Technological Innovation and the Spillover Effects of China's Energy Demand on Belt and Road Economies

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November 25, 2022

Motivation

- Energy is an important input factor for firms and its cost has risen tremendously over the past two decades.
- ***Induced Innovation Hypothesis*** – Sir John Hicks' assertion that changes in relative factor prices should lead to innovations that reduce the need for the relatively expensive factor.
- The induced innovation hypothesis is widely tested in relation to energy related patents.
  [Popp, 2002, Johnstone et al., 2010, Wurlod and Noailly, 2018, Crabb and Johnson, 2010, Triguero et al., 2014, Newell, 2010]

Our Contribution

Limited knowledge about the spillover effects of rising energy demand on innovation in developing countries (generally) and innovation not directly related to energy usage specifically (our focus).

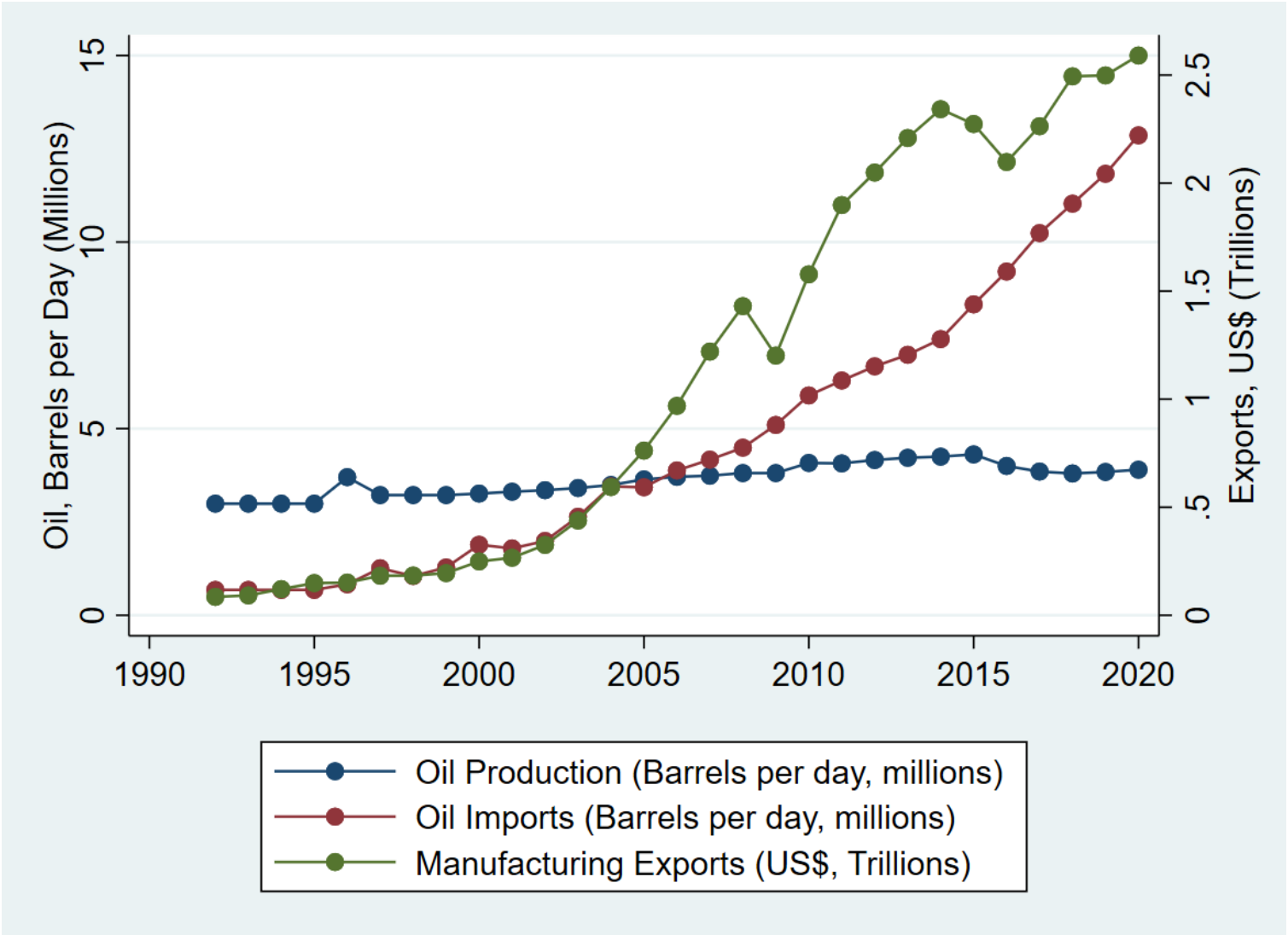
We make three main contributions:

1. We model theoretically how the rise in global energy demand can affect firm-level innovation (similar approach to the **agglomeration** literature, see [Glaeser and Gottlieb, 2009] and [Duranton and Puga, 2004]) and the **energy economics** literature on proximity to oil production and knowledge spillover [Badeeb et al., 2016], [Fang and Chen, 2017], [Lim and Morris, 2022].

2. Empirically, we focus on product and process innovation and not patent counts, the main measure of innovation in the existing literature.

3. We provide new evidence for developing countries.

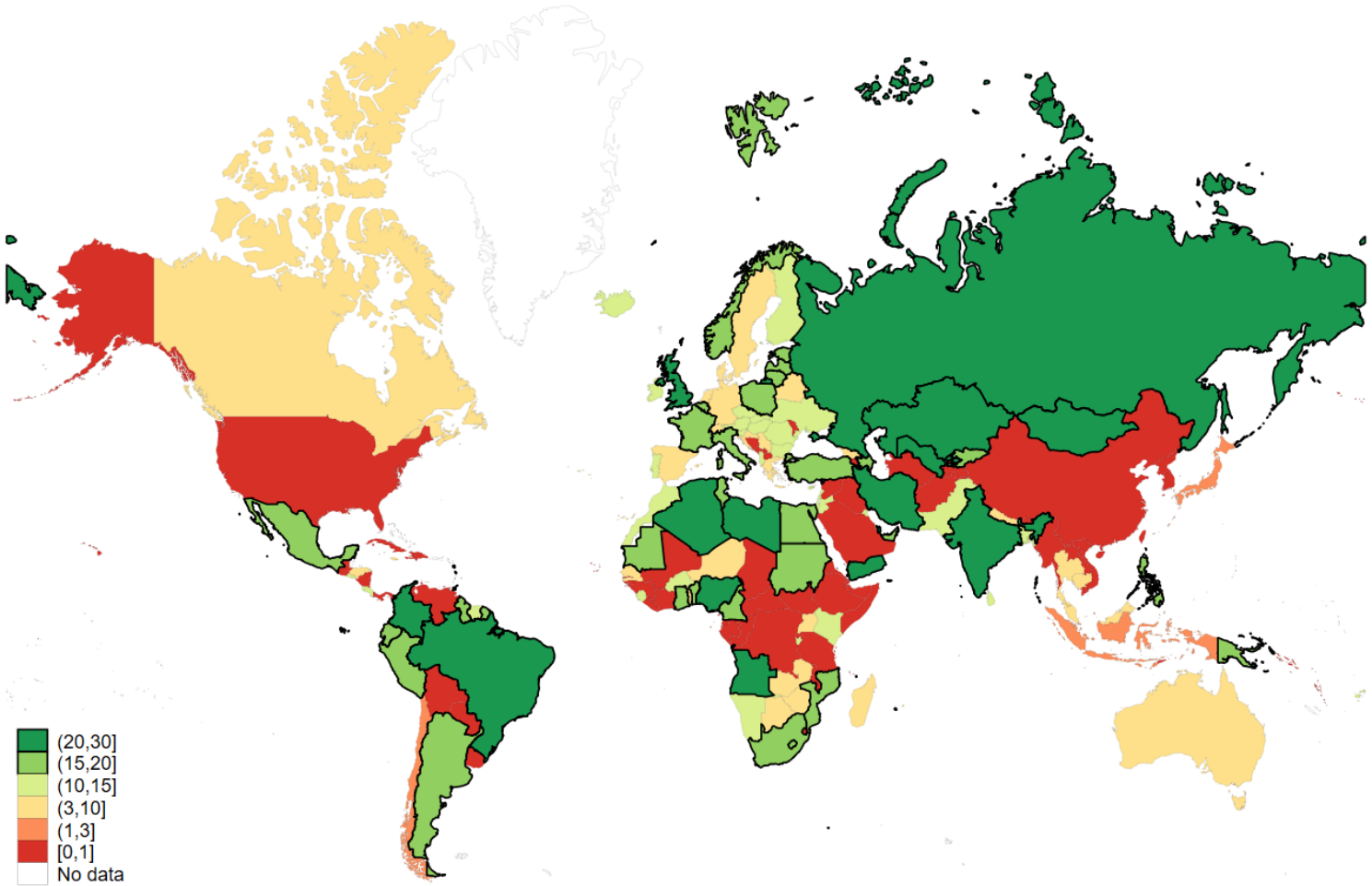
China's Energy Demand



Source: Data on manufacturing exports value are from UN Comtrade. Data on oil imports and production of oil in China are from BP Statistical Review of World Energy.

Change in Energy Exports to China across Countries

In 1992, only 23 countries had positive energy exports to China in 2020 – 85 countries.



Source: UN Comtrade: HS Codes of Chapter 27: Mineral fuels, mineral oils, and products of their distillation; bituminous substances; mineral waxes.

Theoretical Setting

- The central question is whether China is crowding out innovation in the rest of the developing world?

- We differentiate the impact of China's energy demand on small energy exporting and energy importing economies.

Proposition 1: In a small oil exporting economy – the effect of the share of oil exported to China on a domestic firm's innovation engagement depends on the size of the efficiency gains it can make to offset the costs of substituting the source of its energy input.

Proposition 2: In a small oil importing economy – the effect of an increase in China's global energy demand on a domestic firm's innovation depends on the the difference between the magnitude of the competition effect and the energy efficiency effect.

Empirical Strategy – Proposition 1

$$I_{ijct} = \alpha_0 + \alpha_1 \sum_{i}^{N} \frac{EI_i}{EI_j} \left[\Delta EnergyExports_{t-t92}^{c-ch} \right] + \alpha_2 Controls_{ijct} + \varepsilon_{ijct} \quad (1)$$

Where:

- I_{ijct} is the reported innovation of firm i in industry j of country c at time t
- *EnergyExports* is the domestic energy exported to China weighted by firm $i's$ relative energy usage intensity $\frac{EI_i}{EI_j}$. Using 1992 as the base year. So, each firm experiences a different shock when oil is exported to China.
- *Controls* is a battery of firm-characteristic variables, and dummies that capture region - year- income - (industry) - [country] specific fixed effects
- ε is the random error term with the usual properties

Empirical Strategy – Proposition 2

$$I_{ijct} = \beta_0 + \beta_1 \sum_i^N \frac{EI_i}{EI_j} \left[\frac{\Delta M^c}{\Delta M^{Ch\_W}} \right]_{t-t92} + \beta_2 Controls_{ijct} + \varepsilon_{ijct} \qquad (2)$$

Where:

- ΔM^c is the change in imports of energy in country c
- ΔM^{Ch_W} is the change in oil imports in China from the rest of the world.
- Again, using 1992 as the base year.

We will use *EDP* to refer to the relative shock experienced by firm i in country c with increased oil demand in China

Identification

There are at least two endogeneity concerns:

- Measurement and omitted variables issues – bilateral relationships may dictate China's energy policy.
- Simultaneity issue because energy trade may impact innovation but innovation (especially in the energy sector) may drive energy trade.

Solutions:

1. Use an IV approach that builds on the gravity model and instrument *EnergyExports* and *EDP* with the bilateral distance between China and firm *i*.

2. Replace country *c*'s energy trade with China with Russia-China energy trade.

Data

- Firm level data from the World Bank Enterprise Survey (WBES).
- 90 of the 147 countries that have signed a Memorandum of Understanding (MoU) with China as part of the Belt and Road Initiative (BRI).
- 29 countries that export oil to China and 61 non-oil exporting countries in the dataset.
- We combine WBES data with energy data from the United Nations Commodity Trade Statistics Database (UN Comtrade).
- 4 bilateral distance measures matching longitude and latitude as per [Mayer and Zignago, 2011].

Results – Proposition 1

OLS with Energy Exports and Innovation

$$I_{ijct} = \alpha_0 + \alpha_1 \sum_{i}^{N} \frac{EI_i}{EI_j} \left[\Delta EnergyExports_{t-t92}^{c-ch} \right] + \alpha_2 Controls_{ijct} + \varepsilon_{ijct} \quad (3)$$

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
$\Delta EnergyEx.$	0.025***	0.027***	0.001	0.006**	-0.001	0.009***
	(0.006)	(0.006)	(0.003)	(0.002)	(0.003)	(0.003)
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Region FE			✓	✓	✓	✓
Inc FE					✓	✓
N	11726	11726	11726	11726	11726	11726

Control variables: Subsidiary, Managerial Experience, Age, Size (workers and Capital), Technology (Foreign Tech. and Website), Certified Accounts

IV Results – Proposition 1

Energy Exports and Innovation using 3 Distance Measures as Instruments

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
$\Delta EnergyEx.$	0.249***	0.261***	0.250***	0.262***	0.251***	0.262***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
F Stage F	16.314	28.531	28.516	29.236	11.286	93.800
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Reg FE	✓	✓	✓	✓	✓	✓
Inc FE	✓	✓	✓	✓	✓	✓
N	11726	11729	11726	11729	11726	11729

IV Results – Robustness for Proposition 1

Energy Exports and Innovation using 3 Distance Measures as Instruments

Developing Countries Only

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
$\Delta EnergyEx.$	0.225^{***}	0.256^{***}	0.230^{***}	0.256^{***}	0.229^{***}	0.256^{***}
	(0.042)	(0.010)	(0.042)	(0.010)	(0.042)	(0.010)
F Stage F	18.314	22.531	22.516	21.236	12.286	23.800
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Reg FE	✓	✓	✓	✓	✓	✓
Inc FE	✓	✓	✓	✓	✓	✓
N	8339	8339	8339	8339	8339	8339

IV Results – Robustness for Proposition 1

Energy Exports and Innovation using 3 Distance Measures as Instruments

Services Firms Only

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
$\Delta EnergyEx.$	0.253***	0.252***	0.256***	0.253***	0.257***	0.253***
	(0.015)	(0.016)	(0.015)	(0.016)	(0.015)	(0.016)
First Stage F	13.314	23.531	23.516	13.236	13.286	23.800
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Reg FE	✓	✓	✓	✓	✓	✓
Inc FE	✓	✓	✓	✓	✓	✓
N	4527	4532	4527	4532	4527	4532

Results – Proposition 2

IV with Energy Demand Pressure and Innovation

$$I_{ijct} = \beta_0 + \beta_1 \sum_i^N \frac{EI_i}{EI_j} \left[\frac{\Delta M^c}{\Delta M^{Ch\_W}} \right]_{t-t92} + \beta_2 Controls_{ijct} + \varepsilon_{ijct} \qquad (4)$$

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
ΔEDP	0.052***	0.113***	0.051***	0.112***	0.051***	0.111***
	(0.007)	(0.008)	(0.007)	(0.008)	(0.007)	(0.008)
F Stage F	15.314	281.531	26.516	259.236	10.286	93.833
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Reg FE	✓	✓	✓	✓	✓	✓
Inc FE	✓	✓	✓	✓	✓	✓
N	25006	25006	25006	25006	25006	25006

Results with China-World energy trade

Results – Robustness Proposition 2

IV with Energy Demand Pressure and Innovation

China-Russia Trade

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
ΔEDP	0.061***	0.130***	0.059***	0.130***	0.059***	0.128***
	(0.007)	(0.008)	(0.007)	(0.008)	(0.007)	(0.008)
F Stage F	27.875	363.794	44.200	341.751	25.299	162.821
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Reg FE	✓	✓	✓	✓	✓	✓
Inc FE	✓	✓	✓	✓	✓	✓
N	10314	10314	10314	10314	10314	10314

Results – Robustness Proposition 2

IV with Energy Demand Pressure and Innovation

Developing Countries Only

	(1) Process	(2) Product	(3) Process	(4) Product	(5) Process	(6) Product
ΔEDP	0.062***	0.079***	0.059***	0.078***	0.058***	0.076***
	(0.008)	(0.009)	(0.008)	(0.009)	(0.008)	(0.009)
F Stage F	27.875	363.794	44.200	341.751	25.299	162.821
Controls	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓
Reg FE	✓	✓	✓	✓	✓	✓
Inc FE	✓	✓	✓	✓	✓	✓
N	7689	7689	7689	7689	7689	7689

Summary

- We model theoretically how the rise in China's global energy demand influences innovation in other developing countries.
- We focus on countries that are part of China's Belt and Road Initiative (BRI).
- We use an instrumental variables strategy and show there is a positive and robust positive impact of China's increased energy demand on innovation in BRI countries.

Thank You!