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Fluctuations in renewable electricity supply: Gains from international trade through infrastructure?

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Fluctuations in renewable electricity supply: Gains from international trade through infrastructure?

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Abstract 113 countries report producing electricity from non-hydro renewable sources and thereby participate in the global energy transition. This paper shows through a dynamic panel data analysis that imports of electric currents have increased and exports have decreased through the higher share of renewables in electricity production, controlling for other factors. On the one hand more cables have been built recently; but on the other hand some countries are blocking electricity shocks technologically as they suffer from free trade temporarily when receiving supply shocks. This shows that trade currently helps dealing with fluctuations of supply, but temporary losses for recipients of shocks may require payments to leave the borders open.

Keywords: Gains from trade, electric current, gravity, infrastructure. JEL-codes: F14, 15, 18, 59; H54.

Introduction

In simple market models with demand falling and supply increasing with higher prices, a negative shock to the supply function as in a bad harvest increases the price. This insures the supplier against a loss of income and spreads the damage over all subjects on the demand side. This describes the insurance function of the market system. However, Newbery and Stiglitz (1984) show that international trade in the good in question undermines this insurance function if the supply shocks of the countries are not perfectly positively correlated and the otherwise identical economies lack a complete set of risk markets. In this case, the second country has a positive or less negative supply shock decreasing the prices. Therefore with international trade, the country with the lower price undermines the insurance mechanism of the country with the higher price. Producers of one country always loose through trade; consumer loose if they are highly risk averse only because trade reduces prices and reliefs the burden of insuring farmers. If consumers are not worse off, trade is re-distributing against the farmers in the country with reduced insurance.[1] In the case of interest in this paper, international trade in electric current, neighbouring countries' supply shocks are imperfectly positively correlated and therefore international trade could undermine insurance against fluctuations in prices of electricity and revenue of suppliers. In particular, the country with more renewables has the higher price under negative shocks and gets undermined by the prices of other countries with less renewables. In contrast, in case of a positive shock the country with more renewables has a lower price and undermines the insurance of the other countries. Those who get less insurance under trade are interested in curtailing trade temporarily for the length of the shock effect. This question of the impact of renewables on prices and income under uncertainty has been widely ignored in the debate on the transition to renewable energy.[2] In contrast, emphasis was put

[1] Results indicated here hold for price elasticity near unity. Newbery and Stiglitz (1984) discuss modifications in greater detail.

[2] This effect of a shock has to be distinguished from that of renewables structurally being must-run technologies because of the very low marginal costs serving the users with a lower price in the absence of shocks; this could be captured by endowment theory.

on supply security through dampening of supply fluctuations. However, the stability of prices and income may be relevant because concerns regarding stability of prices and revenues may be the reasons why some countries block electricity inflows at the borders.[3]

For both uncertainty questions it is important to get to know what the impact of renewables on exports and imports of electric currents is. If peaks in electricity production are most important in the yearly average of electricity production then a higher share of electricity from renewables should lead to more exports and less imports. If, however, periods of shortages of electricity supply are dominant, a higher share of renewables should lead to more imports and less exports of electricity. In both cases there should be an impact of the share of renewable sources on the volume of trade in electric current in a gravity equation estimate. We test this latter property and the sign of the regression coefficients for bilateral trade data.

Data

We take yearly data on international trade in electric currents from the WITS data base at wits.worldbank.org, SITC4, product code 350. These are data in terms of US $1000. Although the electric currents go through trans-border cables, the trading partner of the two countries on each side of the border may be a third country buying from one country and selling to the other. The data are those of contracts for buying and selling rather than electric currents measured at cables. For example, Serbia reports having 54 trading partners, Jamaica 56 and the Netherlands 95. Obviously these are more trading partners than neighbouring countries with common borders and therefore our test is somewhat indirect. Before having a bilateral panel set of data with country pairs as cross-section units, we have to eliminate those where the partners are free zones (code FRE), special categories (SPE), 'other Asia' (OAS), unspecified (UNS), bunkers (BUN) or holy see, the latter because there are no GDP data which are needed for the gravity equation.

Electricity from renewable sources is measured as 'Electricity production from renewable sources, excluding hydroelectric (% of total)'. Data are taken from World Development Indicators. They mostly go only until 2014 at the moment of downloading. They are denoted as *RNR* and *RNP* for the reporting and the partner country respectively. 113 of 217 countries have at least one positive value. The transition to non-hydro renewables is really global and therefore the questions of this paper are not limited to the EU transition.

The GDP variable is a standard control variable in gravity equations. GDP data are taken from the World Development Indicators. Bilateral country pairs as cross-section units, abbreviated as double index ij, indicate reporting country i and partner country j. There are data from 737 bilateral country pairs reported by exporting countries and from 619 country pairs reported by importing countries. Although each exporter has an importing counterpart these importers seem to report less or less detailed than the exporters. In total 969 different bilateral pairs ij are reported by either exporting or importing countries. In line with the indices we have two GDP variables, those of the reporting country i and those of the partner country j. Non available and zeros exist both.

[3] Janda et al. (2017) describe the problem intuitively and with data for certain weeks and with a model for given capacity choosing production of plants and demand of users.

Distance data for country pairs *ij* are taken from DIST_CEPII.XLS (Mayer and Zignagno 2011). As Serbia and Montenegro are one country there, Yugoslavia, we add the information for the two countries separately.

Econometrics

As exporters and importers of electric current report very asymmetrically leading to very different numbers of observation, we run regressions for imports and exports separately, denoted as *ecex* and *ecim*. We follow the general advice of Wooldridge (2013) to include a lagged dependent variable. With fixed effects the coefficient of the lagged dependent variable would be biased downward by an order of magnitude of *1/T* (Baltagi 2008, chap.8; Judson and Owen 1999). This bias would also have an impact on the other coefficients of interest (Bruno 2005), in our case the effect of renewable electricity. One approach would be to take first differences to get rid of the fixed effects leading to the Anderson-Hsiao estimator, which however is inefficient and leads to too many rejections of regressors. Use of instrumental variables in a GMM estimator by Arellano and Bond (1991) using differenced variables avoids the inefficiency but has weak small sample performance. Blundell and Bond (1998) combine the first-difference approach using lagged levels as instruments with a level equation using lagged first differences as instruments. By construct, whenever one of these has weak instruments the other must have strong instruments. Monte-Carlo studies show that this estimator performs well under conditions of panel homogeneity. This approach is called system GMM and it is the adequate method to estimate a gravity equation as regression for trade volumes (Baltagi et al. 2015). If the differenced equation in system GMM is replaced by orthogonal deviations (see Arellano and Bover 1995; Cameron and Trivedi 2005, chap. 22.4) we have a second version of GMMSYS, which may be advantageous in regard to missing observations (Roodman 2009).[4] Time dummies are included as a measure against cross-section dependence.

Results

For the equation for electricity imports we find (not reporting fixed effects; p-values in parentheses)

LOG(1+ECIM) =
5.76 + 0.357LOG(1+ECIM(-1)) + 0.935(LOG(1+RNR)-LOG(1+RNR(-1)) -0.24LOG(1+RNP)
(0.0004) (0.0009) (0.0837)

Period: 2009-2014; country pairs: 294; obs: 1149; s.e.e: 1.24; Instr.rank: 15; J-stat. = 13.44; p(J) = 0.036. Country and period fixed effects; constant retrieved as $\bar{\bar{y}} - \bar{\bar{x}}\beta$.[5] Estimation method: Panel GMM with orthogonal deviation transformation.[6]

Statistically insignificant regressors have been dropped. The interpretation of this equation for electricity imports of the reporting country is as follows. One percent more renewable electricity of the partner country leads to 0.24 percent less imports of electricity. The sign indicates that periods of

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[4] The moment condition for first differences, $E[z_{is}\, d\varepsilon_{it}] = 0$ for $s \leq t$, is replaced by $E[z_{is}(\varepsilon_{it} - \bar{\varepsilon}_i^F)] = 0$ for $s \leq t$, where $\bar{\varepsilon}_i^F$ is the average over all future residuals.
[5] See Greene (2003), p.291, formula 13-17, with x including the lagged dependent variable.
[6] 2SLS instrument weighting matrix; Cross-section weights (PCSE) standard errors & covariance (d.f. corrected); Instrument specification: (LOG(1+ECIM) with lag -2), LOG(GDPR), LOG(1+RNR)-LOG(1+RNR(-1)), LOG(1+RNP), time dummies.

low renewable electricity production dominate in the partner country and therefore they export less during a year when they have more renewable electricity. For renewable electricity of the reporting country we find that only its change is statistically significant. A higher growth rate translates almost one-to-one into more imports. This again indicates that for trade in electricity the periods of low renewable electricity production during a year are more important than those of high production. Under low electricity production, trade undermines the insurance function here when the correlation of shocks is negative or imperfectly positive. Gains from trade in regard to income stability can then only be positive if the economies are not identical up to the shock as they are in the Newbery-Stiglitz model or if sufficient insurance can be bought. In contrast, from the point of view of secure electricity supply trade is helpful.

The equation for electricity exports is as follows (not reporting fixed effects; p-values in parentheses):

LOG(1+ECEX) = -8.44 + 0.4LOG(1+ECEX(-1)) + 0.523LOG(GDPR) - 0.62LOG(1+RNR) +
(0.000) (0.15) (0.019)

0.524LOG(1+RNP) + 0.398LOG(1+RNR(-1)) - 0.433LOG(1+RNP(-1))
(0.0254) (0.16) (0.0784)

Period: 2009-2014; country pairs: 306; obs: 1191; s.e.e = 1.21; Instr rank: 26; J-stat = 24.79; p(J) = 0.037. Country and period fixed effects; constant retrieved as $\bar{\bar{y}} - \bar{\bar{x}}\beta$.[7] Estimation method: Panel GMM with orthogonal deviation transformation.[8]

We have included some regressors with low statistical significance because dropping them leads to a larger standard error of the regression and a lower p-value for the Hansen-Sargan J-statistic, which indicates mis-specification when dropping these regressors. A larger GDP of the reporting country leads to more electricity exports, perhaps because electricity production grows in proportion with the GDP and includes larger safety margins in the reserves (Droste-Franke et al. 2012). More renewable electricity of the reporting country leads to less exports in the same year and to more exports in the next year, where the latter effect is smaller. Again, more renewables implies not mainly peak supply but rather dominating weak supply of electricity during the year, leading to low exports. More renewable electricity of the partner country leads to more electricity exports in the same year, and less in the next year, where the lagged effect is again smaller. Again, with more renewables the dominating effects are sub-periods of low electricity production dominating the sub-periods of much electricity production. Export reductions mitigate the problem of weak supply and thereby contribute to energy supply security and reduce the undermining of the insurance function abroad.

Conclusion

Having about 300 country pairs in the regressions implies that there are many countries in a transition to renewable electricity. GDP variables play a limited role. Only the GDP of the reporting

[7] See Greene (2003), p.291, formula 13-17, with x including the lagged dependent variable.
[8] 2SLS instrument weighting matrix; Cross-section weights (PCSE) standard errors & covariance (d.f. corrected); Instrument specification: (LOG(1+ECEX),with lags -2 to -4), LOG(GDPR), LOG(1+RNR), LOG(1+RNP), LOG(1+RNR(-1)), LOG(1+RNP(-1)).

country is significant in the import equation. Standard time-invariant gravity arguments such as distance, neighbouring countries and being part of a former same country cannot be included in the dynamic fixed effects approach. Using the Mundlak random effects approach in a static model, Gethmann et al. (in preparation) show that the standard conventional results of gravity equations hold: distance reduces electricity trade, being a neighbouring country increases it; having been part of the same country reduces it, and all GDP variables matter. However, our dynamic extension shows that lagged dependent variables are statistically significant and undermine the role of most GDP variables, which is in line with the fact that electricity provision is perfectly aligned with the needs of the economy and this may neutralise excess supply changes. The signs of the impact of renewable electricity on the volumes of export and import of electricity suggest that sub-periods of a year of low supply of electricity are dominating those of high production of electricity. Countries use more imports and export less whenever electricity production is limited by weather conditions: more renewable capacity leads to more imports and less exports. However, this undermines the income insurance function of the domestic market through imports and strengthens it in the other country through reduced domestic exports. In addition to this unclear effect on insurance of income, international trade increases the security of energy supply, because lack of supply is complemented by additional imports and reduced exports. Moreover, trade can be advantageous if countries differ in other aspects than the shocks and/or can buy insurance. In these cases blocking electricity trade at the border is a measure against undermining the income insurance function, which is a disadvantage born by some market participant analogous to distribution effects of trade liberalisation in textbook models. As blocking is not advantageous overall if the insurance effect is relatively small, investment in the extension of the border-crossing system of electricity cables can make the provision of renewable electricity easier and welfare improving. As cables are the cheap part of the electricity system and investment costs are therefore low, international trade helps reducing the costs of the low-carbon economy. Welfare increases if enough insurance against fluctuations exists or a low demand for it and sources of comparative advantage[9] or scale economies exist in addition to enhanced supply security, which is the dominant concern in the debates on the energy transition. Temporary welfare losses - for electricity importing countries at moments of high imports - through undermining the insurance function may require compensations in order to get agreements on investment in border-crossing cables and on free trade in electric currents.

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[9] Differences in stochastic draws of farmers in the two countries are a source of short run comparative advantage in Newbery and Stiglitz (1984) if expected values are equal.

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