all other covariates that vary across both countries and time, and the coefficients represent cumulative effects.

F.3 Alternative Outcome: International and Triadic Families

F.3.1 Baseline Definition of Clean

Table F.5: Baseline Poisson Estimates with Alternatives Outcome Variables

	(1) Simple Count	(2) Coinventor-Weighted	(3) Citation-Weighted (3y)	(4) Citation-Weighted (5y)	(5) Triadic	(6) Triadic	(7) Granted	(8) Granted	(9) Triadic granted	(10) Triadic granted	(11) More than 2 countries	(12) More than 2 countries	(13) More than 2 OECD	(14) More than 2 OECD
Prices (log, t-1)	0.463***	0.389***	0.533***	0.459***	0.018	-0.143	0.321***	0.262***	-0.078	-0.257**	0.452***	0.352***	0.343***	0.221***
	(0.037)	(0.047)	(0.048)	(0.049)	(0.077)	(0.119)	(0.038)	(0.050)	(0.079)	(0.119)	(0.047)	(0.066)	(0.050)	(0.072)
GDP per capita (log, t-1)	3.565***	2.254***	6.802***	7.688***	3.288***	2.834***	3.722***	2.049***	3.611***	3.264***	4.688***	2.916***	4.832***	3.151***
	(0.470)	(0.570)	(0.435)	(0.455)	(0.966)	(1.017)	(0.370)	(0.404)	(1.006)	(1.080)	(0.567)	(0.569)	(0.586)	(0.586)
Energy RD&D (log, t-1)	-0.210***	-0.139**	-0.193**	-0.250***	-0.601***	-0.525*	-0.365***	-0.309***	-0.423**	-0.310	-0.208*	-0.066	-0.301***	-0.116
	(0.061)	(0.064)	(0.084)	(0.092)	(0.215)	(0.276)	(0.069)	(0.075)	(0.210)	(0.260)	(0.108)	(0.127)	(0.115)	(0.138)
Low-Carbon RD&D (log, t-1)	0.258***	0.193**	-0.078	-0.110	-0.495*	-0.235	0.318***	0.298***	-0.734**	-0.568	-0.116	-0.083	-0.065	-0.055
	(0.077)	(0.075)	(0.107)	(0.120)	(0.291)	(0.360)	(0.084)	(0.085)	(0.289)	(0.357)	(0.142)	(0.157)	(0.149)	(0.170)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coinventor-Weighted		X				X		X		X		X		X
Inventor Clusters (SEs)	110,454	110,454	110,454	110,454	31,543	31,543	91,786	91,786	29,547	29,547	70,786	70,786	62,245	62,245
Observations	763,630	763,630	763,630	763,630	229,664	229,664	636,886	636,886	215,773	215,773	487,116	487,116	438,252	438,252
Pseudo-R2	0.286	0.262	0.371	0.387	0.212	0.214	0.254	0.236	0.205	0.210	0.235	0.227	0.227	0.222

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Note: This table show specifications similar to Panel a of Table 1 in the main text but using different left-hand side variables. Columns 1, 2, and 3 are the same as Column 2, 6, and 4 in Panel a of Table 1. The other columns present results for the count of clean families that are "triadic" (i.e., filed at the USPTO, EPO and JPO), granted in at least one jurisdiction, filed in more than two countries, or filed in more than two OECD countries. Most results are consistent with the baseline results shown in Table 1 except for specifications using triadic families as outcome variables. Triadic families are not very common in our dataset. As shown in Table D.1, the number of clean families for the average clean incumbent is 0.5, but it is only 0.1 for triadic families. The standard deviation is also much lower, and the 90th percentile is 0.

Table F.6: Distributed Lag Estimates with Alternatives Outcome Variables

	(1) Simple Count	(2) Coinventor-Weighted	(3) Citation-Weighted (3y)	(4) Citation-Weighted (5y)	(5) Triadic	(6) Triadic	(7) Granted	(8) Granted	(9) Triadic granted	(10) Triadic granted	(11) More than 2 countries	(12) More than 2 countries	(13) More than 2 OECD	(14) More than 2 OECD
Prices (log, t-1)	0.279***	0.278***	0.327***	0.183***	0.066	0.207	0.176***	0.165**	-0.074	-0.018	0.218***	0.244***	0.209***	0.206**
	(0.044)	(0.054)	(0.061)	(0.063)	(0.108)	(0.141)	(0.050)	(0.065)	(0.110)	(0.141)	(0.061)	(0.072)	(0.067)	(0.082)
Prices (log, t-2)	0.107**	0.221***	0.132**	0.120*	-0.079	-0.109	0.000	0.125**	-0.145	-0.133	0.241***	0.173**	0.170**	0.113
	(0.045)	(0.053)	(0.064)	(0.066)	(0.115)	(0.149)	(0.049)	(0.060)	(0.121)	(0.162)	(0.063)	(0.080)	(0.069)	(0.088)
Prices (log, t-3)	0.160***	0.011	0.107**	0.199***	-0.296***	-0.411***	0.205***	0.114**	-0.277***	-0.362**	0.152***	0.108	0.018	0.002
	(0.046)	(0.055)	(0.054)	(0.058)	(0.101)	(0.133)	(0.045)	(0.053)	(0.103)	(0.141)	(0.058)	(0.072)	(0.063)	(0.077)
L.GDP per capita (log, k$)	4.116***	4.440***	5.543***	5.553***	3.084***	2.707**	3.077***	2.841***	3.430***	2.784**	3.240***	2.295***	3.627***	2.705***
	(1.328)	(1.596)	(0.817)	(0.710)	(0.972)	(1.138)	(0.445)	(0.526)	(1.013)	(1.201)	(0.574)	(0.670)	(0.599)	(0.694)
L2.GDP per capita (log, k$)	0.382	-0.401	2.572***	3.141***	1.341	0.531	1.536***	1.271**	1.111	0.740	2.210***	1.601***	2.155***	1.467**
	(0.812)	(1.044)	(0.565)	(0.513)	(0.844)	(0.976)	(0.408)	(0.496)	(0.864)	(1.015)	(0.505)	(0.593)	(0.519)	(0.611)
L3.GDP per capita (log, k$)	-1.054***	-2.400***	1.051**	1.839***	2.404***	1.376	-0.496	-2.090***	2.911***	1.504	1.441***	0.415	1.849***	0.879
	(0.393)	(0.460)	(0.418)	(0.435)	(0.862)	(0.996)	(0.399)	(0.556)	(0.879)	(1.033)	(0.511)	(0.596)	(0.519)	(0.617)
L.Energy RD&D (log, m$)	-0.487***	-0.344***	-0.505***	-0.634***	-0.461	-0.231	-0.598***	-0.548***	-0.274	-0.112	-0.692***	-0.352*	-0.627***	-0.296
	(0.091)	(0.092)	(0.114)	(0.126)	(0.302)	(0.339)	(0.095)	(0.101)	(0.303)	(0.337)	(0.157)	(0.180)	(0.163)	(0.190)
L2.Energy RD&D (log, m$)	-0.459***	-0.300***	-0.294***	-0.355***	-0.521*	-0.375	-0.522***	-0.321***	-0.627**	-0.460	-0.065	-0.016	-0.090	-0.051
	(0.076)	(0.085)	(0.107)	(0.120)	(0.281)	(0.326)	(0.077)	(0.094)	(0.288)	(0.333)	(0.144)	(0.158)	(0.147)	(0.161)
L3.Energy RD&D (log, m$)	-0.174***	-0.174***	-0.063	-0.093	0.245	0.263	-0.048	-0.008	0.140	0.110	0.090	0.157	0.037	0.148
	(0.058)	(0.062)	(0.089)	(0.104)	(0.190)	(0.211)	(0.064)	(0.072)	(0.197)	(0.221)	(0.102)	(0.115)	(0.107)	(0.119)
L.Low-Carbon RD&D (log, m$)	0.567***	0.402***	0.200	0.208	-0.743**	-0.782*	0.634***	0.574***	-1.015***	-1.035**	0.176	-0.003	0.117	-0.058
	(0.113)	(0.113)	(0.144)	(0.158)	(0.366)	(0.412)	(0.113)	(0.118)	(0.368)	(0.415)	(0.189)	(0.217)	(0.195)	(0.223)
L2.Low-Carbon RD&D (log, m$)	0.473***	0.453***	0.204*	0.230*	0.193	0.419	0.469***	0.359***	0.251	0.382	-0.206	-0.028	-0.198	-0.020
	(0.084)	(0.093)	(0.121)	(0.136)	(0.306)	(0.342)	(0.090)	(0.106)	(0.315)	(0.349)	(0.162)	(0.180)	(0.163)	(0.181)
L3.Low-Carbon RD&D (log, m$)	0.223***	0.233***	0.173	0.218*	-0.384*	-0.101	0.040	0.038	-0.401*	-0.090	0.162	0.081	0.096	0.043
	(0.081)	(0.079)	(0.112)	(0.129)	(0.226)	(0.239)	(0.082)	(0.084)	(0.238)	(0.261)	(0.130)	(0.142)	(0.134)	(0.149)
Cumulative Effect	0.546***	0.511***	0.565***	0.502***	-0.308***	-0.313**	0.381***	0.404***	-0.496***	-0.513***	0.611***	0.525***	0.398***	0.321***
	(0.052)	(0.061)	(0.070)	(0.073)	(0.108)	(0.136)	(0.055)	(0.068)	(0.109)	(0.134)	(0.066)	(0.078)	(0.070)	(0.086)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coinventor-Weighted		X				X		X		X		X		X
Inventor Clusters (SEs)	85,905	85,905	85,905	85,905	24,027	24,027	71,093	71,093	22,413	22,413	54,110	54,110	47,350	47,350
Observations	590,767	590,767	590,767	590,767	175,139	175,139	493,385	493,385	163,736	163,736	374,002	374,002	335,082	335,082
Pseudo-R2	0.290	0.265	0.367	0.382	0.212	0.215	0.256	0.236	0.205	0.210	0.233	0.226	0.225	0.220

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Note: This table show specifications similar to Table F.5 but with three lags of natural gas prices and other variables that vary by country and year.

F.3.2 Broader Definition of Clean

Table F.7: Baseline Poisson Estimates with Alternatives Outcome Variables

	(1) Simple Count	(2) Coinventor-Weighted	(3) Citation-Weighted (3y)	(4) Citation-Weighted (5y)	(5) Triadic	(6) Triadic	(7) Granted	(8) Granted	(9) Triadic granted	(10) Triadic granted	(11) More than 2 countries	(12) More than 2 countries	(13) More than 2 OECD	(14) More than 2 OECD
Prices (log, t-1)	0.375***	0.328***	0.392***	0.359***	0.328***	0.256***	0.315***	0.289***	0.293***	0.212***	0.410***	0.343***	0.372***	0.255***
	(0.024)	(0.027)	(0.037)	(0.039)	(0.046)	(0.063)	(0.026)	(0.030)	(0.047)	(0.063)	(0.031)	(0.037)	(0.032)	(0.040)
GDP per capita (log, t-1)	4.671***	3.372***	7.148***	7.911***	5.291***	4.969***	4.637***	3.436***	5.708***	5.354***	5.221***	4.363***	5.499***	4.640***
	(0.234)	(0.242)	(0.303)	(0.320)	(0.587)	(0.621)	(0.253)	(0.275)	(0.609)	(0.655)	(0.358)	(0.366)	(0.367)	(0.380)
Energy RD&D (log, t-1)	-0.162***	-0.069*	-0.039	-0.047	0.247***	0.337***	-0.221***	-0.135***	0.260***	0.361***	0.279***	0.412***	0.228***	0.355***
	(0.038)	(0.038)	(0.048)	(0.051)	(0.084)	(0.096)	(0.041)	(0.043)	(0.084)	(0.095)	(0.054)	(0.061)	(0.057)	(0.064)
Low-Carbon RD&D (log, t-1)	0.077	0.009	-0.391***	-0.514***	-1.744***	-1.661***	-0.103*	-0.178***	-1.890***	-1.831***	-1.128***	-1.275***	-1.202***	-1.312***
	(0.050)	(0.047)	(0.069)	(0.073)	(0.122)	(0.142)	(0.055)	(0.054)	(0.123)	(0.146)	(0.078)	(0.084)	(0.078)	(0.087)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coinventor-Weighted		X				X		X		X		X		X
Inventor Clusters (SEs)	211,411	211,411	211,411	211,411	73,644	73,644	180,860	180,860	69,561	69,561	145,881	145,881	131,270	131,270
Observations	1,541,861	1,541,861	1,541,861	1,541,861	584,648	584,648	1,335,760	1,335,760	554,843	554,843	1,077,717	1,077,717	991,728	991,728
Pseudo-R2	0.331	0.279	0.387	0.397	0.209	0.192	0.289	0.242	0.203	0.188	0.253	0.223	0.249	0.220

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Note: This table show specifications similar to Table F.5 but for the broader definition of clean.

Table F.8: Distributed Lag Estimates with Alternatives Outcome Variables

	(1) Simple Count	(2) Coinventor-Weighted	(3) Citation-Weighted (3y)	(4) Citation-Weighted (5y)	(5) Triadic	(6) Triadic	(7) Granted	(8) Granted	(9) Triadic granted	(10) Triadic granted	(11) More than 2 countries	(12) More than 2 countries	(13) More than 2 OECD	(14) More than 2 OECD
Prices (log, t-1)	-0.111***	-0.074**	0.033	-0.065	-0.087	-0.052	-0.190***	-0.158***	-0.213***	-0.198**	-0.078*	-0.100**	-0.093*	-0.143***
	(0.034)	(0.037)	(0.080)	(0.079)	(0.073)	(0.085)	(0.037)	(0.041)	(0.074)	(0.084)	(0.045)	(0.051)	(0.048)	(0.055)
Prices (log, t-2)	0.180***	0.227***	0.100	0.068	-0.036	0.025	0.133***	0.192***	-0.070	0.015	0.159***	0.211***	0.144***	0.176***
	(0.031)	(0.035)	(0.063)	(0.064)	(0.072)	(0.099)	(0.034)	(0.039)	(0.075)	(0.107)	(0.043)	(0.052)	(0.046)	(0.056)
Prices (log, t-3)	0.331***	0.293***	0.152**	0.271***	0.105	0.044	0.365***	0.343***	0.169***	0.090	0.361***	0.356***	0.323***	0.314***
	(0.030)	(0.034)	(0.063)	(0.066)	(0.064)	(0.087)	(0.033)	(0.037)	(0.066)	(0.092)	(0.038)	(0.047)	(0.042)	(0.051)
L.GDP per capita (log, k$)	2.536***	2.122***	4.399***	4.658***	3.498***	3.431***	2.698***	2.299***	3.792***	3.478***	3.107***	2.592***	3.570***	3.131***
	(0.312)	(0.353)	(0.336)	(0.345)	(0.588)	(0.668)	(0.283)	(0.314)	(0.607)	(0.703)	(0.364)	(0.402)	(0.372)	(0.418)
L2.GDP per capita (log, k$)	1.854***	1.316***	2.889***	3.292***	2.367***	2.221***	1.780***	1.366***	2.332***	2.584***	1.993***	1.822***	1.992***	1.737***
	(0.259)	(0.301)	(0.273)	(0.280)	(0.509)	(0.605)	(0.250)	(0.291)	(0.521)	(0.634)	(0.316)	(0.361)	(0.325)	(0.375)
L3.GDP per capita (log, k$)	0.914***	0.055	2.656***	3.298***	3.129***	2.560***	1.210***	0.416	3.536***	2.732***	2.887***	2.450***	3.166***	2.725***
	(0.228)	(0.255)	(0.286)	(0.298)	(0.497)	(0.584)	(0.250)	(0.301)	(0.511)	(0.613)	(0.311)	(0.344)	(0.322)	(0.358)
L.Energy RD&D (log, m$)	-0.470***	-0.338***	-0.070	-0.067	0.104	0.132	-0.490***	-0.378***	0.057	0.110	-0.024	0.077	0.017	0.120
	(0.060)	(0.063)	(0.099)	(0.103)	(0.159)	(0.177)	(0.065)	(0.071)	(0.164)	(0.181)	(0.097)	(0.110)	(0.101)	(0.115)
L2.Energy RD&D (log, m$)	-0.361***	-0.258***	-0.242***	-0.188**	-0.219	-0.133	-0.380***	-0.247***	-0.336**	-0.252	-0.077	0.071	-0.109	0.028
	(0.052)	(0.053)	(0.071)	(0.076)	(0.133)	(0.164)	(0.053)	(0.058)	(0.138)	(0.169)	(0.086)	(0.097)	(0.089)	(0.100)
L3.Energy RD&D (log, m$)	0.003	-0.099**	0.051	0.115**	0.236**	0.095	0.133***	0.033	0.179*	0.035	0.298***	0.218***	0.252***	0.178**
	(0.037)	(0.040)	(0.051)	(0.057)	(0.102)	(0.125)	(0.038)	(0.043)	(0.106)	(0.128)	(0.065)	(0.071)	(0.068)	(0.074)
L.Low-Carbon RD&D (log, m$)	0.464***	0.298***	-0.129	-0.265***	-0.996***	-0.986***	0.349***	0.197**	-1.068***	-1.072***	-0.542***	-0.738***	-0.683***	-0.836***
	(0.073)	(0.072)	(0.094)	(0.102)	(0.184)	(0.229)	(0.080)	(0.084)	(0.191)	(0.239)	(0.113)	(0.131)	(0.116)	(0.134)
L2.Low-Carbon RD&D (log, m$)	0.140**	0.169***	-0.014	-0.095	-0.763***	-0.685***	0.011	-0.017	-0.782***	-0.694***	-0.521***	-0.599***	-0.528***	-0.596***
	(0.060)	(0.063)	(0.085)	(0.090)	(0.152)	(0.204)	(0.061)	(0.068)	(0.158)	(0.214)	(0.096)	(0.111)	(0.098)	(0.112)
L3.Low-Carbon RD&D (log, m$)	-0.110**	0.079	-0.393***	-0.473***	-0.872***	-0.577***	-0.340***	-0.176***	-0.865***	-0.603***	-0.541***	-0.335***	-0.588***	-0.392***
	(0.050)	(0.055)	(0.066)	(0.074)	(0.130)	(0.152)	(0.049)	(0.056)	(0.137)	(0.162)	(0.084)	(0.090)	(0.086)	(0.093)
Cumulative Effect	0.399***	0.446***	0.285***	0.274***	-0.018	0.017	0.308***	0.377***	-0.113	-0.093	0.441***	0.467***	0.374***	0.346***
	(0.037)	(0.039)	(0.058)	(0.061)	(0.070)	(0.085)	(0.040)	(0.043)	(0.069)	(0.081)	(0.049)	(0.054)	(0.048)	(0.057)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coinventor-Weighted		X				X		X		X		X		X
Inventor Clusters (SEs)	161,990	161,990	161,990	161,990	55,389	55,389	138,129	138,129	52,162	52,162	110,262	110,262	98,907	98,907
Observations	1,178,924	1,178,924	1,178,924	1,178,924	438,875	438,875	1,021,574	1,021,574	414,871	414,871	817,411	817,411	749,816	749,816
Pseudo-R2	0.337	0.284	0.389	0.398	0.208	0.193	0.295	0.246	0.203	0.188	0.255	0.225	0.251	0.222

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Note: This table show specifications similar to Table F.5 but for the broader definition of clean and with three lags of natural gas prices and other variables that vary by country and year.

F.4 Robustness Check: Truncated Inventor Panel

Here we implement a robustness check where we arbitrarily truncate each inventor's time series to half of its original length. For example, if we observe an inventor filing their first patent in 2000 and their last patent in 2005 (i.e., total length of six years), we would keep observations for this inventor only up to and including 2002.

This robustness check is useful because, although we directly observe when inventors produce their first patent, we do not know for sure when they "exit." We can, therefore, only safely input zeros for years when inventors do not file patents when these years come in between the first and last filing years of the inventor. This robustness check shows that our results are not sensitive to the timing of an inventors' last observed patent.

F.4.1 Baseline Definition of Clean

Table F.9: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.471***	0.473***	0.639***	0.638***	0.456***	0.460***
	(0.085)	(0.084)	(0.117)	(0.116)	(0.106)	(0.105)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	28,506	28,506	28,506	28,506	28,506	28,506
Observations	102,967	102,967	102,967	102,967	102,967	102,967
Pseudo-R2	0.302	0.302	0.435	0.436	0.285	0.286

Dependent variable: Number of Renewable/Nuclear docdb patent families (citation weighted or not).

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.10: Distributed Lag Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.494***	0.501***	0.590***	0.595***	0.615***	0.616***
	(0.142)	(0.142)	(0.189)	(0.189)	(0.161)	(0.162)
Prices (log, t-2)	0.134	0.135	0.320	0.310	0.277*	0.280*
	(0.136)	(0.135)	(0.208)	(0.204)	(0.152)	(0.151)
Prices (log, t-3)	0.011	0.017	0.253	0.261	-0.300*	-0.293*
	(0.134)	(0.134)	(0.189)	(0.188)	(0.157)	(0.157)
Cumulative Effect	0.639***	0.654***	1.163***	1.166***	0.592***	0.603***
	(0.189)	(0.188)	(0.275)	(0.272)	(0.220)	(0.219)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	14,088	14,088	14,088	14,088	14,088	14,088
Observations	46,507	46,507	46,507	46,507	46,507	46,507
Pseudo-R2	0.304	0.305	0.443	0.444	0.284	0.285

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.4.2 Broader Definition of Clean

Table F.11: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.294***	0.297***	0.338***	0.348***	0.112*	0.113*
	(0.059)	(0.058)	(0.082)	(0.081)	(0.067)	(0.066)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	61,102	61,102	61,102	61,102	61,102	61,102
Observations	233,505	233,505	233,505	233,505	233,505	233,505
Pseudo-R2	0.351	0.352	0.428	0.429	0.300	0.300

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families (citation weighted or not).

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.12: Distributed Lag Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.242**	0.254**	0.104	0.123	0.248**	0.256**
	(0.100)	(0.100)	(0.145)	(0.146)	(0.113)	(0.113)
Prices (log, t-2)	0.215**	0.211**	0.387***	0.384***	0.218**	0.213**
	(0.093)	(0.092)	(0.144)	(0.144)	(0.102)	(0.101)
Prices (log, t-3)	-0.058	-0.048	0.098	0.103	-0.303***	-0.292***
	(0.087)	(0.087)	(0.126)	(0.126)	(0.098)	(0.098)
Cumulative Effect	0.400***	0.417***	0.588***	0.609***	0.163	0.176
	(0.130)	(0.129)	(0.185)	(0.185)	(0.145)	(0.144)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	30,072	30,072	30,072	30,072	30,072	30,072
Observations	105,114	105,114	105,114	105,114	105,114	105,114
Pseudo-R2	0.363	0.363	0.437	0.438	0.309	0.310

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5 Robustness Check: Alternative Prices

Here, we conduct robustness checks using various measures of exposure to natural gas prices. Details on the construction of these exposure measures can be found in Subsection A.7. Results from Table F.13 to Table F.36 confirm that our baseline findings for incumbents remain consistent across different methods of measuring exposure to natural gas prices.

F.5.1 Baseline Clean Definition and Baseline Geographic Weights (Based on Energy Patents in All Periods)

Table F.13: Industry Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.588^{***}	0.608^{***}	0.463^{***}	0.467^{***}	0.637^{***}	0.655^{***}	0.533^{***}	0.538^{***}	0.501^{***}	0.525^{***}	0.389^{***}	0.393^{***}
	(0.039)	(0.039)	(0.037)	(0.037)	(0.055)	(0.055)	(0.048)	(0.048)	(0.049)	(0.049)	(0.047)	(0.047)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,454	110,543	110,454	110,543	110,454	110,543	110,454	110,543	110,454	110,543	110,454	110,543
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	763,630	763,940	763,630	763,940	763,630	763,940	763,630	763,940	763,630	763,940	763,630	763,940
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.14: Electricity Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.491^{***}	0.529^{***}	0.390^{***}	0.388^{***}	0.848^{***}	0.864^{***}	0.861^{***}	0.863^{***}	0.209^{***}	0.255^{***}	0.140^{*}	0.137^{*}
	(0.062)	(0.063)	(0.063)	(0.063)	(0.073)	(0.075)	(0.069)	(0.069)	(0.070)	(0.072)	(0.073)	(0.073)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	108,348	108,460	108,348	108,460	108,348	108,460	108,348	108,460	108,348	108,460	108,348	108,460
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	752,331	752,833	752,331	752,833	752,331	752,833	752,331	752,833	752,331	752,833	752,331	752,833
Pseudo-R2	0.287	0.287	0.287	0.287	0.371	0.371	0.371	0.371	0.263	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.15: Household Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.347^{***}	0.351^{***}	0.315^{***}	0.316^{***}	0.396^{***}	0.402^{***}	0.326^{***}	0.329^{***}	0.354^{***}	0.360^{***}	0.319^{***}	0.320^{***}
	(0.030)	(0.030)	(0.031)	(0.031)	(0.042)	(0.042)	(0.041)	(0.041)	(0.039)	(0.039)	(0.041)	(0.041)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,498	110,562	110,498	110,562	110,498	110,562	110,498	110,562	110,498	110,562	110,498	110,562
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	763,944	764,165	763,944	764,165	763,944	764,165	763,944	764,165	763,944	764,165	763,944	764,165
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.2 Baseline Clean Definition and Geographic Weights Based on Energy Patents in Pre-Period

Table F.16: Industry Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.585***	0.595***	0.471***	0.476***	0.550***	0.549***	0.485***	0.486***	0.537***	0.548***	0.434***	0.438***
	(0.044)	(0.045)	(0.038)	(0.039)	(0.061)	(0.061)	(0.049)	(0.049)	(0.056)	(0.056)	(0.049)	(0.050)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,632	110,636	110,632	110,636	110,632	110,636	110,632	110,636	110,632	110,636	110,632	110,636
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	764,481	764,499	764,481	764,499	764,481	764,499	764,481	764,499	764,481	764,499	764,481	764,499
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.17: Electricity Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.441***	0.444***	0.328***	0.333***	0.800***	0.772***	0.714***	0.723***	0.233***	0.242***	0.149**	0.154**
	(0.068)	(0.068)	(0.059)	(0.059)	(0.081)	(0.081)	(0.064)	(0.065)	(0.078)	(0.078)	(0.070)	(0.070)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	108,730	108,758	108,730	108,758	108,730	108,758	108,730	108,758	108,730	108,758	108,730	108,758
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	754,412	754,545	754,412	754,545	754,412	754,545	754,412	754,545	754,412	754,545	754,412	754,545
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.18: Household Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.359***	0.360***	0.322***	0.322***	0.334***	0.326***	0.305***	0.300***	0.393***	0.396***	0.305***	0.300***
	(0.037)	(0.037)	(0.033)	(0.033)	(0.048)	(0.048)	(0.042)	(0.042)	(0.047)	(0.047)	(0.042)	(0.042)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,646	110,649	110,646	110,649	110,646	110,649	110,646	110,649	110,646	110,649	110,646	110,649
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	764,668	764,684	764,668	764,684	764,668	764,684	764,668	764,684	764,668	764,684	764,668	764,684
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.371	0.371

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.3 Baseline Clean Definition and Geographic Weights Based on All Patents in All Periods

Table F.19: Industry Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.565***	0.585***	0.451***	0.455***	0.594***	0.616***	0.497***	0.502***	0.492***	0.516***	0.384***	0.388***
	(0.038)	(0.039)	(0.036)	(0.036)	(0.055)	(0.055)	(0.048)	(0.048)	(0.048)	(0.049)	(0.046)	(0.046)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,574	110,637	110,574	110,637	110,574	110,637	110,574	110,637	110,574	110,637	110,574	110,637
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	764,414	764,630	764,414	764,630	764,414	764,630	764,414	764,630	764,414	764,630	764,414	764,630
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.20: Electricity Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.438***	0.475***	0.378***	0.377***	0.768***	0.786***	0.801***	0.807***	0.212***	0.252***	0.161***	0.160***
	(0.054)	(0.056)	(0.053)	(0.053)	(0.072)	(0.074)	(0.066)	(0.066)	(0.060)	(0.062)	(0.061)	(0.062)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	108,939	109,027	108,939	109,027	108,939	109,027	108,939	109,027	108,939	109,027	108,939	109,027
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	755,558	755,966	755,558	755,966	755,558	755,966	755,558	755,966	755,558	755,966	755,558	755,966
Pseudo-R2	0.287	0.287	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.21: Household Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.340***	0.343***	0.309***	0.309***	0.387***	0.391***	0.314***	0.315***	0.350***	0.354***	0.314***	0.314***
	(0.031)	(0.031)	(0.032)	(0.032)	(0.043)	(0.043)	(0.041)	(0.041)	(0.041)	(0.041)	(0.043)	(0.043)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,613	110,652	110,613	110,652	110,613	110,652	110,613	110,652	110,613	110,652	110,613	110,652
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	764,711	764,846	764,711	764,846	764,711	764,846	764,711	764,846	764,711	764,846	764,711	764,846
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.4 Baseline Clean Definition and Geographic Weights Based on All Patents in Pre-Period

Table F.22: Industry Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.566***	0.587***	0.461***	0.469***	0.542***	0.553***	0.458***	0.465***	0.503***	0.520***	0.396***	0.403***
	(0.043)	(0.044)	(0.039)	(0.039)	(0.061)	(0.062)	(0.050)	(0.050)	(0.056)	(0.057)	(0.050)	(0.050)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,603	110,630	110,603	110,630	110,603	110,630	110,603	110,630	110,603	110,630	110,603	110,630
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	764,523	764,641	764,523	764,641	764,523	764,641	764,523	764,641	764,523	764,641	764,523	764,641
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.23: Electricity Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.422***	0.432***	0.309***	0.312***	0.727***	0.722***	0.643***	0.657***	0.236***	0.251***	0.156***	0.158***
	(0.057)	(0.058)	(0.051)	(0.051)	(0.076)	(0.077)	(0.060)	(0.061)	(0.064)	(0.065)	(0.058)	(0.059)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	108,995	109,043	108,995	109,043	108,995	109,043	108,995	109,043	108,995	109,043	108,995	109,043
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	755,854	756,034	755,854	756,034	755,854	756,034	755,854	756,034	755,854	756,034	755,854	756,034
Pseudo-R2	0.287	0.287	0.287	0.287	0.372	0.372	0.372	0.372	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.24: Household Prices: Baseline Poisson Estimates for Baseline Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.321***	0.324***	0.296***	0.297***	0.325***	0.324***	0.278***	0.278***	0.346***	0.349***	0.307***	0.308***
	(0.035)	(0.035)	(0.033)	(0.033)	(0.048)	(0.048)	(0.043)	(0.042)	(0.048)	(0.048)	(0.046)	(0.046)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	110,627	110,644	110,627	110,644	110,627	110,644	110,627	110,644	110,627	110,644	110,627	110,644
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	764,769	764,836	764,769	764,836	764,769	764,836	764,769	764,836	764,769	764,836	764,769	764,836
Pseudo-R2	0.286	0.286	0.286	0.286	0.371	0.371	0.371	0.371	0.262	0.262	0.262	0.262

Dependent variable: Number of Renewable/Nuclear docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.5 Broader Clean Definition and Baseline Geographic Weights (Based on Energy Patents in All Periods)

Table F.25: Industry Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.386***	0.385***	0.375***	0.374***	0.373***	0.364***	0.392***	0.391***	0.348***	0.349***	0.328***	0.328***
	(0.028)	(0.028)	(0.024)	(0.024)	(0.046)	(0.046)	(0.037)	(0.037)	(0.030)	(0.030)	(0.027)	(0.027)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,411	211,508	211,411	211,508	211,411	211,508	211,411	211,508	211,411	211,508	211,411	211,508
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,541,861	1,542,203	1,541,861	1,542,203	1,541,861	1,542,203	1,541,861	1,542,203	1,541,861	1,542,203	1,541,861	1,542,203
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.26: Electricity Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.610***	0.636***	0.650***	0.650***	0.784***	0.786***	0.978***	0.974***	0.557***	0.585***	0.534***	0.534***
	(0.042)	(0.042)	(0.039)	(0.039)	(0.058)	(0.060)	(0.049)	(0.049)	(0.041)	(0.042)	(0.041)	(0.041)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	208,830	208,969	208,830	208,969	208,830	208,969	208,830	208,969	208,830	208,969	208,830	208,969
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,528,281	1,528,890	1,528,281	1,528,890	1,528,281	1,528,890	1,528,281	1,528,890	1,528,281	1,528,890	1,528,281	1,528,890
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.280	0.280	0.280	0.280

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.27: Household Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.248***	0.250***	0.256***	0.256***	0.283***	0.288***	0.295***	0.297***	0.239***	0.242***	0.238***	0.240***
	(0.021)	(0.021)	(0.021)	(0.020)	(0.031)	(0.031)	(0.029)	(0.029)	(0.023)	(0.023)	(0.023)	(0.023)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,464	211,534	211,464	211,534	211,464	211,534	211,464	211,534	211,464	211,534	211,464	211,534
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,542,154	1,542,399	1,542,154	1,542,399	1,542,154	1,542,399	1,542,154	1,542,399	1,542,154	1,542,399	1,542,154	1,542,399
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.6 Broader Clean Definition and Geographic Weights Based on Energy Patents in Pre-Period

Table F.28: Industry Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.311***	0.310***	0.320***	0.320***	0.261***	0.249***	0.322***	0.319***	0.298***	0.297***	0.301***	0.302***
	(0.030)	(0.030)	(0.025)	(0.025)	(0.046)	(0.046)	(0.037)	(0.037)	(0.032)	(0.032)	(0.027)	(0.027)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,586	211,591	211,586	211,591	211,586	211,591	211,586	211,591	211,586	211,591	211,586	211,591
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,542,696	1,542,718	1,542,696	1,542,718	1,542,696	1,542,718	1,542,696	1,542,718	1,542,696	1,542,718	1,542,696	1,542,718
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.29: Electricity Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.418***	0.436***	0.478***	0.481***	0.507***	0.509***	0.708***	0.711***	0.440***	0.463***	0.431***	0.436***
	(0.043)	(0.044)	(0.037)	(0.037)	(0.055)	(0.056)	(0.044)	(0.044)	(0.044)	(0.044)	(0.037)	(0.037)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	208,900	208,943	208,900	208,943	208,900	208,943	208,900	208,943	208,900	208,943	208,900	208,943
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,528,726	1,528,923	1,528,726	1,528,923	1,528,726	1,528,923	1,528,726	1,528,923	1,528,726	1,528,923	1,528,726	1,528,923
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.30: Household Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.212***	0.214***	0.228***	0.228***	0.203***	0.203***	0.239***	0.238***	0.222***	0.224***	0.239***	0.238***
	(0.024)	(0.024)	(0.021)	(0.021)	(0.034)	(0.034)	(0.030)	(0.030)	(0.026)	(0.026)	(0.030)	(0.030)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,611	211,615	211,611	211,615	211,611	211,615	211,611	211,615	211,611	211,615	211,611	211,615
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,542,909	1,542,929	1,542,909	1,542,929	1,542,909	1,542,929	1,542,909	1,542,929	1,542,909	1,542,929	1,542,909	1,542,929
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.387	0.387

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.7 Broader Clean Definition and Geographic Weights Based on All Patents in All Periods

Table F.31: Industry Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.351***	0.349***	0.350***	0.351***	0.340***	0.334***	0.364***	0.364***	0.318***	0.318***	0.308***	0.308***
	(0.027)	(0.028)	(0.024)	(0.024)	(0.045)	(0.045)	(0.036)	(0.036)	(0.029)	(0.029)	(0.026)	(0.026)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,574	211,641	211,574	211,641	211,574	211,641	211,574	211,641	211,574	211,641	211,574	211,641
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,542,985	1,543,225	1,542,985	1,543,225	1,542,985	1,543,225	1,542,985	1,543,225	1,542,985	1,543,225	1,542,985	1,543,225
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.32: Electricity Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.567***	0.588***	0.589***	0.589***	0.726***	0.723***	0.898***	0.896***	0.551***	0.570***	0.501***	0.499***
	(0.041)	(0.042)	(0.037)	(0.038)	(0.056)	(0.058)	(0.048)	(0.048)	(0.040)	(0.041)	(0.039)	(0.039)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	209,750	209,846	209,750	209,846	209,750	209,846	209,750	209,846	209,750	209,846	209,750	209,846
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,533,243	1,533,677	1,533,243	1,533,677	1,533,243	1,533,677	1,533,243	1,533,677	1,533,243	1,533,677	1,533,243	1,533,677
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.280	0.280	0.280	0.280

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.33: Household Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.224***	0.226***	0.239***	0.239***	0.269***	0.273***	0.277***	0.278***	0.219***	0.221***	0.225***	0.225***
	(0.021)	(0.021)	(0.020)	(0.020)	(0.031)	(0.031)	(0.029)	(0.029)	(0.023)	(0.023)	(0.022)	(0.022)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,619	211,660	211,619	211,660	211,619	211,660	211,619	211,660	211,619	211,660	211,619	211,660
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,543,247	1,543,398	1,543,247	1,543,398	1,543,247	1,543,398	1,543,247	1,543,398	1,543,247	1,543,398	1,543,247	1,543,398
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.5.8 Broader Clean Definition and Geographic Weights Based on All Patents in Pre-Period

Table F.34: Industry Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.267***	0.268***	0.287***	0.289***	0.209***	0.198***	0.263***	0.264***	0.258***	0.258***	0.261***	0.265***
	(0.031)	(0.031)	(0.025)	(0.025)	(0.053)	(0.054)	(0.040)	(0.040)	(0.033)	(0.033)	(0.028)	(0.028)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,590	211,621	211,590	211,621	211,590	211,621	211,590	211,621	211,590	211,621	211,590	211,621
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,543,072	1,543,217	1,543,072	1,543,217	1,543,072	1,543,217	1,543,072	1,543,217	1,543,072	1,543,217	1,543,072	1,543,217
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.35: Electricity Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.451***	0.476***	0.439***	0.442***	0.534***	0.558***	0.650***	0.655***	0.483***	0.507***	0.423***	0.424***
	(0.042)	(0.043)	(0.035)	(0.035)	(0.060)	(0.063)	(0.043)	(0.043)	(0.042)	(0.043)	(0.036)	(0.036)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	209,699	209,769	209,699	209,769	209,699	209,769	209,699	209,769	209,699	209,769	209,699	209,769
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,533,090	1,533,372	1,533,090	1,533,372	1,533,090	1,533,372	1,533,090	1,533,372	1,533,090	1,533,372	1,533,090	1,533,372
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.388	0.388	0.388	0.280	0.280	0.280	0.280

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.36: Household Prices: Baseline Poisson Estimates for Broader Definition of Clean

	(1) Simple Count	(2) Simple Count	(3) Simple Count	(4) Simple Count	(5) Citation-Weighted	(6) Citation-Weighted	(7) Citation-Weighted	(8) Citation-Weighted	(9) Coinventor-Weighted	(10) Coinventor-Weighted	(11) Coinventor-Weighted	(12) Coinventor-Weighted
Prices (log, t-1)	0.164***	0.166***	0.192***	0.194***	0.191***	0.194***	0.213***	0.213***	0.182***	0.185***	0.197***	0.199***
	(0.023)	(0.023)	(0.021)	(0.021)	(0.036)	(0.036)	(0.031)	(0.031)	(0.026)	(0.026)	(0.024)	(0.024)
Year FEs	X	X	X	X	X	X	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X	X	X	X	X	X	X
Tenure FEs	X	X	X	X	X	X	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X	X	X	X	X	X	X
Inventor Clusters (SEs)	211,622	211,644	211,622	211,644	211,622	211,644	211,622	211,644	211,622	211,644	211,622	211,644
Price Panel	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced	Balanced	Unbalanced
Price Weights	-	-	GDP	GDP	-	-	GDP	GDP	-	-	GDP	GDP
Observations	1,543,282	1,543,378	1,543,282	1,543,378	1,543,282	1,543,378	1,543,282	1,543,378	1,543,282	1,543,378	1,543,282	1,543,378
Pseudo-R2	0.331	0.331	0.331	0.331	0.387	0.387	0.387	0.387	0.279	0.279	0.279	0.279

Dependent variable: Number of Renewable/Nuclear/Enabling docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.6 Additional Results: Effect on Grey, Dirty, and Non-Energy Patenting

In this section, we look at the effect of changes in natural gas prices on other types of patenting, mainly: grey, dirty, and non-energy. The regression tables below replicate the specifications shown in Panels a and b of Table 1 but with different outcome variables. The data sample used in these regressions is also the same as in Table 1, meaning it focuses on clean incumbents. Since only a few clean incumbents also patent in grey and dirty, the number of observations in regressions using grey or dirty patenting as outcome variables is smaller.

We find that increases in natural gas prices lead to a higher number of grey and dirty patents. One caveat here is that this effect concerns only the sample of inventors patenting both in clean and grey or dirty. We interpret this effect as increased incentives to innovate in efficient natural gas technologies or other fossil fuel technologies, such as coal, that could replace natural gas for electricity generation.

We also find that increases in natural gas prices lead to a lower number of non-energy patents. This indicates that the induced innovation effect in energy technologies might come at the expense of innovation in other sectors.

F.6.1 Effect on Grey Patenting

Table F.37: Baseline Poisson Estimates for Grey Patenting (Baseline Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.426^{***}	0.411^{***}	0.641^{***}	0.586^{***}	0.369^{***}	0.362^{***}
	(0.078)	(0.085)	(0.090)	(0.095)	(0.100)	(0.110)
GDP per capita (log, t-1)	6.941^{***}	6.997^{***}	7.426^{***}	7.428^{***}	5.666^{***}	5.769^{***}
	(1.149)	(1.155)	(0.881)	(0.878)	(1.419)	(1.421)
Energy RD&D (log, t-1)	0.045	-0.026	0.342^{**}	0.193	0.144	0.111
	(0.160)	(0.168)	(0.142)	(0.162)	(0.174)	(0.180)
Low-Carbon RD&D (log, t-1)	0.064	0.193	-0.312^{*}	0.005	-0.106	-0.041
	(0.199)	(0.201)	(0.187)	(0.203)	(0.208)	(0.207)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	19,932	19,932	19,932	19,932	19,932	19,932
Observations	180,621	180,607	180,621	180,607	180,621	180,607
Pseudo-R2	0.231	0.231	0.294	0.295	0.211	0.212

Dependent variable: Number of grey docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.38: Baseline Poisson Estimates for Grey Patenting (Broader Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.219***	0.264***	0.232***	0.257***	0.221***	0.265***
	(0.065)	(0.072)	(0.075)	(0.080)	(0.079)	(0.091)
GDP per capita (log, t-1)	6.483***	5.941***	7.154***	7.046***	5.487***	4.931***
	(0.801)	(0.924)	(0.644)	(0.686)	(1.015)	(1.164)
Energy RD&D (log, t-1)	-0.042	0.019	0.274*	0.286**	0.111	0.145
	(0.151)	(0.140)	(0.146)	(0.143)	(0.177)	(0.160)
Low-Carbon RD&D (log, t-1)	0.401**	0.214	-0.218	-0.279	0.227	0.077
	(0.178)	(0.167)	(0.183)	(0.179)	(0.197)	(0.182)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	28,425	28,425	28,425	28,425	28,425	28,425
Observations	285,764	285,746	285,764	285,746	285,764	285,746
Pseudo-R2	0.213	0.214	0.264	0.264	0.200	0.201

Dependent variable: Number of grey docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.39: Distributed Lag Estimates for Grey Patenting (Baseline Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	-0.083	-0.068	0.016	0.036	-0.216	-0.201
	(0.105)	(0.110)	(0.133)	(0.135)	(0.131)	(0.137)
Prices (log, t-2)	0.193*	0.164	0.128	0.092	0.383***	0.357***
	(0.110)	(0.110)	(0.151)	(0.149)	(0.125)	(0.125)
Prices (log, t-3)	0.512***	0.511***	0.833***	0.803***	0.374***	0.377***
	(0.103)	(0.103)	(0.140)	(0.139)	(0.117)	(0.117)
L.GDP per capita (log, k$)	7.676***	7.802***	6.662***	6.785***	7.485***	7.589***
	(1.881)	(1.824)	(1.755)	(1.752)	(1.893)	(1.824)
L2.GDP per capita (log, k$)	-1.468*	-1.222	-0.996	-0.743	-2.746***	-2.444***
	(0.825)	(0.812)	(1.019)	(1.030)	(0.925)	(0.901)
L3.GDP per capita (log, k$)	-1.250	-1.241	0.632	0.448	-1.204	-1.165
	(1.006)	(0.970)	(0.919)	(0.906)	(1.142)	(1.106)
L.Energy RD&D (log, m$)	-0.395*	-0.452*	-0.179	-0.251	-0.158	-0.189
	(0.232)	(0.236)	(0.235)	(0.240)	(0.275)	(0.283)
L2.Energy RD&D (log, m$)	-0.523***	-0.540***	-0.346*	-0.360*	-0.301	-0.320
	(0.170)	(0.172)	(0.192)	(0.196)	(0.200)	(0.202)
L3.Energy RD&D (log, m$)	-0.123	-0.124	0.087	0.069	-0.249*	-0.246*
	(0.113)	(0.112)	(0.173)	(0.171)	(0.138)	(0.138)
L.Low-Carbon RD&D (log, m$)	0.475*	0.623**	0.197	0.424	0.082	0.167
	(0.252)	(0.259)	(0.260)	(0.269)	(0.280)	(0.291)
L2.Low-Carbon RD&D (log, m$)	0.580***	0.612***	0.325	0.402*	0.500**	0.526**
	(0.198)	(0.200)	(0.223)	(0.223)	(0.241)	(0.243)
L3.Low-Carbon RD&D (log, m$)	0.228	0.248*	-0.032	0.030	0.289	0.295
	(0.146)	(0.143)	(0.210)	(0.205)	(0.196)	(0.194)
Cumulative Effect	0.623***	0.606***	0.977***	0.931***	0.542***	0.533***
	(0.095)	(0.102)	(0.125)	(0.126)	(0.111)	(0.125)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	16,856	16,856	16,856	16,856	16,856	16,856
Observations	147,576	147,566	147,576	147,566	147,576	147,566
Pseudo-R2	0.232	0.233	0.295	0.296	0.213	0.213

Dependent variable: Number of grey docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.40: Distributed Lag Estimates for Grey Patenting (Broader Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	-0.083	-0.068	0.016	0.036	-0.216	-0.201
	(0.105)	(0.110)	(0.133)	(0.135)	(0.131)	(0.137)
Prices (log, t-2)	0.193*	0.164	0.128	0.092	0.383***	0.357***
	(0.110)	(0.110)	(0.151)	(0.149)	(0.125)	(0.125)
Prices (log, t-3)	0.512***	0.511***	0.833***	0.803***	0.374***	0.377***
	(0.103)	(0.103)	(0.140)	(0.139)	(0.117)	(0.117)
L.GDP per capita (log, k$)	7.676***	7.802***	6.662***	6.785***	7.485***	7.589***
	(1.881)	(1.824)	(1.755)	(1.752)	(1.893)	(1.824)
L2.GDP per capita (log, k$)	-1.468*	-1.222	-0.996	-0.743	-2.746***	-2.444***
	(0.825)	(0.812)	(1.019)	(1.030)	(0.925)	(0.901)
L3.GDP per capita (log, k$)	-1.250	-1.241	0.632	0.448	-1.204	-1.165
	(1.006)	(0.970)	(0.919)	(0.906)	(1.142)	(1.106)
L.Energy RD&D (log, m$)	-0.395*	-0.452*	-0.179	-0.251	-0.158	-0.189
	(0.232)	(0.236)	(0.235)	(0.240)	(0.275)	(0.283)
L2.Energy RD&D (log, m$)	-0.523***	-0.540***	-0.346*	-0.360*	-0.301	-0.320
	(0.170)	(0.172)	(0.192)	(0.196)	(0.200)	(0.202)
L3.Energy RD&D (log, m$)	-0.123	-0.124	0.087	0.069	-0.249*	-0.246*
	(0.113)	(0.112)	(0.173)	(0.171)	(0.138)	(0.138)
L.Low-Carbon RD&D (log, m$)	0.475*	0.623**	0.197	0.424	0.082	0.167
	(0.252)	(0.259)	(0.260)	(0.269)	(0.280)	(0.291)
L2.Low-Carbon RD&D (log, m$)	0.580***	0.612***	0.325	0.402*	0.500**	0.526**
	(0.198)	(0.200)	(0.223)	(0.223)	(0.241)	(0.243)
L3.Low-Carbon RD&D (log, m$)	0.228	0.248*	-0.032	0.030	0.289	0.295
	(0.146)	(0.143)	(0.210)	(0.205)	(0.196)	(0.194)
Cumulative Effect	0.623***	0.606***	0.977***	0.931***	0.542***	0.533***
	(0.095)	(0.102)	(0.125)	(0.126)	(0.111)	(0.125)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	16,856	16,856	16,856	16,856	16,856	16,856
Observations	147,576	147,566	147,576	147,566	147,576	147,566
Pseudo-R2	0.232	0.233	0.295	0.296	0.213	0.213

Dependent variable: Number of grey docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.6.2 Effect on Dirty Patenting

Table F.41: Baseline Poisson Estimates for Dirty Patenting (Baseline Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.278***	0.384***	0.278***	0.359***	0.239***	0.339***
	(0.073)	(0.076)	(0.098)	(0.099)	(0.083)	(0.089)
GDP per capita (log, t-1)	2.032***	0.832	3.034***	2.280***	1.620**	0.307
	(0.516)	(0.569)	(0.566)	(0.632)	(0.637)	(0.664)
Energy RD&D (log, t-1)	-0.222*	-0.137	-0.178	-0.062	-0.244*	-0.189
	(0.125)	(0.112)	(0.151)	(0.131)	(0.139)	(0.126)
Low-Carbon RD&D (log, t-1)	0.567***	0.323**	0.481***	0.159	0.517***	0.326**
	(0.146)	(0.132)	(0.174)	(0.154)	(0.153)	(0.139)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	19,703	19,703	19,703	19,703	19,703	19,703
Observations	202,886	202,878	202,886	202,878	202,886	202,878
Pseudo-R2	0.246	0.247	0.300	0.302	0.227	0.228

Dependent variable: Number of dirty docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.42: Baseline Poisson Estimates for Dirty Patenting (Broad Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.200***	0.289***	0.187**	0.247***	0.219***	0.318***
	(0.057)	(0.059)	(0.074)	(0.076)	(0.068)	(0.070)
GDP per capita (log, t-1)	2.486***	1.127**	3.514***	2.805***	1.893***	0.381
	(0.416)	(0.459)	(0.494)	(0.553)	(0.483)	(0.515)
Energy RD&D (log, t-1)	-0.232**	-0.169*	-0.215*	-0.133	-0.159	-0.122
	(0.107)	(0.094)	(0.123)	(0.109)	(0.122)	(0.108)
Low-Carbon RD&D (log, t-1)	0.696***	0.410***	0.507***	0.174	0.600***	0.380***
	(0.125)	(0.112)	(0.144)	(0.128)	(0.137)	(0.122)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	31,843	31,843	31,843	31,843	31,843	31,843
Observations	343,803	343,795	343,803	343,795	343,803	343,795
Pseudo-R2	0.230	0.232	0.270	0.272	0.220	0.221

Dependent variable: Number of dirty docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.43: Distributed Lag Estimates for Dirty Patenting (Baseline Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	-0.056	-0.090	-0.032	-0.105	-0.061	-0.077
	(0.102)	(0.106)	(0.138)	(0.141)	(0.118)	(0.123)
Prices (log, t-2)	0.107	0.207**	0.128	0.212	0.049	0.136
	(0.099)	(0.101)	(0.160)	(0.157)	(0.119)	(0.120)
Prices (log, t-3)	0.320***	0.418***	0.268**	0.373***	0.360***	0.448***
	(0.092)	(0.097)	(0.135)	(0.137)	(0.099)	(0.103)
L.GDP per capita (log, k$)	1.925**	1.407	2.637***	2.227**	1.050	0.460
	(0.894)	(0.968)	(1.013)	(1.074)	(0.947)	(1.033)
L2.GDP per capita (log, k$)	-1.766**	-2.466***	-0.972	-1.506	-0.988	-1.684
	(0.838)	(0.884)	(0.977)	(1.024)	(1.003)	(1.060)
L3.GDP per capita (log, k$)	0.292	0.428	1.038	1.155	0.339	0.399
	(0.747)	(0.767)	(0.878)	(0.909)	(0.914)	(0.930)
L.Energy RD&D (log, m$)	-0.415**	-0.419***	-0.451**	-0.446**	-0.388**	-0.394**
	(0.162)	(0.160)	(0.207)	(0.204)	(0.175)	(0.173)
L2.Energy RD&D (log, m$)	-0.204*	-0.224*	0.082	0.047	-0.127	-0.155
	(0.119)	(0.123)	(0.151)	(0.150)	(0.138)	(0.142)
L3.Energy RD&D (log, m$)	-0.219**	-0.204*	-0.094	-0.091	-0.139	-0.135
	(0.100)	(0.104)	(0.117)	(0.118)	(0.116)	(0.123)
L.Low-Carbon RD&D (log, m$)	0.683***	0.452**	0.545**	0.301	0.542***	0.362*
	(0.190)	(0.191)	(0.237)	(0.239)	(0.205)	(0.206)
L2.Low-Carbon RD&D (log, m$)	0.345***	0.283**	-0.034	-0.102	0.306**	0.265*
	(0.131)	(0.133)	(0.175)	(0.177)	(0.152)	(0.154)
L3.Low-Carbon RD&D (log, m$)	0.272**	0.221*	0.212	0.149	0.227*	0.183
	(0.120)	(0.125)	(0.141)	(0.145)	(0.135)	(0.143)
Cumulative Effect	0.371***	0.535***	0.364***	0.480***	0.348***	0.508***
	(0.097)	(0.103)	(0.137)	(0.138)	(0.112)	(0.121)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	17,553	17,553	17,553	17,553	17,553	17,553
Observations	169,872	169,864	169,872	169,864	169,872	169,864
Pseudo-R2	0.244	0.245	0.302	0.303	0.225	0.226

Dependent variable: Number of dirty docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.44: Distributed Lag Estimates for Dirty Patenting (Broad Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	-0.082	-0.138	-0.111	-0.190*	-0.012	-0.037
	(0.086)	(0.089)	(0.111)	(0.113)	(0.100)	(0.103)
Prices (log, t-2)	0.046	0.151*	0.226**	0.312***	-0.026	0.078
	(0.081)	(0.082)	(0.110)	(0.111)	(0.098)	(0.098)
Prices (log, t-3)	0.284***	0.381***	0.128	0.222**	0.347***	0.432***
	(0.072)	(0.074)	(0.097)	(0.099)	(0.084)	(0.085)
L.GDP per capita (log, k$)	2.514***	2.033***	3.900***	3.627***	1.826**	1.301*
	(0.700)	(0.745)	(0.842)	(0.873)	(0.730)	(0.785)
L2.GDP per capita (log, k$)	-1.093	-1.765**	-0.100	-0.619	-0.562	-1.273
	(0.671)	(0.708)	(0.825)	(0.872)	(0.792)	(0.838)
L3.GDP per capita (log, k$)	-0.515	-0.495	-0.425	-0.496	-0.929	-0.999
	(0.617)	(0.633)	(0.727)	(0.751)	(0.747)	(0.757)
L.Energy RD&D (log, m$)	-0.413***	-0.447***	-0.476***	-0.506***	-0.297**	-0.328**
	(0.134)	(0.133)	(0.173)	(0.172)	(0.149)	(0.147)
L2.Energy RD&D (log, m$)	-0.207**	-0.240**	0.028	-0.023	-0.117	-0.148
	(0.099)	(0.101)	(0.119)	(0.120)	(0.113)	(0.116)
L3.Energy RD&D (log, m$)	-0.274***	-0.276***	-0.160	-0.181*	-0.264***	-0.270***
	(0.084)	(0.086)	(0.099)	(0.099)	(0.099)	(0.104)
L.Low-Carbon RD&D (log, m$)	0.747***	0.507***	0.479**	0.253	0.610***	0.413**
	(0.159)	(0.159)	(0.195)	(0.194)	(0.171)	(0.170)
L2.Low-Carbon RD&D (log, m$)	0.342***	0.281***	0.043	-0.004	0.307**	0.266**
	(0.107)	(0.108)	(0.145)	(0.146)	(0.129)	(0.130)
L3.Low-Carbon RD&D (log, m$)	0.331***	0.292***	0.291**	0.255**	0.363***	0.331***
	(0.101)	(0.104)	(0.124)	(0.126)	(0.119)	(0.124)
Cumulative Effect	0.249***	0.395***	0.243**	0.344***	0.309***	0.473***
	(0.078)	(0.081)	(0.102)	(0.104)	(0.091)	(0.095)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	28,049	28,049	28,049	28,049	28,049	28,049
Observations	283,264	283,256	283,264	283,256	283,264	283,256
Pseudo-R2	0.227	0.229	0.270	0.271	0.218	0.220

Dependent variable: Number of dirty docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

F.6.3 Effect on Non-Energy Patenting

Table F.45: Baseline Poisson Estimates for Non-Energy Patenting (Baseline Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	-0.130***	-0.086***	-0.365***	-0.324***	-0.099***	-0.069**
	(0.029)	(0.027)	(0.040)	(0.042)	(0.034)	(0.032)
GDP per capita (log, t-1)	7.266***	5.189***	7.540***	6.293***	6.182***	4.050***
	(0.434)	(0.451)	(0.412)	(0.407)	(0.592)	(0.612)
Energy RD&D (log, t-1)	-0.280***	-0.208***	-0.260***	-0.204***	-0.138**	-0.113**
	(0.058)	(0.043)	(0.055)	(0.047)	(0.054)	(0.045)
Low-Carbon RD&D (log, t-1)	0.580***	0.242***	0.175*	-0.057	0.408***	0.175*
	(0.078)	(0.073)	(0.092)	(0.091)	(0.097)	(0.099)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	104,410	104,410	104,410	104,410	104,410	104,410
Observations	795,653	795,653	795,653	795,653	795,653	795,653
Pseudo-R2	0.659	0.662	0.633	0.635	0.601	0.604

Dependent variable: Number of non-energy docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.46: Baseline Poisson Estimates for Non-Energy Patenting (Broader Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	-0.093***	-0.043**	-0.264***	-0.214***	-0.083***	-0.052**
	(0.022)	(0.022)	(0.039)	(0.038)	(0.025)	(0.023)
GDP per capita (log, t-1)	7.583***	5.621***	7.431***	6.165***	6.579***	4.549***
	(0.299)	(0.318)	(0.297)	(0.314)	(0.402)	(0.426)
Energy RD&D (log, t-1)	-0.246***	-0.180***	-0.255***	-0.182***	-0.074**	-0.056*
	(0.036)	(0.028)	(0.045)	(0.038)	(0.035)	(0.031)
Low-Carbon RD&D (log, t-1)	0.521***	0.168***	0.267***	-0.041	0.306***	0.058
	(0.052)	(0.050)	(0.067)	(0.063)	(0.065)	(0.068)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	189,357	189,357	189,357	189,357	189,357	189,357
Observations	1,481,872	1,481,872	1,481,872	1,481,872	1,481,872	1,481,872
Pseudo-R2	0.622	0.626	0.649	0.651	0.568	0.572

Dependent variable: Number of non-energy docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.47: Distributed Lag Estimates for Non-Energy Patenting (Baseline Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.605***	0.410***	0.323***	0.194***	0.664***	0.458***
	(0.037)	(0.038)	(0.069)	(0.075)	(0.043)	(0.044)
Prices (log, t-2)	-0.551***	-0.469***	-0.526***	-0.496***	-0.523***	-0.430***
	(0.032)	(0.032)	(0.051)	(0.051)	(0.046)	(0.045)
Prices (log, t-3)	-0.689***	-0.520***	-0.641***	-0.512***	-0.714***	-0.531***
	(0.037)	(0.036)	(0.081)	(0.080)	(0.052)	(0.048)
L.GDP per capita (log, k$)	4.803***	4.073***	4.386***	3.872***	5.131***	4.243***
	(0.515)	(0.523)	(0.539)	(0.536)	(0.663)	(0.658)
L2.GDP per capita (log, k$)	1.487***	0.919*	2.894***	2.490***	0.518	-0.116
	(0.484)	(0.498)	(0.395)	(0.420)	(0.806)	(0.821)
L3.GDP per capita (log, k$)	1.259**	1.104*	2.245***	2.073***	1.717*	1.610
	(0.597)	(0.609)	(0.422)	(0.430)	(1.028)	(1.037)
L.Energy RD&D (log, m$)	0.266***	0.166***	0.417***	0.349***	0.339***	0.229***
	(0.066)	(0.064)	(0.077)	(0.076)	(0.075)	(0.071)
L2.Energy RD&D (log, m$)	-0.079	-0.153***	-0.131*	-0.180**	0.089	0.007
	(0.055)	(0.053)	(0.072)	(0.070)	(0.068)	(0.067)
L3.Energy RD&D (log, m$)	-0.109***	-0.136***	-0.083	-0.096*	-0.012	-0.046
	(0.040)	(0.038)	(0.053)	(0.054)	(0.055)	(0.053)
L.Low-Carbon RD&D (log, m$)	0.642***	0.501***	0.132	0.128	0.441***	0.287**
	(0.102)	(0.106)	(0.105)	(0.113)	(0.134)	(0.138)
L2.Low-Carbon RD&D (log, m$)	0.251***	0.212***	0.197***	0.180***	0.094	0.064
	(0.047)	(0.045)	(0.067)	(0.069)	(0.062)	(0.061)
L3.Low-Carbon RD&D (log, m$)	-0.045	-0.072*	-0.234***	-0.254***	-0.035	-0.064
	(0.038)	(0.038)	(0.055)	(0.058)	(0.050)	(0.050)
Cumulative Effect	-0.635***	-0.579***	-0.844***	-0.814***	-0.573***	-0.503***
	(0.047)	(0.046)	(0.062)	(0.063)	(0.054)	(0.054)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	90,951	90,951	90,951	90,951	90,951	90,951
Observations	676,925	676,925	676,925	676,925	676,925	676,925
Pseudo-R2	0.664	0.665	0.639	0.640	0.601	0.603

Dependent variable: Number of non-energy docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

Table F.48: Distributed Lag Estimates with Non-Energy Patenting (Broader Definition of Clean)

	(1) Simple Count	(2) Simple Count	(3) Citation-Weighted	(4) Citation-Weighted	(5) Coinventor-Weighted	(6) Coinventor-Weighted
Prices (log, t-1)	0.531***	0.355***	0.395***	0.281***	0.576***	0.389***
	(0.028)	(0.029)	(0.087)	(0.086)	(0.035)	(0.035)
Prices (log, t-2)	-0.587***	-0.485***	-0.504***	-0.450***	-0.568***	-0.457***
	(0.024)	(0.024)	(0.054)	(0.053)	(0.033)	(0.033)
Prices (log, t-3)	-0.573***	-0.416***	-0.651***	-0.540***	-0.610***	-0.444***
	(0.028)	(0.027)	(0.077)	(0.077)	(0.037)	(0.036)
L.GDP per capita (log, k$)	4.233***	3.542***	3.743***	3.240***	4.500***	3.679***
	(0.342)	(0.352)	(0.390)	(0.388)	(0.449)	(0.457)
L2.GDP per capita (log, k$)	2.333***	1.722***	3.522***	3.037***	1.627***	0.948*
	(0.322)	(0.332)	(0.304)	(0.308)	(0.548)	(0.562)
L3.GDP per capita (log, k$)	0.909**	0.817*	1.715***	1.555***	1.171	1.122
	(0.411)	(0.421)	(0.333)	(0.336)	(0.743)	(0.756)
L.Energy RD&D (log, m$)	0.293***	0.198***	0.479***	0.417***	0.401***	0.293***
	(0.047)	(0.046)	(0.087)	(0.084)	(0.054)	(0.051)
L2.Energy RD&D (log, m$)	-0.134***	-0.201***	-0.127**	-0.176***	0.034	-0.043
	(0.039)	(0.037)	(0.056)	(0.053)	(0.049)	(0.048)
L3.Energy RD&D (log, m$)	-0.111***	-0.135***	-0.129***	-0.143***	-0.021	-0.053
	(0.029)	(0.027)	(0.040)	(0.041)	(0.040)	(0.038)
L.Low-Carbon RD&D (log, m$)	0.705***	0.517***	0.242***	0.160*	0.474***	0.279***
	(0.069)	(0.071)	(0.080)	(0.082)	(0.090)	(0.092)
L2.Low-Carbon RD&D (log, m$)	0.253***	0.203***	0.255***	0.226***	0.101**	0.065
	(0.035)	(0.033)	(0.062)	(0.064)	(0.045)	(0.043)
L3.Low-Carbon RD&D (log, m$)	-0.091***	-0.122***	-0.234***	-0.257***	-0.079**	-0.109***
	(0.030)	(0.029)	(0.050)	(0.049)	(0.038)	(0.037)
Cumulative Effect	-0.629***	-0.546***	-0.760***	-0.710***	-0.602***	-0.512***
	(0.036)	(0.036)	(0.050)	(0.050)	(0.041)	(0.041)
Year FEs	X	X	X	X	X	X
Inventor FEs	X	X	X	X	X	X
Tenure FEs		X		X		X
Country-Year Covariates	X	X	X	X	X	X
Inventor Clusters (SEs)	161,994	161,994	161,994	161,994	161,994	161,994
Observations	1,238,822	1,238,822	1,238,822	1,238,822	1,238,822	1,238,822
Pseudo-R2	0.629	0.630	0.656	0.657	0.570	0.572

Dependent variable: Number of non-energy docdb patent families.

Poisson pseudo-maximum likelihood. Standard errors clustered by inventor in parentheses.

G Robustness of Inventor Entry Results

G.1 Primary Outcomes: Entry by Renewable and Nuclear Inventors

Table G.1: Renewable and Nuclear Inventor Entry Elasticities, Balanced Panel

	(1) New to Patenting	(2) New to Patenting	(3) From Grey/Dirty	(4) From Grey/Dirty	(5) From Non-Energy	(6) From Non-Energy
Prices (log, t-1)	0.258**	-0.046	0.167*	0.017	0.044	-0.119
	(0.110)	(0.144)	(0.096)	(0.131)	(0.127)	(0.146)
Prices (log, t-2)		0.128		-0.240*		-0.257*
		(0.171)		(0.137)		(0.148)
Prices (log, t-3)		0.536***		0.679***		0.314**
		(0.195)		(0.134)		(0.151)
Cumulative Effect		0.618***		0.456***		-0.062
		(0.166)		(0.124)		(0.181)
Year FEs	X	X	X	X	X	X
Firm FEs	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X
Firm Clusters (SEs)	3,933	3,779	4,993	4,703	4,912	4,642
Observations	53,921	43,733	67,617	53,109	66,541	52,559
Pseudo-R2	0.692	0.699	0.605	0.605	0.643	0.647

Dependent variables: number of renewable/nuclear inventors per group.

Sample: balanced panel from 2000 to 2014.

Poisson pseudo-maximum likelihood. Standard errors clustered by firm in parentheses.

Table G.2: Renewable and Nuclear Inventor Entry Elasticities, Unbalanced Panel

	(1) New to Patenting	(2) New to Patenting	(3) From Grey/Dirty	(4) From Grey/Dirty	(5) From Non-Energy	(6) From Non-Energy
Prices (log, t-1)	0.169*	-0.049	0.022	-0.000	0.036	-0.094
	(0.089)	(0.122)	(0.096)	(0.115)	(0.104)	(0.125)
Prices (log, t-2)		0.178		-0.311**		-0.146
		(0.138)		(0.121)		(0.126)
Prices (log, t-3)		0.422***		0.587***		0.195
		(0.163)		(0.119)		(0.134)
Cumulative Effect		0.551***		0.276**		-0.045
		(0.140)		(0.126)		(0.152)
Year FEs	X	X	X	X	X	X
Firm FEs	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X
Firm Clusters (SEs)	8,724	7,101	9,503	8,212	9,538	7,993
Observations	89,046	65,648	104,019	77,108	102,932	75,509
Pseudo-R2	0.634	0.658	0.556	0.565	0.586	0.602

Dependent variables: number of renewable/nuclear inventors per group.

Sample: unbalanced panel from 2000 to 2014.

Poisson pseudo-maximum likelihood. Standard errors clustered by firm in parentheses.

G.2 Alternative Outcomes: Broader Definition of Clean

Table G.3: Clean Inventor Entry Elasticities, Balanced Panel

	(1) New to Patenting	(2) New to Patenting	(3) From Grey/Dirty	(4) From Grey/Dirty	(5) From Non-Energy	(6) From Non-Energy
Prices (log, t-1)	0.212**	-0.099	0.066	0.006	-0.087	-0.135
	(0.090)	(0.112)	(0.083)	(0.126)	(0.085)	(0.106)
Prices (log, t-2)		0.126		0.074		-0.340***
		(0.121)		(0.133)		(0.114)
Prices (log, t-3)		0.553***		0.269**		0.310***
		(0.137)		(0.120)		(0.105)
Cumulative Effect		0.580***		0.349***		-0.165
		(0.124)		(0.107)		(0.118)
Year FEs	X	X	X	X	X	X
Firm FEs	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X
Firm Clusters (SEs)	5,898	5,626	5,065	4,747	6,722	6,346
Observations	80,816	65,023	68,913	54,060	91,158	71,800
Pseudo-R2	0.741	0.749	0.582	0.580	0.699	0.705

Dependent variables: number of clean inventors per group.
Sample: balanced panel from 2000 to 2014.
Poisson pseudo-maximum likelihood. Standard errors clustered by firm in parentheses.

Table G.4: Clean Inventor Entry Elasticities, Unbalanced Panel

	(1) New to Patenting	(2) New to Patenting	(3) From Grey/Dirty	(4) From Grey/Dirty	(5) From Non-Energy	(6) From Non-Energy
Prices (log, t-1)	0.150*	-0.085	-0.122	-0.111	-0.110	-0.101
	(0.077)	(0.097)	(0.091)	(0.124)	(0.073)	(0.092)
Prices (log, t-2)		0.117		0.037		-0.296***
		(0.101)		(0.120)		(0.099)
Prices (log, t-3)		0.451***		0.196*		0.226**
		(0.121)		(0.108)		(0.094)
Cumulative Effect		0.483***		0.122		-0.171*
		(0.109)		(0.117)		(0.102)
Year FEs	X	X	X	X	X	X
Firm FEs	X	X	X	X	X	X
Country-Year Covariates	X	X	X	X	X	X
Firm Clusters (SEs)	13,617	11,027	9,645	8,242	13,999	11,574
Observations	137,558	100,413	105,871	78,124	147,863	107,325
Pseudo-R2	0.685	0.707	0.530	0.537	0.647	0.663

Dependent variables: number of clean inventors per group.
Sample: unbalanced panel from 2000 to 2014.
Poisson pseudo-maximum likelihood. Standard errors clustered by firm in parentheses.

H Carbon Pricing Details and Robustness

H.1 Implementation

Our empirical strategy allows us to estimate elasticities that characterize how natural gas price variation induces innovation through the intensive margin by increasing the rate at which incumbent inventors patent, and through the extensive margin by increasing the number of inventors that work on clean technology. This section details the back-of-the-envelope calculation we use to combine the effects along those two margins and to analyze the potential impacts of a broad-based policy to price carbon.

The total number of clean patent families in a given year can be written as the product of the average number of patents filed per year by an inventor and the number of active inventors:

$$PAT_t^C = \overline{PAT}_t^C N_t. \tag{H.1}$$

To study the role of entry by inventors of different types, we decompose the number of incumbent inventors based on its evolution over time:

$$N_t = N_{t-1} + E_t^{g/d} + E_t^{non-energy} + E_t^{new} - X_t \tag{H.2}$$

where E_t^k denotes the number of inventors of type k who enter at the beginning of period t, and X_t denotes the number of incumbent inventors who exit at the beginning of period t.[3]

Taking the derivative of both sides of equation H.1 with respect to lagged natural gas prices and substituting equation H.2 yields

$$\frac{dPAT_t^C}{dP_{t-1}} = \frac{d\overline{PAT}_t^C}{dP_{t-1}} N_t + \overline{PAT}_t^C \frac{dN_t}{dP_{t-1}} \tag{H.3}$$

$$= \frac{d\overline{PAT}_t^C}{dP_{t-1}} N_t + \overline{PAT}_t^C \left(\frac{dN_{t-1}}{dP_{t-1}} + \frac{dE_t^{g/d}}{dP_{t-1}} + \frac{dE_t^{non-energy}}{dP_{t-1}} + \frac{dE_t^{new}}{dP_{t-1}} - \frac{dX_t}{dP_{t-1}} \right) \tag{H.4}$$

The first term captures the intensive margin change in patenting from a change in natural gas prices, holding the number of incumbent inventors fixed.

The second term captures the extensive margin change in patenting from a change in the number of inventors of each type, holding expected patenting per entrant fixed. This term is comprised of several parts. For clarity, the measure of average patenting output, $\overline{PAT}_t^C$, is unconditional and does not depend directly on the type of inventor (we relax this below). Within the parentheses, the first derivative is assumed to be zero based on timing: individuals enter and exit at the beginning of the year based on prices in the prior year, before prices for the coming year are realized, so there is no contemporaneous effect of prices on the number of incumbents. We use firm-level data to

3. Entrants are classified into types based on their prior patenting activity. g/d denotes inventors who have previously patented in grey and/or dirty technology but not in clean technology. $non-energy$ denotes inventors who have previously patented in technology areas outside of the set of energy technologies studied in this paper. *new* denotes inventors who were not previously observed in the patent data.

estimate the effects of natural gas prices on entry by inventors of each type, as described in Section 3.3. Since we do not directly observe exit, we assume that the rate of exit is not affected by natural gas prices. If higher natural gas prices led to lower rates of exit, this analysis would understate the role of extensive margin responses (and vice versa).

We approximate the aggregate impact of a change in natural gas prices by rewriting equation H.4 in terms of elasticities and multiplying both sides by the percentage change in prices, $\Delta P_t(\%)$:

$$\Delta PAT_t^C = \varepsilon_P^{\overline{PAT}^C} \overline{PAT}_t^C N_t \Delta P_t(\%) + \sum_k \overline{PAT}_t^{C,k} E_t^k \varepsilon_P^{E^k} \Delta P_t(\%), \tag{H.5}$$

where $\varepsilon_P^{\overline{PAT}_t^C}$ is the elasticity of output with respect to natural gas prices, and $\varepsilon_P^{E^k}$ is the elasticity of the number of entrants of type k with respect to natural gas prices. To provide a richer characterization of the mechanisms of induced innovation, we allow for average patenting rates to vary by entrant type, as denoted by the k subscript in $\overline{PAT}_t^{C,k}$. To compute effects of a persistent price change over a time horizon longer than one year, we further allow for average patenting by new entrants to vary over the course of their tenure. We also account for how a persistent price change has persistent effects on entry.

We use this framework to quantify the potential effects of carbon pricing on the amount and sources of clean innovation. To do so, we first compute how pricing carbon would increase the price of natural gas. For the social cost of carbon, we use the current U.S. Government value of \$51 per metric ton of CO_2 (in 2020 terms). We deflate this value to base year dollars using the U.S. GDP implicit price deflator from OECD (2023). We then convert the social cost of carbon into the same units as the natural gas price data (dollars per megawatt-hour) using conversion factors of 2,204.6 pounds per metric ton,[4] 0.97 pounds CO_2 per kilowatt-hour for electricity generation from natural gas,[5] and 1,000 kilowatt-hours per megawatt-hour. After deflation and conversion, the U.S. Government value of the social cost of carbon corresponds to 54% of the GDP-weighted global average price of natural gas in 2014.

Focusing on 2014 as our base year, we compute the predicted number of additional clean patents that would be generated over the course of 10 years in response to a permanent increase in the natural gas price equivalent to the social cost of carbon. Table 3 in the main text presents the resulting predictions in aggregate and by margin of response. Tables H.1 and H.3 in this appendix present analogous results from different model specifications and outcome variables to assess the robustness of the results.[6]

Inference. We compute standard errors via the delta method. To simplify notation, equation H.5 can be rewritten as

4. Source: EPA's Greenhouse Gases Equivalencies Calculator - Calculations and References, https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references, accessed May 10, 2023.

5. Source: U.S. Energy Information Administration State Electricity Profiles Tables 5 and 7, with data from 2021, https://www.eia.gov/tools/faqs/faq.php?id=74&t=11, accessed May 10, 2023.

6. For the appendix results that use distributed lag models, we use the cumulative effect estimates and treat them as if they take effect immediately rather than phasing in over three years for simplicity. This approach is conservative insofar as accounting for the gradual phase in of the effects would shrink the contribution of the extensive margin relative to the intensive margin, which is the main focus of our analysis. This is because the intensive margin effects phase in quickly (Table F.3), whereas the extensive margin effects phase in more slowly (Table G.1).

$$\Delta PAT_t^C = c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}$$

where all the non-stochastic terms are subsumed into a type-specific constant, c^k, with c^{inc} denoting the constant for incumbents.

Using this notation, the level of the change in patents attributable to incumbents is $c^{inc}\varepsilon_P^{\overline{PAT}^C}$ and the derivative of the level with respect to the output elasticity is c^{inc}. Applying the delta method, we approximate the standard error of the change in patenting attributable to incumbents as the product of the standard error of the output elasticity and c^{inc}. Standard errors for the other level changes are computed analogously using their respective elasticities' standard errors and type-specific constants.

The share of the change in patents attributable to incumbents can be written as:

$$s^{inc}(\varepsilon) = \left(c^{inc}\varepsilon_P^{\overline{PAT}^C}\right)\left(c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}\right)^{-1}.$$

By the delta method, the variance of the share is approximately

$$Var\left(s^{inc}(\varepsilon)\right) \approx \nabla s^{inc}(\varepsilon)^T \frac{\Sigma}{n} \nabla s^{inc}(\varepsilon)$$

where the gradient of the share with respect to the elasticities is

$$\nabla s^{inc}(\varepsilon) = \begin{bmatrix} c^{inc}\left(c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}\right)^{-1} - c^{inc}\left(c^{inc}\varepsilon_P^{\overline{PAT}^C}\right)\left(c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}\right)^{-2} \\ -c^{g/d}\left(c^{inc}\varepsilon_P^{\overline{PAT}^C}\right)\left(c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}\right)^{-2} \\ -c^{non-energy}\left(c^{inc}\varepsilon_P^{\overline{PAT}^C}\right)\left(c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}\right)^{-2} \\ -c^{new}\left(c^{inc}\varepsilon_P^{\overline{PAT}^C}\right)\left(c^{inc}\varepsilon_P^{\overline{PAT}^C} + \sum_k c^k \varepsilon_P^{E^k}\right)^{-2} \end{bmatrix}.$$

Since the elasticities are estimated separately using different data, their covariances are unknown, so we assume they are independent and use the individual variance estimates to construct the variance-covariance matrix Σ. Standard errors for the other shares are computed analogously using their respective gradients.

H.2 Limitations

First, this analysis is an approximation. While the price change we study is on the same order of magnitude as the country-level natural gas price variation observed in the raw data, our first-order approximation does not account for higher-order effects of natural gas prices on innovation by incumbents and entry by new inventors. If the supply of patents or inventors are highly convex, our predictions may overstate the magnitude of induced innovation.

Second, our analysis focuses on the effects of a change in natural gas prices. In reality, carbon pricing would also increase the price of other emitting sources of electricity generation such as coal. Furthermore, economy-wide carbon pricing could lead to increased demand for electricity from other sectors, such as electric vehicle charging from the transportation sector, which would also affect the returns to clean innovation. Both of these effects are beyond the scope of our analysis.

Third, our analysis does not account for differences in the quality of different patents. The results in Tables 3 and H.1 through H.3 are simple counts of patent families. Given the relative magnitudes of the estimates in Table 1, the effects are likely to be larger for alternative measures such as citation-weighted patents that attempt to proxy for the quality of innovations.

H.3 Robustness of Carbon Pricing Simulation Results

H.3.1 Alternative Specifications

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	36,710	80.7
	(4,438)	(6.2)
Extensive margin response		
Entry from grey/dirty	1,615	3.6
	(927)	(2.0)
Entry from non-energy	540	1.2
	(1,557)	(3.4)
Entry to patenting	6,616	14.5
	(2,807)	(5.5)
Total	45,481	100.0
	(5,555)	.

(a) Single lag, balanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	48,234	71.2
	(5,758)	(5.7)
Extensive margin response		
Entry from grey/dirty	4,410	6.5
	(1,199)	(1.8)
Entry from non-energy	-760	-1.1
	(2,218)	(3.3)
Entry to patenting	15,839	23.4
	(4,255)	(5.3)
Total	67,724	100.0
	(7,590)	.

(b) Distributed lag, balanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	36,710	84.1
	(4,438)	(7.5)
Extensive margin response		
Entry from grey/dirty	279	0.6
	(1,233)	(2.8)
Entry from non-energy	555	1.3
	(1,576)	(3.6)
Entry to patenting	6,108	14.0
	(3,221)	(6.5)
Total	43,651	100.0
	(5,837)	.

(c) Single lag, unbalanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	48,234	67.9
	(5,758)	(6.1)
Extensive margin response		
Entry from grey/dirty	3,554	5.0
	(1,622)	(2.2)
Entry from non-energy	-685	-1.0
	(2,315)	(3.3)
Entry to patenting	19,908	28.0
	(5,058)	(5.7)
Total	71,010	100.0
	(8,169)	.

(d) Distributed lag, unbalanced firm panel

Table H.1: Predicted Impacts of Carbon Pricing for Narrow Definition of Clean

Note: Predicted changes in the number of renewable and nuclear patent families due to a persistent 54% increase in natural gas prices over the course of 10 years, relative to a base year of 2014. Each panel uses elasticities and other inputs based on a different lag structure and firm dataset. Both the balanced and unbalanced firm panels range from 2000 to 2014. Standard errors are constructed using the delta method. Panel a reproduces the results from Table 3 in the main text. The total change in patenting in Panel a represents an increase of 26% relative to baseline patenting rates.

H.3.2 Alternative Base Year: 2010

The qualitative findings are robust to using alternative base years other than 2014. Table H.2 presents results using 2010 as the base year. Both the level of induced patenting and the share of induced patenting attributable to incumbent inventors are higher than in Table H.1.

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	50,964	83.2
	(6,161)	(6.2)
Extensive margin response		
Entry from grey/dirty	2,179	3.6
	(1,250)	(2.0)
Entry from non-energy	1,024	1.7
	(2,951)	(4.7)
Entry to patenting	7,118	11.6
	(3,020)	(4.6)
Total	61,284	100.0
	(7,573)	.

(a) Single lag, balanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	66,963	75.7
	(7,994)	(5.9)
Extensive margin response		
Entry from grey/dirty	5,949	6.7
	(1,618)	(1.9)
Entry from non-energy	-1,440	-1.6
	(4,203)	(4.8)
Entry to patenting	17,041	19.3
	(4,577)	(4.6)
Total	88,512	100.0
	(10,253)	.

(b) Distributed lag, balanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	50,964	85.3
	(6,161)	(7.6)
Extensive margin response		
Entry from grey/dirty	366	0.6
	(1,620)	(2.7)
Entry from non-energy	1,102	1.8
	(3,129)	(5.1)
Entry to patenting	7,296	12.2
	(3,847)	(5.8)
Total	59,728	100.0
	(8,073)	.

(c) Single lag, unbalanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	66,963	71.2
	(7,994)	(6.5)
Extensive margin response		
Entry from grey/dirty	4,670	5.0
	(2,132)	(2.2)
Entry from non-energy	-1,360	-1.4
	(4,594)	(5.0)
Entry to patenting	23,781	25.3
	(6,042)	(5.4)
Total	94,053	100.0
	(11,228)	.

(d) Distributed lag, unbalanced firm panel

Table H.2: Predicted Impacts of Carbon Pricing for Narrow Definition of Clean

Note: Predicted changes in the number of renewable and nuclear patent families due to a persistent 58% increase in natural gas prices over the course of 10 years, relative to a base year of 2010. Each panel uses elasticities and other inputs based on a different lag structure and firm dataset. Both the balanced and unbalanced firm panels range from 2000 to 2014. Standard errors are constructed using the delta method. The total change in patenting in Panel a represents an increase of 27% relative to baseline patenting rates.

H.3.3 Alternative Outcome: Clean Patenting

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	67,821	87.7
	(5,492)	(6.3)
Extensive margin response		
Entry from grey/dirty	711	0.9
	(886)	(1.1)
Entry from non-energy	-2,510	-3.2
	(2,469)	(3.3)
Entry to patenting	11,347	14.7
	(4,811)	(5.4)
Total	77,369	100.0
	(7,758)	.

(a) Single lag, balanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	92,106	75.4
	(8,054)	(4.9)
Extensive margin response		
Entry from grey/dirty	3,739	3.1
	(1,146)	(1.0)
Entry from non-energy	-4,765	-3.9
	(3,407)	(2.9)
Entry to patenting	31,073	25.4
	(6,643)	(4.5)
Total	122,153	100.0
	(11,042)	.

(b) Distributed lag, balanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	67,821	93.0
	(5,492)	(8.0)
Extensive margin response		
Entry from grey/dirty	-1,739	-2.4
	(1,286)	(1.8)
Entry from non-energy	-3,861	-5.3
	(2,554)	(3.7)
Entry to patenting	10,743	14.7
	(5,535)	(6.6)
Total	72,964	100.0
	(8,305)	.

(c) Single lag, unbalanced firm panel

Source	**Patents**	**Share (%)**
Intensive margin response		
Incumbent inventors	92,106	75.3
	(8,054)	(5.6)
Extensive margin response		
Entry from grey/dirty	1,732	1.4
	(1,661)	(1.3)
Entry from non-energy	-6,021	-4.9
	(3,592)	(3.1)
Entry to patenting	34,543	28.2
	(7,795)	(5.0)
Total	122,361	100.0
	(11,887)	.

(d) Distributed lag, unbalanced firm panel

Table H.3: Predicted Impacts of Carbon Pricing for Broad Definition of Clean

Note: Predicted changes in the number of clean patent families due to a persistent 54% increase in natural gas prices over the course of 10 years, relative to a base year of 2014. Each panel uses elasticities and other inputs based on a different lag structure and firm dataset. Both the balanced and unbalanced firm panels range from 2000 to 2014. Standard errors are constructed using the delta method.

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