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The impact of environmental regulations on manufacturing outsourcing: re-examining the pollution haven effect in global value chains

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Abstract As countries worldwide attempt to address a series of global and domestic environmental challenges, the pollution haven effect remains an ongoing concern among trade and environment researchers and policymakers. This paper examines the pollution haven effect in the context of global value chains using inter-country input-output data at the manufacturing industry level from 1995-2009. This paper pays special attention to the issue of "double-counting" caused by intermediate trade. The analysis utilizes two outsourcing measures and two revealed comparative advantage measures appropriate for analyzing global value chains. I propose women's political power as a novel instrumental variable to address the endogeneity of environmental regulation. Regression results show that more stringent environmental policies are not a significant determinant of manufacturing outsourcing and competitiveness in global value chains. At the same time, women's political power is associated with more stringent environmental policies.

Keywords Environmental policy, Pollution haven effect, Global value chains, Outsourcing

JEL Codes Q56, Q58, F18, F12, F14

1. Introduction

As countries worldwide attempt to address a series of pressing global and domestic environmental challenges, the pollution haven effect remains an ongoing concern among trade and environment scholars and policymakers. In theory (Copeland and Taylor 1994; 2003), more stringent environmental regulations can increase the production cost of pollution-intensive ("dirty") goods. Thus, countries with more stringent regulations will face a comparative disadvantage in "dirty" goods, while those with less strict regulations will face a comparative advantage. If environmental regulations are a pivotal determinant of the volume and direction of trade, countries with less stringent regulations will specialize more in "dirty" goods and become pollution havens. For policymakers, the main concern is a trade-off between environmental protection and the economic benefits associated with pollution-intensive activities. If the pollution haven effect is significant, it could deter policymakers from tightening environmental

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policies, resulting in sub-optimal environmental protection in a country (Jaffe, Peterson, Portney and Stavins 1995; Dechezlepretre and Sato 2017).

Since the 1980s (McGuire 1982; Kalt 1988), empirical studies of the pollution haven effect have focused on two main questions. First, is there a pollution haven effect? Second, are environmental regulations strong enough to fundamentally alter or even reverse the pattern of trade of “dirty” goods? Or are they weaker than the other determinants of trade such that we can only detect a pollution haven effect at the margin (Copeland, Shapiro and Taylor 2021)? Ederington and Minier (2003) and Levinson and Taylor (2008) found that higher pollution abatement costs in the U.S. were associated with higher net imports of “dirty” goods. Ederington, Levinson and Minier (2005) found that domestic pollution abatement costs had a statistically significant and positive effect on the U.S.’s net imports of pollution-intensive goods from low-income and low-standard countries. They also found that pollution-intensive industries tended to be less mobile, making it more costly to relocate when domestic environmental regulations became more stringent. Aichele and Felbermayr (2015) found that the ratification of the Kyoto Protocol increased the committed countries’ imports from non-committed countries. However, in Branger, Quirion and Chevallier (2016), a higher carbon price in the E.U. Emissions Trading System had no significant effect on the net imports of steel and cement. Similarly, in Naegele and Zaklan (2019), higher emission costs in the E.U. ETS did not cause a shift of manufacturing activities from regions with stronger regulations to regions with weaker regulations.

Since the 1970s, enabled by trade liberalization and more efficient communication and transportation technologies, firms can fragment their production process and outsource one or more stages to foreign countries with lower production costs. Production fragmentation and outsourcing have led to complex production networks that span multiple countries, i.e., global value chains.[2] The rise of global value chains has some important implications for studying the pollution haven effect. First, it makes the pollution haven effect more subtle. To circumvent domestic environmental regulations or avoid paying pollution abatement costs, firms only need to outsource the “dirtier” production stages impacted more by domestic environmental regulations instead of relocating their entire production to foreign countries (Cherniwchan, Copeland and Taylor 2017).

[2] Timmer, Erumban, Los, Stehrer and de Vries (2014) showed that foreign value-added embodied in manufacturing goods had increased rapidly since the early 1990s. Los, Timmer and de Vries (2015) showed that international production fragmentation mainly took place between countries in different regions.

Second, it makes traditional trade measures less suitable for testing the pollution haven effect. It is well known that traditional trade measures such as gross and net exports "double-count" the value of intermediate goods that cross borders more than once (Johnson and Noguera 2012; Koopman, Wang and Wei 2014). As global value chains become more prevalent (Johnson and Noguera 2017), traditional trade measures will suffer more from "double-counting," making it more problematic to use them in global value chain analysis. In global value chains, a country with large exports of "dirty" final goods may not be a pollution haven if it has outsourced most of the pollution-intensive intermediate production stages to foreign countries. Similarly, a country that imports many "dirty" final goods may be a pollution haven if it produces and exports a large volume of "dirty" intermediate goods.

Third, in global value chains, producing a "dirty" final good can indirectly involve production stages that take place overseas. To fully assess the pollution haven effect in global value chains, we need to trace all domestic and foreign activities directly and indirectly required to produce a final good.

Building on current literature, this paper examines the pollution haven effect in the context of global value chains. I constructed two foreign outsourcing measures and two revealed comparative advantage measures using panel data from the WIOD during 1995-2009. Environmental regulations are proxied by the OECD EPS Index. I use three econometric specifications to assess whether more stringent environmental policies are associated with more outsourcing or lower revealed comparative advantage of manufacturing industries. Bias can arise due to unobserved heterogeneity and the endogeneity of environmental regulations. I address unobserved heterogeneity with a set of time-variant and invariant fixed effects. And I propose a novel instrumental variable that measures women's political power for dealing with the endogeneity of environmental regulations. In addition to regressions with the full sample, I use two subsamples of 1995-2000 and 2004-2009 to check robustness. Overall, the regression results do not show a significant pollution haven effect at the industry level in global value chains.

The contribution of the paper is threefold. First, this paper uses two outsourcing and two revealed comparative advantage measures more appropriate in the context of global value chains. Specifically, all the measures fully account for the "double-counting" issue caused by production fragmentation, intermediate trade, and the direct and indirect linkages of production activities in global value chains. Second, I use a novel instrumental variable to deal with the endogeneity of environmental regulations. The IV – women's political power – is measured by the percentage of seats held by women in the lower or single chamber of a country's national parliament. Recent studies show that women have a stronger preference for environmental protection, and the stringency of a country's environmental policy significantly correlates with women's representation in politics. And we can use fixed effects to control for the other paths by which women's political power can impact trade outcomes. Third, this paper extends the scope of analysis to the world economy instead of focusing on a single country. Pollution haven studies that focus on a single country may not reflect the full dynamics in global value chains. Most importantly, after a country outsources its production to another country in a global value chain, the latter can further outsource its production to a third country, and so on. Without considering the full dynamics of outsourcing in an industry's whole global value chain, we risk overestimating or underestimating the extent of outsourcing between two trade partner countries. This paper addresses this issue by using inter-country input-output table data that covers the entire global economy.

This paper is closely related to several recent studies on the impact of environmental policies on trade in global value chains. Clark, Marchese and Zarrilli (2000) found that industries in the U.S. with high pollution abatement costs were less likely to offshore their assembly operations to developing countries. Using input-output data, Levinson (2010) showed that we would significantly underestimate the pollution content of U.S. imports if we do not fully consider the impact of intermediate trade. Cole, Elliott and Okubo (2014) found that Japanese firms adopting environmental management-type practices were more likely to outsource operations to countries without such practices. Kozluk and Timiliotis (2016) found that although more stringent environmental policies would lower a country's gross manufacturing exports, they were not a strong determinant of export patterns. Antonietti, de Marchi and di Maria (2017) found that as domestic environmental policies became more stringent, Italian manufacturing firms were more likely to outsource their production to developing countries. Cherniwchan (2017) examined the impact of trade liberalization on air emissions generated by U.S. manufacturing plants. Regression results show that lower tariffs on pollution-intensive intermediate imports from Mexico are associated with lower PM_{10} and SO_2 emissions per worker of manufacturing plants. Ben-David, Kleimeier and Viehs (2018) found that more stringent domestic environmental regulations would lower a firm's self-reported domestic CO_2 emissions but increase its foreign emissions.

The organization of the paper is as follows. Section 2 explains the data sources and the construction of relevant variables. Section 3 describes the econometric specifications and the strategy for dealing with bias caused by unobserved heterogeneity and endogeneity associated with environmental policies. Section 4 presents and discusses the regression results. Section 5 contains conclusions, policy implications, and further research questions.

2. Data and methods

The primary data sources include the World Input-Output Database (WIOD), the OECD Environmental Policy Stringency Index, and the Inter-Parliamentary Union's Historical Data on Women in National Parliaments. The period of the analysis is 1995 to 2009. The paper focuses on 14 aggregated manufacturing industries.[3] This section explains the construction of variables used for testing the pollution haven effect in global value chains.

2.1 Production fragmentation and outsourcing

Feenstra and Hanson (1996; 1999) offered a straightforward method of measuring international production fragmentation and outsourcing. Using data on intermediate trade, they measured foreign outsourcing as the share of foreign intermediate inputs in an industry's total use of intermediates inputs. A higher share indicates more foreign outsourcing. Feenstra and Hanson developed two versions of the measurement. The broad version considers all foreign intermediate inputs, while the narrow version only considers foreign intermediate inputs purchased from the same industry. The idea behind the narrow measure is that foreign outsourcing is the overseas transfer of production activities that a product could have performed domestically. Thus, when a firm relies more on foreign intermediate inputs from the same industry, it signals more outsourcing. Similarly, Hummels, Ishii and Yi (2001) measured international production fragmentation as the amount of foreign intermediate inputs used to produce a country's exports.

The recent development of inter-country input-output tables (ICIO) significantly improved the empirical research of global value chains (Tukker and Dietzenbacher 2013; Inomata 2014). Most importantly, ICIO allows researchers to track the value-added flow from where it is created to where it is absorbed in the final demand (Johnson and Noguera 2012; 2017). In global value chains, because production can cross borders multiple times, a country's imports of intermediate inputs may contain value-added created in the importing country itself, or value-added created in a third country. To fully account for this situation, Los, Timmer and de Vries (2015) traced all domestic and foreign value-

[3] The 14 aggregated industries include food, beverages and tobacco; textiles and textile products; leather, leather and footwear; wood and products of wood and cork; pulp, paper, printing and publishing; coke, refined petroleum and nuclear fuel; chemicals and chemical products; rubber and plastics; other non-metallic minerals; basic metals and fabricated metal; machinery that were not elsewhere classified; electrical and optical equipment; transport equipment; manufacturing industry that was not elsewhere classified and recycling.

adding activities directly and indirectly required to produce an industry's final good and measured international production fragmentation as the share of foreign value-added in the value of an industry's final good.

In this paper, I construct a measure of outsourcing based on Feenstra and Hanson (1996; 1999), Los, Timmer and de Vries (2015) and Johnson and Noguera (2012; 2017). First, I decompose the value of an industry's final good into the value added by all domestic and foreign activities directly and indirectly required to produce the final good:

$$Y_{jd} = \sum_i \sum_o V_{iojd}. \cdots (1)$$

In Equation (1), Y_{jd} is the value of the final good of industry j of country d. V_{iojd} is the value-added that originates from industry i of country o. Second, I measure outsourcing as the share of foreign value-added from the same industry in the value of an industry's final good:

$$OUT_{jd} = 100 \times (\sum_{o \neq d} V_{jojd})/Y_{jd}. \cdots (2)$$

In Equation (2), $\sum_{o \neq d} V_{jojd}$ represents total foreign value-added from the same industry as the final good. We can consider OUT_{jd} as a revised narrow measure in the spirit of Feenstra and Hanson (1996; 1999). I use the input-output tables in the WIOD (1995-2009) to calculate the two measures defined in Equation (1) and Equation (2).[4]

2.2 Revealed comparative advantage

Another critical policy question is how environmental regulations impact a country's competitiveness in global value chains. The revealed comparative advantage (RCA) index has been used widely to indicate a country's ability to produce a good relative to all other countries in the global economy. Balassa (1965) first conceptualized the index, and constructed it as the ratio of a country's share of world exports of a particular product and the country's share of overall world exports. An index value above one is considered an indicator that the country has a revealed comparative advantage in that product (French 2017).[5]

Some recent literature has examined the impact of environmental regulations on a country's revealed comparative advantage in pollution-intensive goods. Using data from twenty-five OECD countries and nine major East Asian developing countries during 1965-1995, Xu (2000) found no systematic changes in trade patterns over time. Grether and de Melo (2004) examined twenty-two high-income countries and thirty less-developed countries between 1981

[4] Data is retrieved from www.wiod.org/release13. See details in Appendix B.

[5] Because trade is determined by many factors (such as trade policies), a country's revealed comparative advantage does not necessarily reflect its comparative advantage as determined by factor endowment.

and 1998. They found that the RCA of less-developed countries has increased in four polluting industries, including pulp and paper, industrial chemicals, nonmetallic minerals, and iron and steel. Cole, Elliott and Shimamoto (2005) examined the RCA of U.S. manufacturing industries between 1978 and 1994 and found no systemic evidence that the U.S.'s specialization in pollution-intensive industries had declined. They also showed that the U.S.'s competitive advantage in human and physical capital-intensive industries offsets the negative impact of environmental regulations on the U.S.'s RCA in pollution-intensive industries. Marconi (2012) studied the bilateral RCA between fourteen E.U. countries and China during 1999-2006 and found that the E.U. countries had kept or improved their advantages in water and air-polluting industries, while their advantages in cleaner industries had declined. One possible explanation is that cleaner industries are more mobile than pollution-intensive industries, implying that industrial mobility may significantly impact specialization more than environmental policies. Sauvage (2014) analyzed the RCA of twenty-six OECD countries in environmental goods between 2002 and 2012 and found that more stringent environmental policies could increase a country's export of environmental goods.

In all the studies mentioned above, the RCA index is based on gross exports. However, because of production fragmentation and double-counting of intermediate inputs that cross borders more than once, a country's RCA in gross exports is no longer reflective of a country's actual specialization in global value chains. Koopman, Wang and Wei (2014) showed that a country's RCA in value-added trade could drastically differ from its RCA in gross exports. Therefore, when examining the impact of environmental regulations on specialization in global value chains, we must first filter out the distortion caused by the double-counting of intermediate trade.

In this paper, I use ICIO data from the WIOD to construct two RCA indices at the country × industry level. The first RCA index is based on factor income earned in global value chains (Timmer, Los, Stehrer, de Vries and Pijoan-Mas 2013). In Equation (1), V_{iojd} is the value-added created by industry i of country o and absorbed in the final good of industry j of country d. Because value-added accrue as income to the labor or capital factors employed in industry i of country o, we can calculate country o's total factor income earned from industry j by adding up V_{iojd} by i and d. Then, the income-based RCA index can be calculated as:

$$RCAINC_{jo} = 100 \times (INC_{jo}/\sum_o INC_{jo})/(\sum_j INC_{jo}/\sum_j \sum_o INC_{jo}). \cdots (3)$$

In Equation (3), $INC_{jo}=\sum_i \sum_d V_{iojd}$ is country o's total factor income from industry j. $\sum_o INC_{jo}$ is the world's total factor income from industry j. $\sum_j INC_{jo}$ is country o's total factor income from all industries. $\sum_j \sum_o INC_{jo}$ is the world's overall factor income. The index is scaled by 100. An index value above 100 means that country o derives a larger share of factor income from industry *j* relative to all other countries, implying a revealed comparative advantage in activities directly and indirectly required to produce industry *j*'s final good.

Following Koopman, Wang and Wei (2014) and Borin and Mancini (2019), I calculate the second RCA index based on the *net* domestic value-added in a country's gross exports. In global value chains, a country's gross exports embody both domestic and foreign value-added. And due to the border crossing of intermediate inputs, both domestic and foreign value-added will suffer from double-counting. Thus, *net* domestic value-added is the domestic value-added in a country's gross exports net of the double-counted value. Then, we can construct the second RCA index as:

$$RCADVA_{jo} = 100 \times (NDVA_{jo}/\textstyle\sum_o NDVA_{jo})/(\sum_j NDVA_{jo}/\sum_j\sum_o NDVA_{jo}). \cdots (4)$$

In Equation (4), $NDVA_{jo}$ is the net domestic value-added in industry *j* of country *o*'s gross exports. $\sum_o NDVA_{jo}$ is the net domestic value-added in all countries' export of industry *j*. $\sum_j DVA_{jo}$ is the net domestic value-added in country *o*'s overall exports. $\sum_j\sum_o DVA_{jo}$ is the net domestic value-added in the world's overall exports. When the index is above 100, we can consider the country as having a revealed comparative advantage in the export of industry *j*.

2.3 Environmental policy stringency

There are several conceptual and empirical challenges when measuring the stringency of environmental policies (Botta and Kozluk 2014; Brunel and Levinson 2016). A single measure of stringency (such as the presence of a specific type of environmental policy in a country) may not capture the multidimensionality of environmental regulations. Although two countries adopt similar environmental policies, the strictness can differ between the two countries. For instance, a policy regulating a pollution-intensive industry will appear more stringent in countries with a larger share of that industry. By contrast, a policy that exempts older firms will appear less stringent in countries with more old firms. More importantly, simultaneity, omitted variables, and unobserved heterogeneity can cause endogeneity in the environmental policy variable, leading to biased estimation results.

I use the OECD Environmental Policy Stringency (EPS) index to proxy environmental regulations in this paper.[6] Constrained by data availability in the WIOD, the EPS index used is from twenty-six OECD countries and six non-OECD countries between 1995 and 2009. The EPS index is built in two septs. First, the stringency of a group of market and non-market environmental regulatory instruments is evaluated on a scale of 0 to 6, with higher numbers

[6] In Albrizio, Kozluk and Zipperer (2017), the EPS index was used to examine how environmental policies impact industry-level and firm-level productivity growth in OECD countries.

being more stringent. Then, the individual indices are combined into a composite index on the same scale. The composite index captures the multidimensionality of environmental regulations. The EPS index focuses on environmental regulations that mainly impact the transportation and energy sectors. Although transportation and energy do not represent the whole economy, there are advantages in focusing on these two sectors. Because transportation and energy are upstream in all manufacturing production, they are present in all industrialized and industrializing countries and are of comparable economic importance across countries. Moreover, both sectors tend to be pollution-intensive in all countries and are subject to an identifiable and comparable set of environmental regulatory instruments (Botta and Kozluk 2014).

3. Econometric specifications

3.1 Baseline specifications

I define three econometric specifications to examine the impact of environmental regulations on manufacturing outsourcing in global value chains.

The first specification is akin to an empirical gravity equation (Aichele and Felbermayr 2015; Naegele and Zaklan 2019):

$$V_{jojdt} = \exp\left[\alpha + \beta \times \left(\frac{EPS_{dt}}{EPS_{ot}} \times EMROW_{jt}\right) + \upsilon_{odt} + \upsilon_{jdt} + \upsilon_{jot} + \upsilon_{jod}\right] + \epsilon_{jojdt}. \ldots (5)$$

In Equation (5), subscript *j* indicates a manufacturing industry. *o* indicates the origin country where value is created. *d* is the destination country where value is absorbed in the final goods (*o*≠*d*). *t* indicates year. The dependent variable V_{jojd} represents the value in the final good of industry *j* of country *d* that originates from the same industry of country *o*.

EPS_d and EPS_o are the OECD environmental policy stringency index of country *d* and country o, respectively. The ratio $\frac{EPS_d}{EPS_o}$ captures the relative stringency of environmental policies between the two countries. Suppose the pollution haven effect exists in global value chains. In that case, we should expect polluting industries in country *d* to outsource more to country *o*, as country *d*'s environmental policies become more stringent relative to country *o*.

However, different industries would have heterogeneous responses to the same national environmental policies. Because pollution-intensive industries depend more on polluting activities, we expect them to have a higher incentive to seek out "pollution havens" when domestic environmental regulations become more stringent. One way to address this heterogeneity is to interact the country-level environmental policy stringency with a variable that captures the pollution characteristics at the industry level.[7] In this paper, $\frac{EPS_d}{EPS_o}$ is interacted with the share of air emission-generating energy in the total energy use of industry j of the rest of the world ($EMROW_j$).[8] To fully describe all flows in the world economy, the WIOD models countries not covered by the main input-output data as an aggregated rest-of-the-world region and provides energy use data at the industry level (Timmer, Dietzenbacher, Los, Stehrer and de Vries 2015). The advantage of using $EMROW_j$ as part of the interaction term is twofold. First, because countries both compete and connect in global value chains, the percentage of air emission-generating energy in total energy use in the rest of the world will be correlated with the measure of the in-sample countries. Thus it is an appropriate indicator of the environmental characteristics of manufacturing industries in global value chains. Second, because the rest-of-the-world countries are not in the sample, there is a lower chance of introducing endogeneity into the econometric model. Based on Equation (5), a positive coefficient β would mean that as environmental policies in country d get more stringent relative to country o, more emission-intensive industries will outsource more to country o.[9]

In Equation (5), the purpose of including fixed effects is to capture time-variant and invariant factors that can impact global outsourcing. υ_{odt} captures all time-variant origin-and-destination country-pair factors. Time-variant industry-level specific factors in the origin or destination countries are captured by υ_{jdt} or υ_{jot}, respectively. Time-invariant factors of bilateral trade are captured by υ_{jod}.[10] The fixed effects help address unobserved heterogeneity and omitted variables that correlate with bilateral trade and environmental policies. They also control for trade barriers between each country and their trade partners ("multilateral resistance"). They can also correct for year-to-year price changes without introducing bias (Baldwin and Taglioni 2007).

[7] For example, Broner, Bustos and Carvalho (2012), Chung (2014), Albrizio, Kozluk and Zipperer (2017) and Bagayev and Lochard (2017) interacted the country-level environmental policy with the industry-level pollution intensity (pollution per unit of output) or energy intensity (energy use per unit of output).

[8] Energy use data is from the WIOD's environmental accounts (Genty, Arto and Neuwahl 2012). Energy use that does *not* generate air emissions includes electricity, heat, nuclear, hydroelectric, geothermal, solar, wind power, and other sources.

[9] Chung (2014) argued that the interaction term identified the sources of comparative advantage in a difference-in-differences type strategy.

[10] The final dataset comprises 30 countries, 14 aggregated manufacturing industries, and 15 time periods (1995-2009).

The second specification is:

$$OUT_{jdt} = \alpha + \beta \times (EPS_{dt} \times EMROW_{jt}) + \upsilon_{dt} + \upsilon_{jt} + \upsilon_{jd} + \epsilon_{jdt}. \dots (6)$$

In Equation (6), the dependent variable OUT_{jd} represents foreign value-added as a percentage of the value of the final good of industry *j* of country *d*. It is necessary to note that the variable only considers foreign value-added from the same industry as the final good. The key independent variable $EPS_d \times EMROW_j$ is the interaction between country *d*'s EPS index and the share of air emission-generating energy in the total energy use of industry *j* of the rest of the world. A positive coefficient β would mean that as environmental policies in country *d* get more stringent, manufacturing industries that are more emission-intensive would outsource more to the other countries in global value chains. The specification in Equation (6) also includes several fixed effects to control for time-variant and invariant factors that could influence industry *j* of country *d*'s outsourcing in global value chains: υ_{dt} captures time-variant factors specific to country *d*; υ_{jt} captures time-variant factors specific to industry *j*; time-invariant factors are captured by υ_{jd}.

The third specification focuses on revealed comparative advantage:

$$RCAadj_{jot} = \frac{RCA_{jot} - 100}{RCA_{jot} + 100} = \alpha + \beta \times (EPS_{ot} \times EMROW_{jt}) + \upsilon_{ot} + \upsilon_{jt} + \upsilon_{jo} + \epsilon_{jot}. \dots (7)$$

In Equation (7), RCA_{jo} is either the factor income-based RCA index defined in Equation (3) or the domestic value-added-based RCA index defined in Equation (4). Because the original RCA indices take values between 0 and infinity, using them as regression dependent variables will give too much weight to RCA values above 100. After the transformation (*RCA*-100)/(*RCA*+100), the dependent variable will take values between negative and positive 100, and thus regressions using the transformed index will treat all RCA values symmetrically (Cole, Elliott and Shimamoto 2005).

The key independent variable $EPS_o \times EMROW_j$ is the interaction between country *o*'s EPS index and the share of air emission-generating energy in the total energy use of industry *j* of the rest of the world. Equation (7) also includes a set of fixed effects similar to those in Equation (6) to control for time-variant and invariant factors that can impact a country's manufacturing revealed comparative advantage in global value chains.

3.2 Endogeneity and instrumental variable

The endogeneity of the environmental policy independent variable is a major concern among pollution haven effect researchers (Cole, Elliott and Fredriksson, 2006; Levinson and Taylor 2008; Brunel and Levinson 2016; Millimet and

Roy 2016). One reason for endogeneity is the unobservable industry or country-specific factors that correlate with an industry's propensity to export (or outsource) and pollute. The panel data allows us to deal with unobserved heterogeneity by including multiple time-variant and invariant fixed effects.

Another main source of endogeneity is simultaneity. In empirical tests of the pollution haven effect, the independent variable of interest is usually some environmental policy measure, and the dependent variable is typically some measure of trade. Exogeneity of the independent variable requires that the impact of environmental policies on trade is unidirectional. But international trade may also impact environmental regulations, causing simultaneity between the dependent and independent variables (Eliste and Fredriksson 2002; Cole, Elliott and Fredriksson 2006; Levinson and Taylor 2008). For instance, in major exporting countries of pollution-intensive goods, the government may be reluctant to enact stringent environmental regulations due to political pressures from the pollution-intensive industries. Researchers have utilized quasi-natural experiments and instrumental variables to deal with simultaneity. However, quasi-experiments are rare in economics, and valid instrumental variables that meet both the correlation requirement and the exclusion restriction are hard to find.

In this paper, due to simultaneity, international outsourcing can influence the stringency of environmental regulations in both the origin and destination countries (EPS_o *and* EPS_d, respectively). This paper proposes a novel instrumental variable to mitigate the simultaneity issue associated with environmental policies – *the percentage of seats held by women members in the single or lower chamber of a country's parliament (*$WOMEN_o$ or $WOMEN_d$*)*. Studies show that women tend to have greater environmental concerns than men. They tend to participate more in pro-environmental activities, convey better scientific knowledge of climate change, have stronger pro-environmental attitudes, perceive environmental problems that pose health and safety risks as more serious, and prefer more robust environmental protection from the government (McCright 2010; McCright and Xiao 2014; Xiao and McCright 2015). Economists play important roles in the making of environmental policies. Surveys of economists in the U.S. and Europe show that female economists prefer environmental protection more than male economists (May, McGarvey and Whaples 2014; May, McGarvey and Kucera 2018).

Furthermore, women's representation in national parliaments can lead countries to adopt more stringent environmental policies (Fredriksson and Wang 2011; Mavisakalyan and Tarverdi 2019; Atchison and Down 2019; Ramstetter and Habersack 2020). Therefore, conditional on other factors, the percentage of parliament seats held by women will strongly correlate with the stringency of environmental policies, thus meeting the requirement that changes in the IV are associated with changes in the endogenous variable.[11] However, as always, satisfying the exclusion restriction is more challenging. In the case of the proposed IV here, there are reasons to believe that women's representation in national parliaments may impact trade through other paths. Since we use panel data in this paper, we can control for the other paths by including a set of time-variant and time-invariant fixed effects, which help with lessening the chance that the IV fails to satisfy the exclusion restriction.

In what follows, the percentage of seats held by women members in the single or lower chamber of a country's parliament (*WOMENo* or *WOMENd*) will be used to construct relevant I.V.s for different econometric specifications.

4. Results and discussions

This section presents and discusses estimation results from the three econometric specifications defined in Section 3.[12]

4.1 Outsourcing

Table 1 shows the estimation results of the empirical gravity model defined in Equation (5). The model is estimated by the Poisson Pseudo Maximum Likelihood (PPML) estimator, and robust standard errors are two-way clustered by industry and country pair to account for serial correlation within the panel. Although the Poisson estimator is often used to fit count data, Santos Silva and Tenreyro (2006) showed that PPML could also fit a variety of non-negative and non-count data and generate consistent estimations robust to different patterns of heteroscedasticity. In addition, in the case of trade data, a major challenge is the presence of a large proportion of zero bilateral trade flows. When taking the logarithm of trade flows, researchers have resorted to several unsatisfactory solutions. By contrast, the PPML estimator provides a natural way to deal with zero trades. For these reasons, the PPML estimator has been widely used to estimate gravity models. Because the gravity model defined in Equation (5) contains multi-way fixed effects, the ppmlhdfe statistical package developed by Correia, Guimarães and Zylkin (2020; 2021) is used.

Table 1

We first discuss estimation results using the full sample. In Column (1), the dependent variable V_{jojd} is the value of an industry's final good that originates from the same industry in a foreign country. The regression coefficient shows that

[11] Appendix A Figure A2 shows the percentage of women parliamentarians for the countries in the final sample. It can be seen that all countries are having more women in national parliaments between 1995 and 2009.

[12] Due to the space limit, descriptive statistics are provided in Appendix A.

the relative stringency of environmental policies between two countries does not significantly affect outsourcing in global value chains.

The following two columns show instrumental variable regression results. The instrumental variable for the independent variable is ($WOMEN_{dt}/WOMEN_{ot}$)×$EMROW_{jt}$. As detailed in Section 3.2, $WOMEN_{dt}/WOMEN_{ot}$ is the ratio of the percentage of seats held by women in the national parliament between the destination country and origin country. Results of the first-stage regression are reported in Column (2). The results show that the ratio of women's representation in national parliament has a positive and statistically significant effect on the relative environmental policy stringency between the two countries. After standardization, a one standard deviation increase in the relative representation of women in national parliament will result in an expected increase in the relative stringency of environmental regulations by 0.0437 of its standard deviation. Second-stage regression results are reported in Column (3). Following the method suggested by Lin and Wooldridge (2019), the predicted overall error component from the first stage ($\hat{e}_{jodt}$) is used as the control function in the second stage. Although the IV regression shows a positive effect of relative stringency of environmental policies on outsourcing, the effect is still statistically insignificant.

Additional regressions using two sub-samples (1995-2000 and 2004-2009) are performed to check robustness. The results are shown in Table 1. The sub-samples are selected for these two periods to exclude the impacts of two major global events between 2001 and 2003. First, Mainland China officially joined the World Trade Organization in 2001. Second, most countries ratified the Kyoto Protocol between 2001 and 2003. These two events could introduce abrupt changes to both global environmental policies and international trade patterns. Models in all three columns are estimated with the same methods as in the full sample. The additional results further confirm the lack of a pollution haven effect in global value chains. Although the effect of relative environmental policy stringency on outsourcing is significant and positive in 1995-2000, it becomes insignificant in the IV regression in Column (3). By contrast, the effect of women's political representation on environmental policy stringency remains statistically significant and positive in both sub-sample results.

Next, estimation results based on the specification in Equation (6) are shown in Table 2. The dependent variable OUT_{jdt} is the percentage of foreign value-added in the value of an industry's final good. Because the model contains multi-way fixed effects, the reghdfe statistical package developed by Correia (2017) is used for estimation. Robust standard errors are two-way clustered by industry and country to account for serial correlation within the panel.

Table 2

When the full sample is used, the estimation result in Column (1) shows that a country's EPS index does not have a statistically significant effect on the percentage of foreign value-added embodied in a country's final goods. The following two columns show results from the IV regression. Column (2) shows results from the first stage, in which the interaction term $WOMEN_{dt} \times EMROW_{jt}$ is used as IV for the endogenous variable. An interesting result is that women's representation in national parliaments has a significant and positive effect on a country's EPS index. A one standard deviation increase in the percentage of women parliamentarians will result in an expected increase in the stringency of environmental regulations by 0.475 standard deviation. In Column (3), the second-stage regression results again show that the stringency of environmental policies does not significantly impact the percentage of foreign value-added embodied in manufacturing final goods, although the effect is positive. Table 2 also shows additional regression results using the two subsamples of 1995-2000 and 2004-2009. The results are consistent with the finding from the full sample.

4.2 Revealed comparative advantage

Table 3 shows the estimation results based on Equation (7). The dependent variable is either the transformed RCA index based on factor incomes ($RCAINCadj_{jot}$), or the transformed RCA index based on the net domestic value-added in gross exports ($RCADVAadj_{jot}$). Estimation utilizes the reghdfe statistical package developed by Correia (2017). Robust standard errors are two-way clustered by industry and country.

Table 3

The pollution haven effect implies that stringent domestic environmental regulations could lower a country's revealed comparative advantage in pollution-intensive manufacturing industries. However, the results from the full sample in Column (1) and Column (3) show no evidence that environmental regulations significantly impact a country's manufacturing RCA. Similarly, no significant effect is found from the IV regression results shown in Column (2) and Column (4).[13] Two subsamples of 1995-2000 and 2004-2009 are used to check robustness, and the results confirm the finding from the full sample.

4.3 Discussions

[13] Only results from the second stage are shown in Table 3 Column (2) and Column (4). The first-stage regression results are omitted, because they are identical to Column (2) in Table 2.

Overall, results from the regression analyses do not show robust evidence that the stringency of environmental policies can significantly impact outsourcing and revealed comparative advantage in manufacturing industries in global value chains. There are many reasons why we don't find a pollution haven effect in international trade (Brunnermeier and Levinson 2004). First, if the cost of complying with environmental regulations is only a small fraction of a polluting firm's total cost, but the relocation cost is high, the firm would have little incentive to relocate to countries with less stringent regulations. Second, environmental regulations can motivate polluting firms to innovate (Porter and van der Linde 1995). If the efficiency gain from innovations is large enough and the net gain from environmental regulations is positive, firms will have little incentive to relocate. Third, regulators may offer subsidies to firms that can offset the cost increase caused by environmental regulation. Fourth, other factors such as capital intensity, industrial mobility, endowment, and trade policies may play a more important role in determining the pattern of trade in "dirty" goods.

5. Conclusions

This paper re-examines the pollution haven effect in global value chains using ICIO data of 1995-2009. A novel instrumental variable – women's political power – is used to address the endogeneity of environmental regulations, and two sub-samples are used to check the robustness of the results. Overall, the regression results do not show that the stringency of environmental regulations can significantly impact manufacturing outsourcing or a country's manufacturing competitiveness in global value chains. However, results from the first stage of the IV regressions show that women's political representation in a country's national parliament has a positive and statistically significant impact on the stringency of a country's environmental policies.

The main policy implication of the research is threefold. First, policymakers are reluctant to tighten domestic environmental regulations because doing so can potentially lower the competitiveness of domestic manufacturing industries in the world market. This paper shows that environmental policy stringency is not a significant determinant of trade patterns in global value chains. Second, it will be necessary to investigate what is truly preventing policymakers from tightening domestic environmental policies. Third, the paper shows that women's political representation is associated with higher stringency of environmental policies. The implication is that social and political reforms such as empowering women and promoting gender equality are essential to improve national and global environmental protection.

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Table 1: Environmental policy stringency and outsourcing (foreign value-added): regression results

	(1) V_{jojd}	(2) $WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$	(3) V_{jojd}
Full sample			
$EPS_{dt}/EPS_{ot}\times EMROW_{jdt}$	-0.00108		0.00520
	(0.00119)		(0.0334)
$WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$		0.0328***	
		(0.00316)	
$\hat{e}_{jodt}$			-0.00630
			(0.0335)
Observations	182207	182700	182207
1995-2000			
$EPS_{dt}/EPS_{ot}\times EMROW_{jdt}$	0.00748**		0.102
	(0.00251)		(0.0626)
$WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$		0.0144***	
		(0.00213)	
$\hat{e}_{jodt}$			-0.0942
			(0.0624)
Observations	72848	73080	72848
2004-2009			
$EPS_{dt}/EPS_{ot}\times EMROW_{jdt}$	0.000734		-0.00233
	(0.00136)		(0.0273)
$WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$		0.0457***	
		(0.00660)	
$\hat{e}_{jodt}$			0.00307
			(0.0275)
Observations	72848	73080	72848
Country pair-year FE	Yes		Yes
Industry-destination-year FE	Yes		Yes
Industry-origin-year FE	Yes		Yes
Industry-destination-origin FE	Yes		Yes
Origin-year FE		Yes	
Destination-year FE		Yes	
Industry-year FE		Yes	

Notes. Column 1 and Column 3: Dep Var = Value of final good originating from the same industry in a foreign country. Column 2: Dep Var = Ratio of the percentage of women in national parliaments × percentage of air emission-generating energy in total energy use in the rest-of-the-world by industry. Observations that have missing values are excluded. Robust standard errors in parentheses are clustered by country pair × industry. Significance levels: * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 2: Environmental policy stringency and outsourcing (percentage of foreign value-added): regression results

	(1) OUT_{jdt}	(2) $EPS_{dt} \times EMROW_{jt}$	(3) OUT_{jdt}
Full sample			
$EPS_{dt} \times EMROW_{jt}$	-0.00856		0.0783
	(0.00943)		(0.0400)
$WOMEN_{dt} \times EMROW_{jt}$		0.0234^{***}	
		(0.00452)	
$\hat{e}_{jdt}$			-0.0906^{*}
			(0.0445)
Observations	6299	6300	6299
1995-2000			
$EPS_{dt} \times EMROW_{jt}$	-0.0106		0.157
	(0.0159)		(0.0814)
$WOMEN_{dt} \times EMROW_{jt}$		0.0172^{***}	
		(0.00255)	
$\hat{e}_{jdt}$			-0.184^{*}
			(0.0834)
Observations	2520	2520	2520
2004-2009			
$EPS_{dt} \times EMROW_{jt}$	-0.00796		0.0315
	(0.00600)		(0.0583)
$WOMEN_{dt} \times EMROW_{jt}$		0.0176^{***}	
		(0.00392)	
$\hat{e}_{jdt}$			-0.0401
			(0.0592)
Observations	2519	2520	2519
Country-year FE	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes
Industry-country FE	Yes	Yes	Yes

Notes. Column 1 and Column 3: Dep Var = Percentage of foreign value-added from the same industry as the final good. Column 2: Dep Var = Percentage of women in national parliaments × percentage of air emission-generating energy in total energy use in the rest-of-the-world. Observations that have missing values are excluded. Robust standard errors in parentheses are clustered by country × industry. Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3: Environmental policy stringency and revealed comparative advantage: regression results

	Factor income-based		Net Domestic Value-based	
	(1)	(2)	(3)	(4)
	$RCAINCadj_{jot}$	$RCAINCadj_{jot}$	$RCADVAadj_{jot}$	$RCADVAadj_{jot}$
Full sample				
$EPS_{ot} \times EMROW_{jt}$	0.159	0.649	-0.00377	0.760
	(0.0904)	(0.359)	(0.115)	(0.454)
$\hat{e}_{jot}$		-0.511		-0.796
		(0.357)		(0.441)
Observations	6285	6285	6289	6289
1995-2000				
$EPS_{ot} \times EMROW_{jt}$	-0.0819	-0.454	-0.155	0.00537
	(0.157)	(0.534)	(0.149)	(0.681)
$\hat{e}_{jot}$		0.410		-0.177
		(0.522)		(0.691)
Observations	2512	2512	2508	2508
2004-2009				
$EPS_{ot} \times EMROW_{jt}$	0.0220	0.236	-0.0261	1.093
	(0.0510)	(0.461)	(0.0745)	(0.617)
$\hat{e}_{jot}$		-0.217		-1.137
		(0.468)		(0.624)
Observations	2514	2514	2520	2520
Country-year FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes
Industry-country FE	Yes	Yes	Yes	Yes

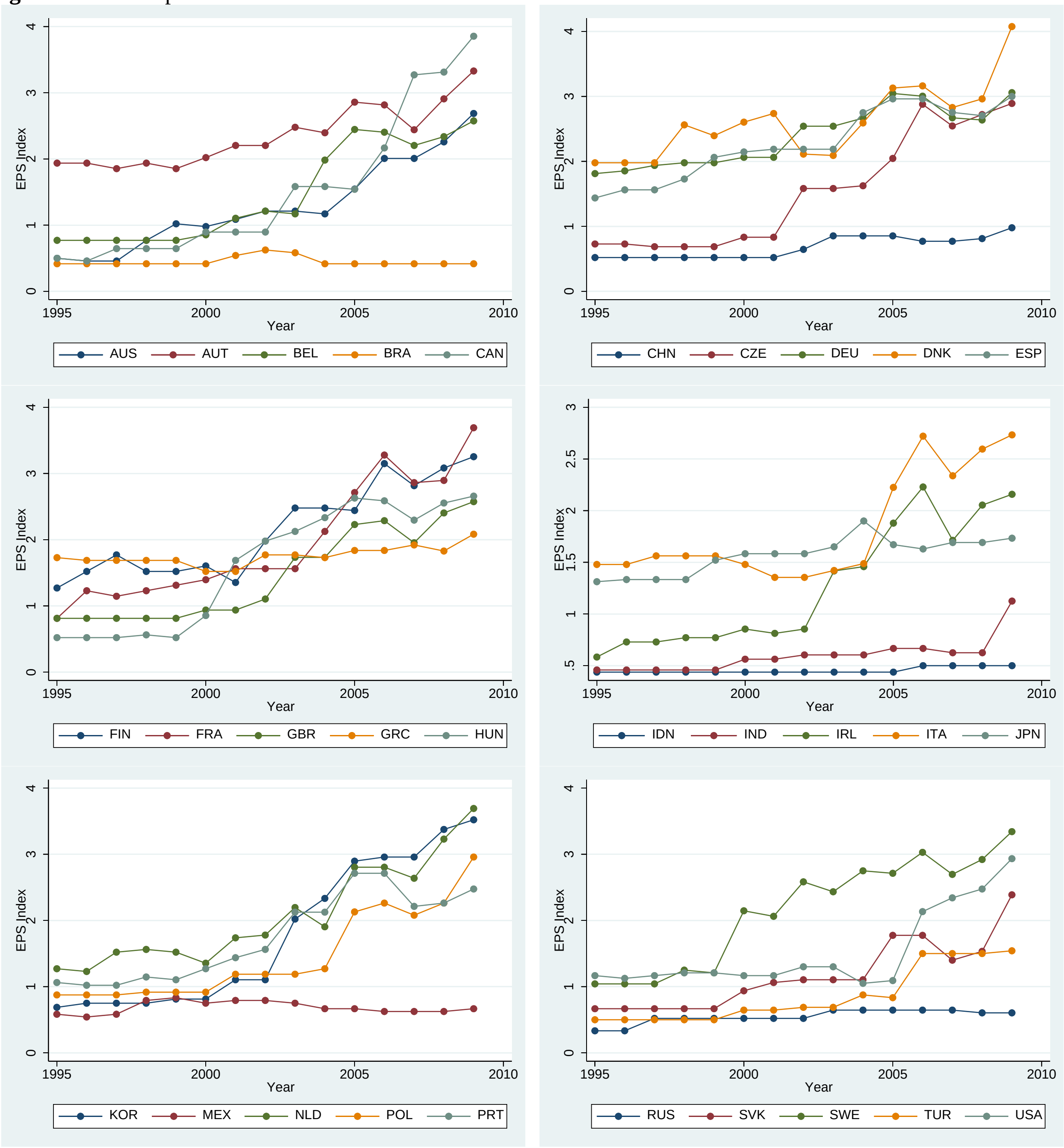
Notes. Column 1 and Column 2: Dep Var = Transformed RCA index based on factor income in global value chains. Column 3 and Column 4: Dep Var = Transformed RCA index based on net domestic value added in gross exports. Observations that have missing values are excluded. Robust standard errors in parentheses are clustered by country × industry. Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix A. Supplemental data and figures

Table A1: Descriptive statistics

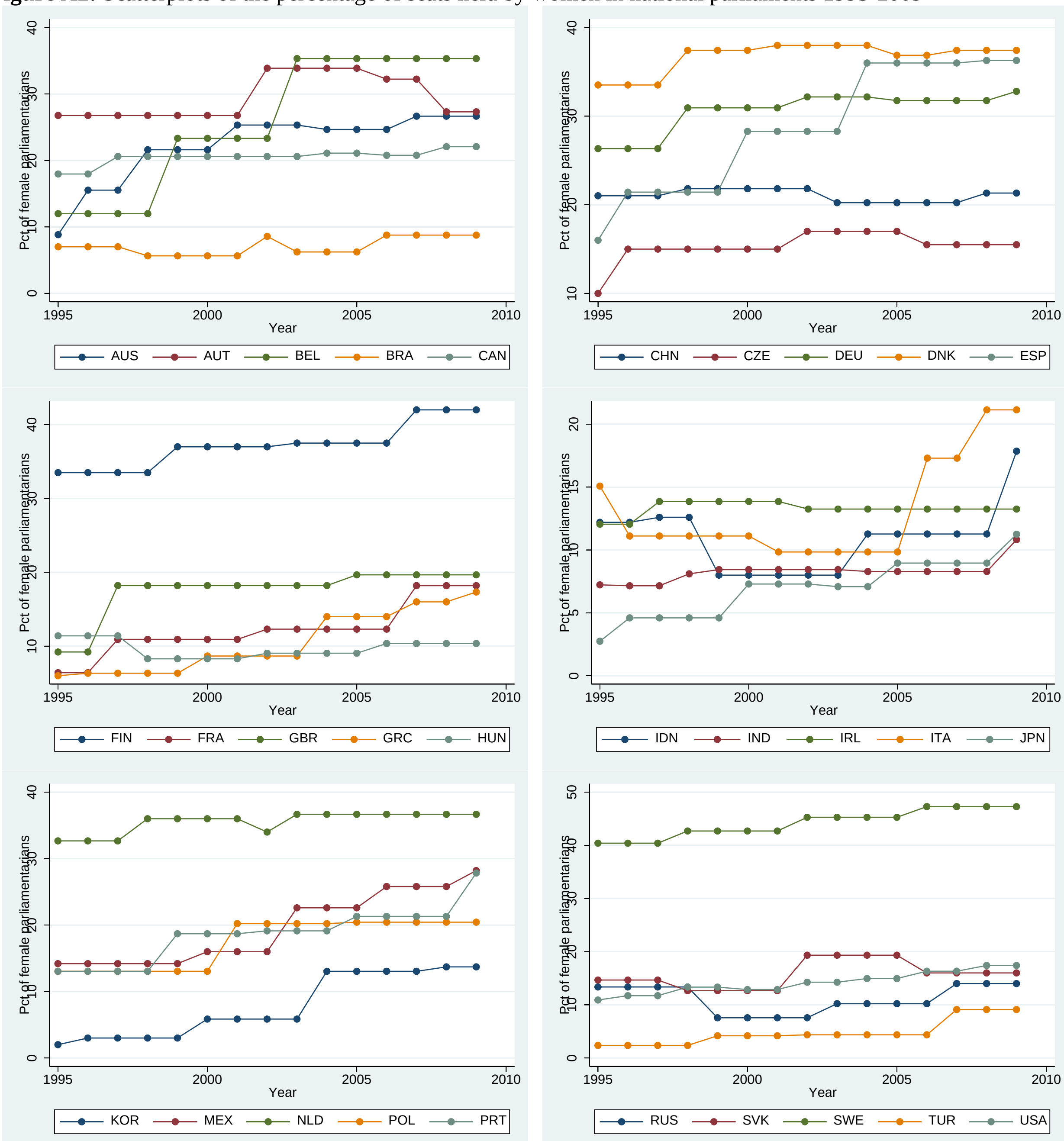
	Observations	Mean	S.D.	Min.	Max.
Table 1 (full sample)					
V_{jojd}	182,265	12.9139	94.12131	0	6166.788
$EPS_{dt}/EPS_{ot}\times EMROW_{jt}$	182,700	109.2618	94.75362	6.999043	920.4393
$WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$	182,700	119.4034	126.1251	3.534235	1871.095
Table 1 (1995-2000)					
V_{jojd}	72,848	10.09504	74.62005	7.17e-06	5602.917
$EPS_{dt}/EPS_{ot}\times EMROW_{jt}$	73,080	105.2212	79.54884	10.87636	579.1866
$WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$	73,080	130.788	156.537	3.534235	1871.095
Table 1 (2004-2009)					
V_{jojd}	72,906	16.7302	115.2592	0	6166.788
$EPS_{dt}/EPS_{ot}\times EMROW_{jt}$	73,080	116.8046	114.5718	6.999043	920.4393
$WOMEN_{dt}/WOMEN_{ot}\times EMROW_{jt}$	73,080	108.1828	91.7387	6.196608	1009.291
Table 2 (full sample)					
OUT_{jdt}	6,299	3.2729	3.215449	.0093273	20.82284
$EPS_{dt}\times EMROW_{jt}$	6,300	122.1166	70.22709	23.66389	383.5164
$WOMEN_{dt}\times EMROW_{jt}$	6,300	1527.577	889.6209	142.7872	4472.149
Table 2 (1995-2000)					
OUT_{jdt}	2,520	3.208548	3.144884	.0093273	20.8027
$EPS_{dt}\times EMROW_{jt}$	2,520	84.10601	43.84275	23.66389	241.3277
$WOMEN_{dt}\times EMROW_{jt}$	2,520	1338.498	837.5786	142.7872	3965.971
Table 2 (2004-2009)					
OUT_{jdt}	2,519	3.327291	3.298382	.0339398	20.82284
$EPS_{dt}\times EMROW_{jt}$	2,520	165.4455	75.77726	27.97388	383.5164
$WOMEN_{dt}\times EMROW_{jt}$	2,520	1721.857	893.4468	292.9629	4472.149
Table 3 (full sample)					
$RCAINCadj_{jot}$	6,285	1.822856	26.23925	-88.59908	75.57949
$RCADVAadj_{jot}$	6,289	-9.025437	36.63057	-100	79.07862
Table 3 (1995-2000)					
$RCAINCadj_{jot}$	2,512	2.484123	25.44502	-88.59908	73.44331
$RCADVAadj_{jot}$	2,509	-8.319078	36.13534	-97.03481	79.07862
Table 3 (2004-2009)					
$RCAINCadj_{jot}$	2,514	.6538354	27.08677	-77.86648	75.57949
$RCADVAadj_{jot}$	2,520	-9.782039	37.14433	-100	77.7456

Figure A1: Scatterplots of EPS index 1995-2009



Sources. OECD Environmental Policy Stringency Index 1990-2015.

Figure A2: Scatterplots of the percentage of seats held by women in national parliaments 1995-2009



Sources. Inter-Parliamentary Union Historical Data on Women in National Parliaments 1945-2018.

Appendix B. Methodology

B.1 decomposing the value of final goods

The WIOD comprises 35 industries and 40 countries plus a model of the rest-of-the-world (Timmer, Dietzenbacher, Los, Stehrer and de Vries 2015). For each year, we can describe the main structure of the input-output tables using four matrices: a 1435×1435 intermediate transaction matrix $\mathbf{Z}$, a 1×1435 value-added vector $\mathbf{U}$, a 1435×1 gross output vector $\mathbf{X}$, and a 1435×1 final good vector $\mathbf{Y}$. Additionally, we can obtain a 1435×1435 direct requirement matrix $\mathbf{A}$ by dividing the entries of $\mathbf{Z}$ by the entries of $\mathbf{X}$. In input-output analysis, all outputs must either be used either as intermediate inputs or final demand (Miller and Blair 2009). Using matrix notations, we can express this condition as $\mathbf{X} = \mathbf{AX} + \mathbf{Y} = (\mathbf{I}-\mathbf{A})^{-1}\mathbf{Y}$. In the second identity, $(\mathbf{I}-\mathbf{A})^{-1}$, known as the Leontief inverse matrix, shows the total inputs directly and indirectly required to produce one unit of an industry's output. The Leontief inverse matrix will be used to decompose the value of final goods in global value chains:

$$\mathbf{V} = \hat{\mathbf{U}}(\mathbf{I}-\mathbf{A})^{-1}\hat{\mathbf{Y}}. \cdots \text{(B1)}$$

In Equation (B1), $\hat{\mathbf{U}}$ is a diagonal matrix, in which the main diagonal elements are the value-added to gross output ratios by industry and country. $\hat{\mathbf{Y}}$ is also a diagonal matrix, in which the elements of the main diagonal are the value of final goods by industry and country. In essence, the calculation traces all the value absorbed in an industry's final good to where they first originate in the global value chains (Johnson 2018). The entries of the resulting matrix $\mathbf{V}$ correspond to V_{iojd} in Equation (1) and Equation (2).

B.2 Calculating net domestic value-added in gross exports

In WIOD, the direct requirement matrix $\mathbf{A}$ comprises a series of submatrices. Each submatrix $\mathbf{A}_{od}$ identifies intermediate linkages within a country (if $d=o$) and between two countries (if $d\neq o$). Using $\mathbf{A}_{oo}$, we can obtain a "local" Leontief inverse matrix $(\mathbf{I}-\mathbf{A}_{oo})^{-1}$. Then, we can calculate the net domestic value-added embodied in country o's gross exports using the following equation:

$$\mathbf{NDVA}_o = \hat{\mathbf{U}}_o(\mathbf{I}-\mathbf{A}_{oo})^{-1}\mathbf{E}_o. \cdots \text{(B2)}$$

In Equation (B2), $\hat{\mathbf{U}}_o$ is a diagonal matrix, in which entries on the main diagonal are country o's value-added to output ratios. $\mathbf{E}_o$ contains country o's gross exports by industry. The resulting vector $\mathbf{NDVA}_o$ shows the net domestic value-added in country o's gross exports by industry, i.e., $NDVA_{jo}$ in Equation (4). The calculation is done with the icio statistical package developed by Belotti, Borin and Mancini (2020) and Borin and Mancini (2019).