

Roads and the Real Exchange Rate

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Introduction

Real exchange rate – a key relative price that affects many other relative prices across countries

Lots of international controversy over its assessment

- Korea
- China

This paper studies the role of infrastructure improvement in affecting the real exchange rate



Our understanding is incomplete yet policy discussions often assume we know the complete model

- Balassa-Samuelson Effect
- Froot-Rogoff Effect
- No one takes ascertaining determinants of the RER more seriously than the IMF due to scrutiny of its work
- Official IMF methodology lists six fundamentals
- Infrastructure is not featured in existing RER models

Policy implications of the infrastructure effect:

- Miscalculations in IMF's exchange rate misalignment analysis?
- Additional ways for improving the external competitiveness for problem countries in a currency union?

Motivation

- The effect of infrastructure improvement on the RER is often neglected yet potentially important
- Costs of transporting goods differ widely across countries/over time
- **Better infrastructure** -> **three channels for lower prices**
-> **lower RER**

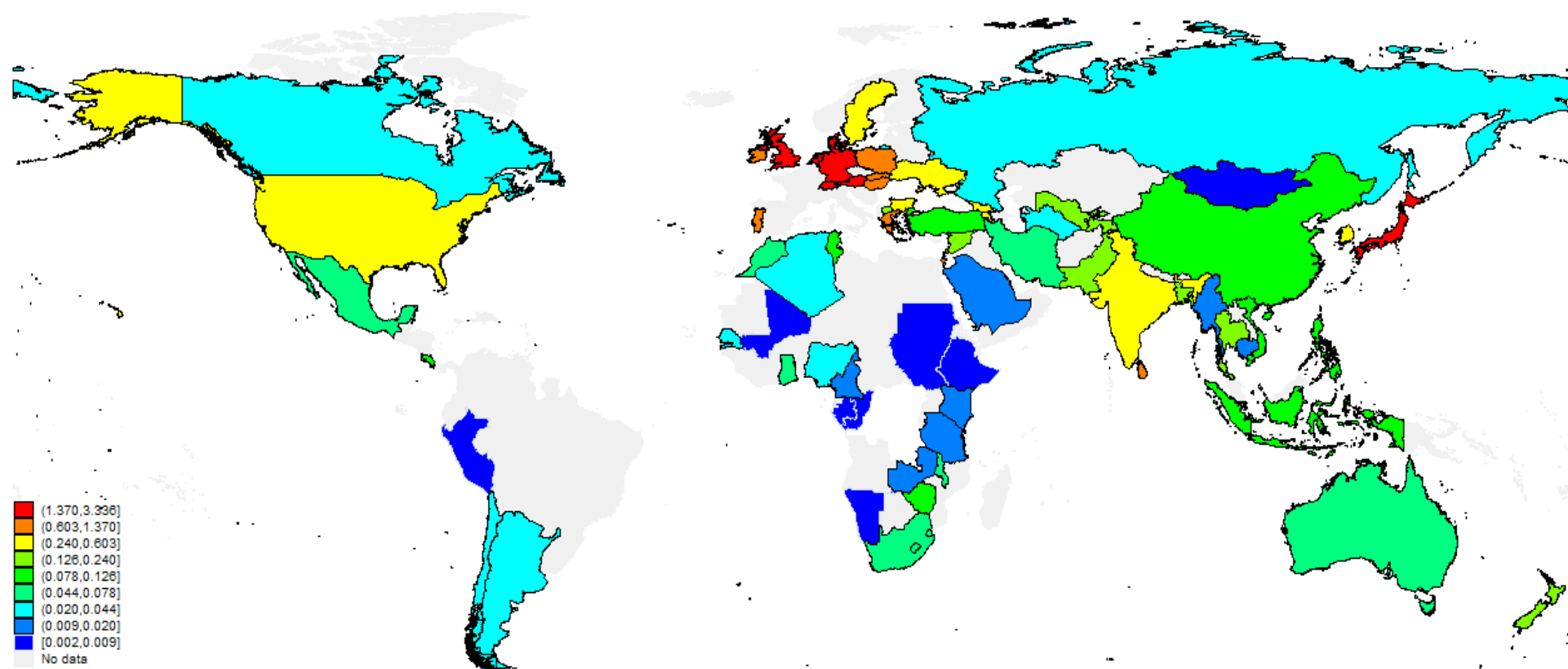


Roadmap for the paper

1. Motivation
2. Theory (abbreviated today)
3. Initial cross country evidence
4. Selecting robust determinants by Bayesian Model Averaging
5. Instrumental Variable Approach
6. Many more robustness checks and Extensions
7. Conclusions

Motivation

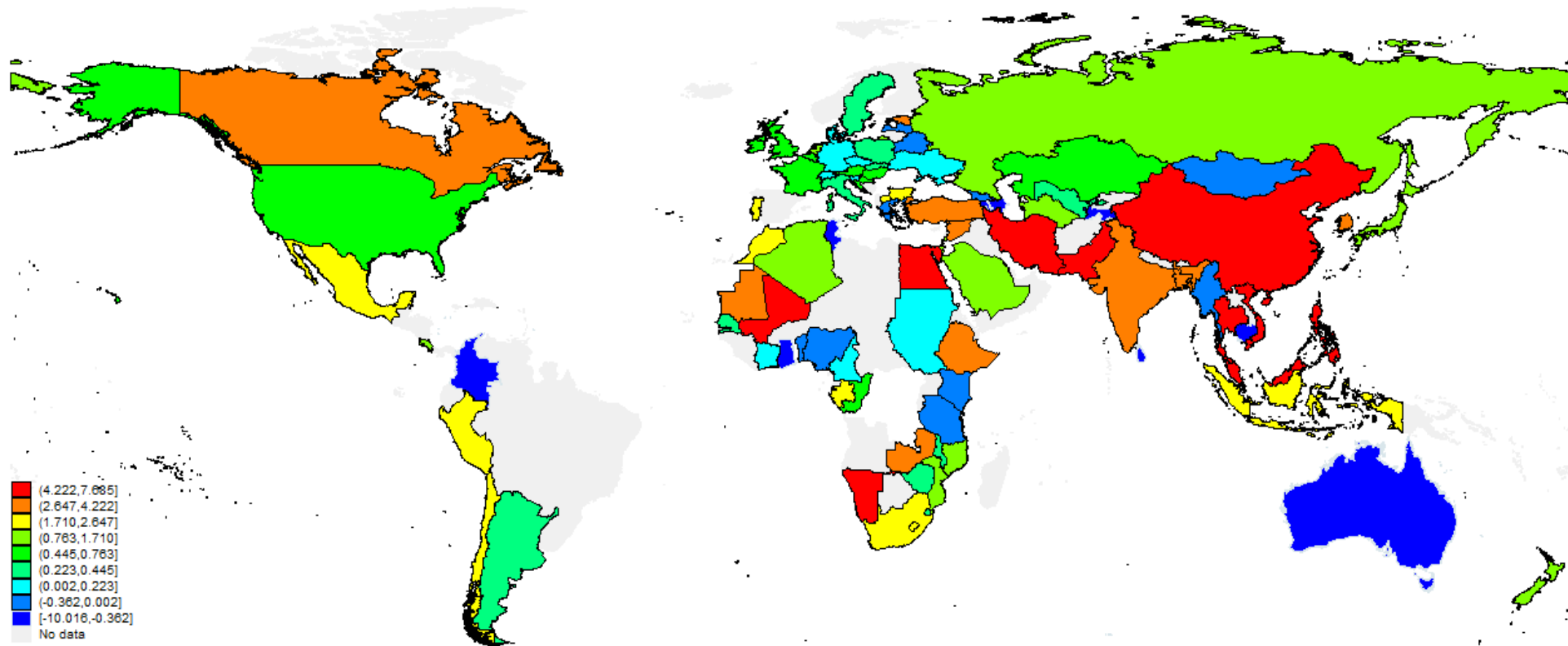
- Large Variations in Road Density in 1995



Data Source: World Bank, International Transport Form, Ministry of Railway and Ministry of Transport of China

Motivation

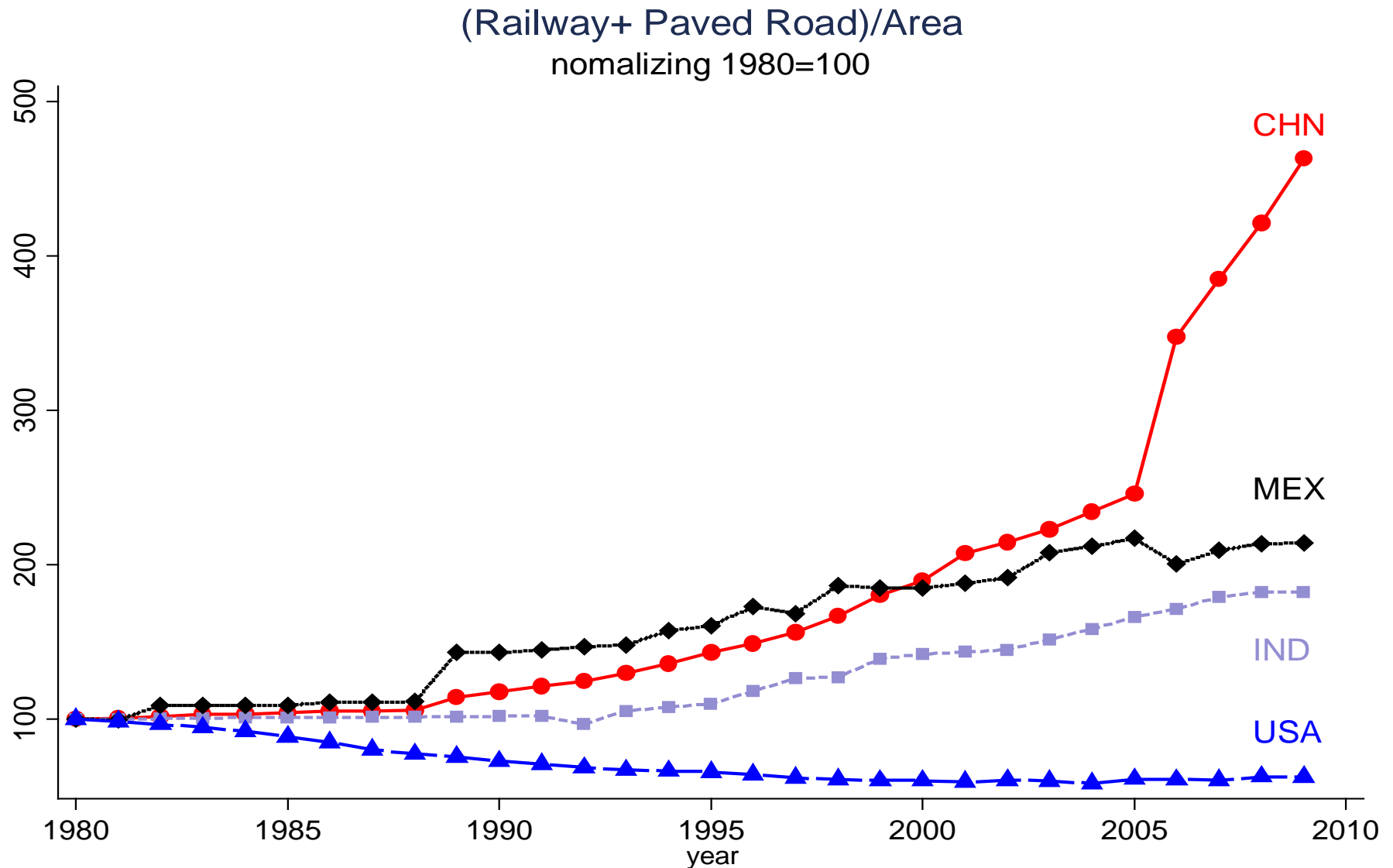
- Average Growth Rates in Road Density (1995-2008)



Data Source: World Bank, International Transport Form, Ministry of Railway and Ministry of Transport of China

Motivation

- Infrastructure Density in Four Countries (1980-2010)



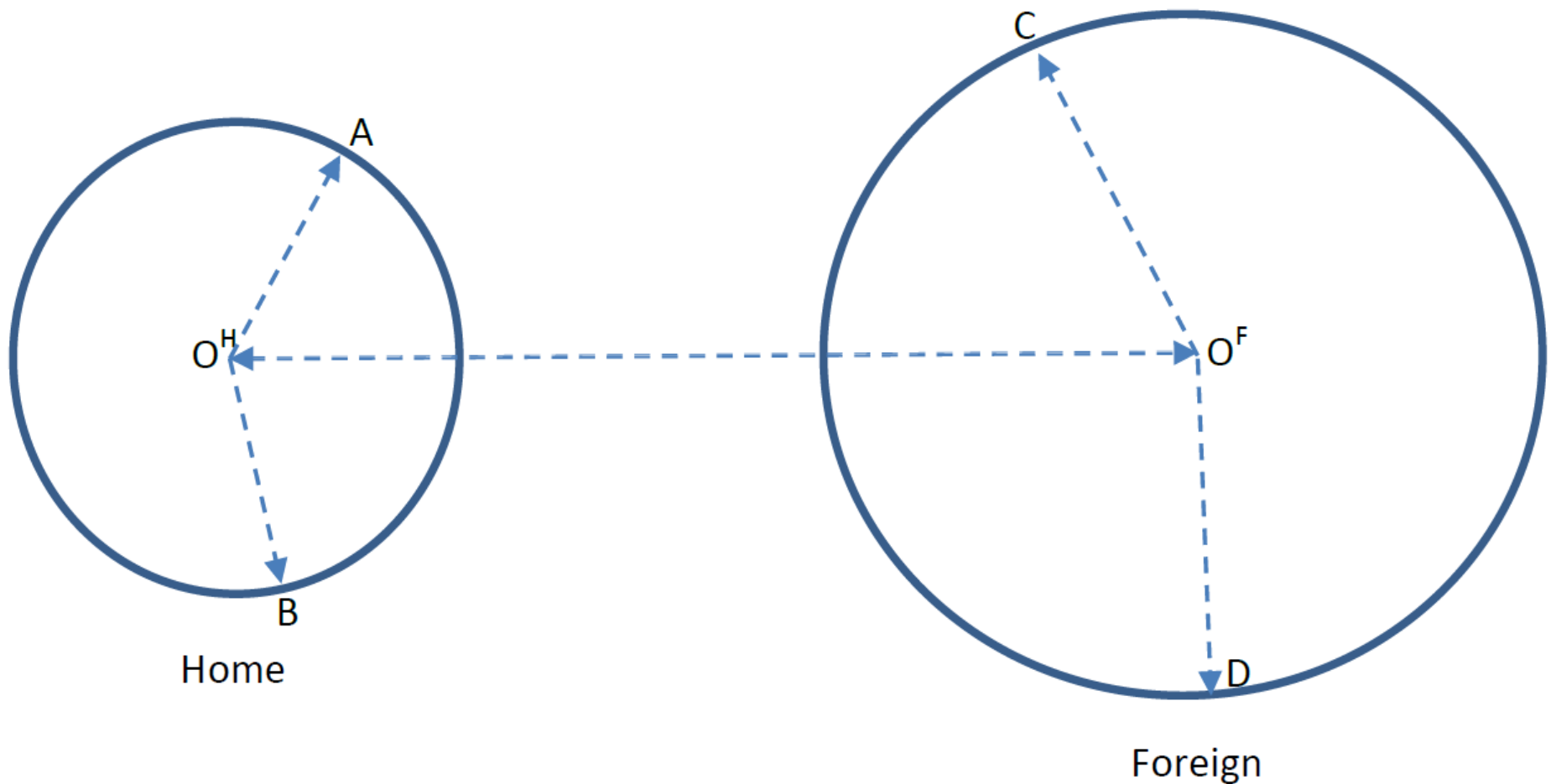
Data Source: World Bank, International Transport Form, Ministry of Railway and Ministry of Transport of China

Model

- Assumptions:

- Two countries: Home, N regions; Foreign, N^* regions
- Modified version of Melitz and Ottaviano (2007)
- Consumers have identical preferences over differentiated varieties
- Heterogeneous firms – differing by (exogenous) productivity
- Improvement in infrastructure is modeled as a reduction in trading costs
- Separate domestic and international trading costs

Two countries: **Home**, N regions; **Foreign**, N^* regions



Model

- Consumer's preference over differentiated varieties

Preference

$$U = q_0^c + \alpha \int_{i \in \Omega} q_i^c di - \frac{1}{2} \gamma \int_{i \in \Omega} (q_i^c)^2 di - \frac{1}{2} \eta \left(\int_{i \in \Omega} q_i^c di \right)^2$$

A linear inverse demand:

$$p_i = \alpha - \gamma q_i^c - \eta Q^c$$

For all surviving firms,

$$p_i \leq \frac{\alpha \gamma + \eta n \bar{p}}{\eta n + \gamma} \equiv p_A^{\max}$$

Model

- Trade Cost

- Labor is the only factor of production
- Numeraire good is produced by one unit of labor and its market is competitive (unit wage)
- Trade cost τ_{kj} : good produced in k and sold in j

$$\tau_{kj} > 1 \text{ if } i \neq j \text{ and } \tau_{kk} = 1$$

- Within-Home trade cost, Home-to-Foreign trade cost, within-Foreign trade cost, Foreign-to-Home trade cost are: $\tau_1, \tau_2, \tau_1^*, \tau_2^*$

Model

- Endogenous Firm Choice of Markets

For a firm that sells goods only locally

$$p_{kk}(c) = \frac{1}{2} (c_D^k + c), \quad q_{kk}(c) = \frac{L_k}{2\gamma} (c_D^k - c), \quad \pi_{kk}(c) = \frac{L_k}{4\gamma} (c_D^k - c)^2$$

For a firm that sells goods in Home region h and Foreign region f

$$p_{kh}(c) = \frac{\tau_{kh}}{2} \left(\frac{c_D^h}{\tau_{kh}} + c \right), \quad q_{kh}(c) = \frac{L_h}{2\gamma} \tau_{kh} \left(\frac{c_D^h}{\tau_{kh}} - c \right), \quad \pi_{kh}(c) = \frac{L_h}{4\gamma} \tau_{kh}^2 \left(\frac{c_D^h}{\tau_{kh}} - c \right)^2$$
$$p_{kf}(c) = \frac{\tau_{kf}}{2} \left(\frac{c_D^f}{\tau_{kf}} + c \right), \quad q_{kf}(c) = \frac{L_f}{2\gamma} \tau_{kf} \left(\frac{c_D^f}{\tau_{kf}} - c \right), \quad \pi_{kf}(c) = \frac{L_f}{4\gamma} \tau_{kf}^2 \left(\frac{c_D^f}{\tau_{kf}} - c \right)^2$$

Model

- Endogenous Firm Choice of Markets

$$c_D^k = p_k^{\max}$$

c_D^k is the cost of a local firm that is just indifferent between exiting and staying in region k 's market

The entry condition for a firm:

$$\sum_{h \in Home} \int_0^{\frac{c_D^h}{\tau_{kh}}} \pi_{kh}(c) dG(c) + \sum_{f \in Foreign} \int_0^{\frac{c_D^f}{\tau_{kf}}} \pi_{kf}(c) dG(c) = f_E$$

Model

- Free Entry Condition

Productivity draw $1/c$ follows a Pareto distribution,

$$G(c) = \left(\frac{c}{c_M} \right)^m, \quad m > 0 \text{ and } c \in [0, c_M]$$

Threshold for firms entry in Home region h and Foreign region f

$$c_D^h = \left(\frac{\gamma\phi}{L_h} \frac{1 - \rho_2 + (N^* - 1)(\rho_1^* - \rho_2)}{(1 + (N - 1)\rho_1)(1 + (N^* - 1)\rho_1^*) - NN^*\rho_2\rho_2^*} \right)^{\frac{1}{m+2}}$$

$$c_D^f = \left(\frac{\gamma\phi}{L_f} \frac{1 - \rho_2^* + (N - 1)(\rho_1 - \rho_2^*)}{(1 + (N - 1)\rho_1)(1 + (N^* - 1)\rho_1^*) - NN^*\rho_2\rho_2^*} \right)^{\frac{1}{m+2}}$$

Model

- Key building blocks for the main proposition

- (i) If the within-Home trade cost τ_1 declines while all other trade costs remain constant, local CPI in any Home region falls. Foreign regional CPI rises.
 - However, the number of entrants from region h may decline because (a) lower trade cost \rightarrow more firms enter the market; and (b) the least productive local firms are crowded out.
- (ii) If the international trade cost from Home to Foreign declines while all other trade costs remain constant, local CPI in any Home region falls. Foreign regional CPI rises. The number of entrants in any particular region may decline.

- From Regional Prices to Home RER

- Regional CPI

$$P_k = \frac{m + 2}{m + 3} c_D^k$$

- National CPI

$$P_H = \sum_{k \in \text{Home}} \frac{L_k}{\sum_{h \in \text{Home}} L_h} P_k$$

- The Home RER

$$RER_H = \frac{P_H}{P_F}$$

Proposition 1: If

$$\max(\tau_1, \tau_1^*) \leq \min(\tau_2, \tau_2^*)$$

under a sufficient condition

$$\frac{\partial \tau_2^*}{\partial \tau_1} \frac{\tau_1}{\tau_2^*} \leq \frac{N-1}{N}$$

we can show that, as τ_1 falls, each Home region experiences a decline in CPI and Home's real exchange rate depreciates.

Profit to sales ratio:

For firms only sell goods locally,

$$r = \frac{c_D^k - c}{c_D^k + c}$$

The ratio declines as the within-Home trade cost falls

For firms sell goods in other Home regions,

$$r = \frac{\frac{L_k}{4\gamma} (c_D^k - c)^2 + \sum_{h \neq k} \max \left(0, \frac{L_h}{4\gamma} \tau_1^2 \left(\frac{c_D^h}{\tau_1} - c \right)^2 \right)}{\frac{L_k}{4\gamma} \left((c_D^k)^2 - c^2 \right) + \sum_{h \neq k} \max \left(0, \frac{L_h}{4\gamma} \tau_1^2 \left(\left(\frac{c_D^h}{\tau_1} \right)^2 - c^2 \right) \right)}$$

Ambiguous effect on the ratio

Mechanisms for better transport infrastructure to reduce RER:

Lower price of outside goods

- **reduces the cost of goods produced and shipped in from outside the region**

The competition effect:

- **introduces competition that in turn reduces the markup in the goods prices**

The input cost effect:

- **reduces the cost of inputs going into the production of local goods** (Appendix E)

The productivity effect:

- **promotes innovation that further reduces the cost** (Appendix D)

Remarks:

- **When purely domestic transport infrastructure improves, the CPI falls, and therefore RER falls**
- **Better infrastructure leads to a fall in prices of both traded and non-traded goods. RER falls because all prices fall.**
Not useful to think of RER as the relative price of non-tradable
- **There are multiple possible channels – we do not pin down the relative importance of the channels**

Roads and RER

- Key International Variables (1980-2009)

Variable Definition	Variable Names	Obs.	Mean	Median	Std. Dev.	Min	Max
REER = Real Effective Exchange Rate, period=1980-2009	Log REER	2710	4.74	4.63	0.55	2.97	15.3
	Change in Log REER	83	-0.40	-0.21	0.83	-6.14	0.58
BERE=Bilateral RER against US\$, period=1980-2009	Log BRER	4276	-3.14	-2.54	2.63	-10.6	3.10
	Change in Log BRER	96	-0.29	-0.33	0.73	-3.11	4.30
Transport Infrastructure=Total Length of (paved roads +railways)/area size, unit=km/km ² , 1980-2009	Infrastructure	2422	0.49	0.21	0.69	0.002	4.09
	Log Infrastructure	2422	-1.93	-1.57	1.86	-6.36	1.41
	Change in Log Infrastructure	56	0.16	0.10	0.38	-0.75	1.53
Transport Infrastructure= Volume of Goods Transported/area size, unit= million ton-km/km ²	Goods Transported	1204	0.35	0.22	0.50	0.0002	6.28
	Log Goods Transported	1204	-1.71	-1.53	1.28	-8.50	1.84
	Change in Log Goods Transported	21	0.53	0.57	0.61	-1.27	1.48

Data Source: International Financial Statistics, World Bank, International Transport Forum, Ministry of Railway of China and Ministry of Transport of China



Start with some initial panel regression results

Specification

- Log RER (j,t) on log infrastructure (j,t), other determinants, and separate country and year fixed effects
- Choice of regressors is guided by the literature (Rogoff, 1996; and IMF, 2006): income (or relative productivity), government expenditure/GDP, real interest, net foreign asset position, terms of trade, and trade reforms (or trade openness) + infrastructure
- Standard errors clustered by country
- All (non-dummy) regressors are scaled by their respective standard deviations

Roads and RER

Cross Country Panel Regressions of RER on Infrastructure

Dependent Variable Variable Form	Log Real Effective Exchange Rate(Index 2005=100)							
	Annual Frequency				Every Third Year			
Log Infrastructure	-0.87 ^{***} (0.28)	-0.87 ^{***} (0.24)	-0.49 ^{***} (0.17)	-0.60 ^{***} (0.17)	-0.76 ^{**} (0.29)	-0.83 ^{***} (0.26)	-0.59 ^{**} (0.23)	-0.74 ^{***} (0.23)
Log GDP/capita	0.44 ^{***} (0.15)	0.01 (0.21)	0.51 ^{***} (0.18)	0.67 ^{***} (0.18)	0.43 ^{**} (0.16)	0.08 (0.21)	0.41 [*] (0.20)	0.57 ^{***} (0.18)
GOV/GDP	0.07 (0.07)	0.08 (0.05)	0.08 (0.05)	0.08 (0.08)	0.09 (0.07)	0.19 ^{**} (0.06)	0.07 (0.09)	0.10 (0.11)
Terms of Trade		-0.03 (0.02)	0.01 (0.02)	0.02 (0.04)		-0.05 [*] (0.03)	0.004 (0.02)	0.05 (0.05)
Net Foreign Asset/GDP		0.27 ^{***} (0.09)	0.14 (0.09)	0.01 (0.09)		0.18 ^{**} (0.08)	0.11 [*] (0.05)	0.09 (0.10)
Real Interest Rate		0.08 ^{**} (0.04)	0.03 (0.02)	0.04 (0.03)		0.09 [*] (0.05)	-0.0005 (0.05)	0.009 (0.05)
Dummy for Trade Liberalization		-0.22 [*] (0.13)				-0.22 [*] (0.11)		
Tariff rate			0.006 (0.006)	0.006 (0.004)			0.002 (0.002)	0.003 [*] (0.002)
Relative Productivity				-0.01 (0.03)				-0.008 (0.02)
Country FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
R ² (within)	0.27	0.27	0.18	0.24	0.26	0.33	0.12	0.20
Max # Years	30	24	20	20	10	8	6	6
# Countries	53	48	47	39	53	48	47	38
# non-missing obs.	1306	784	632	481	437	264	198	153

Notes:

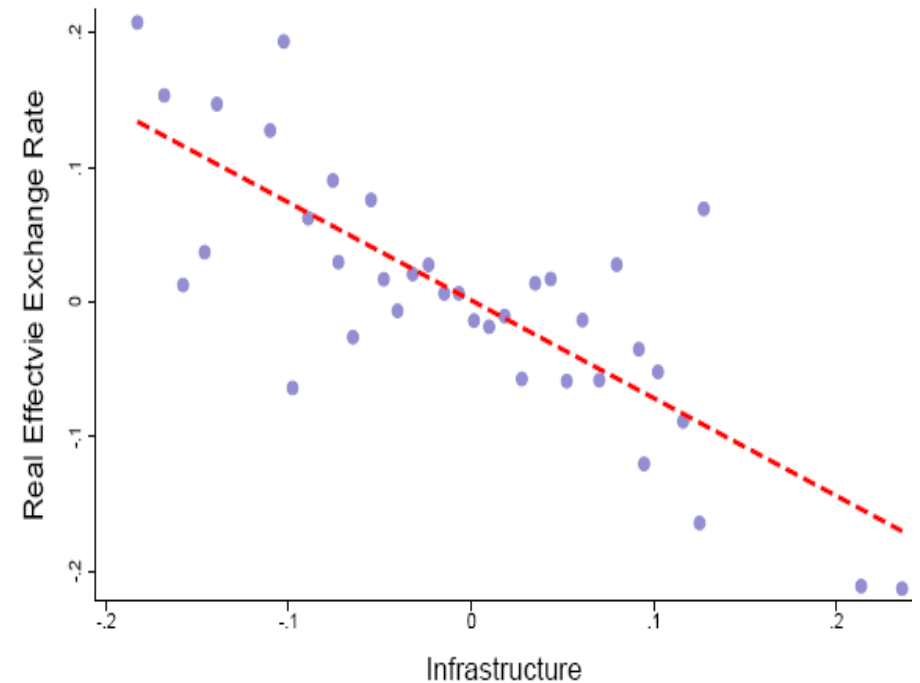
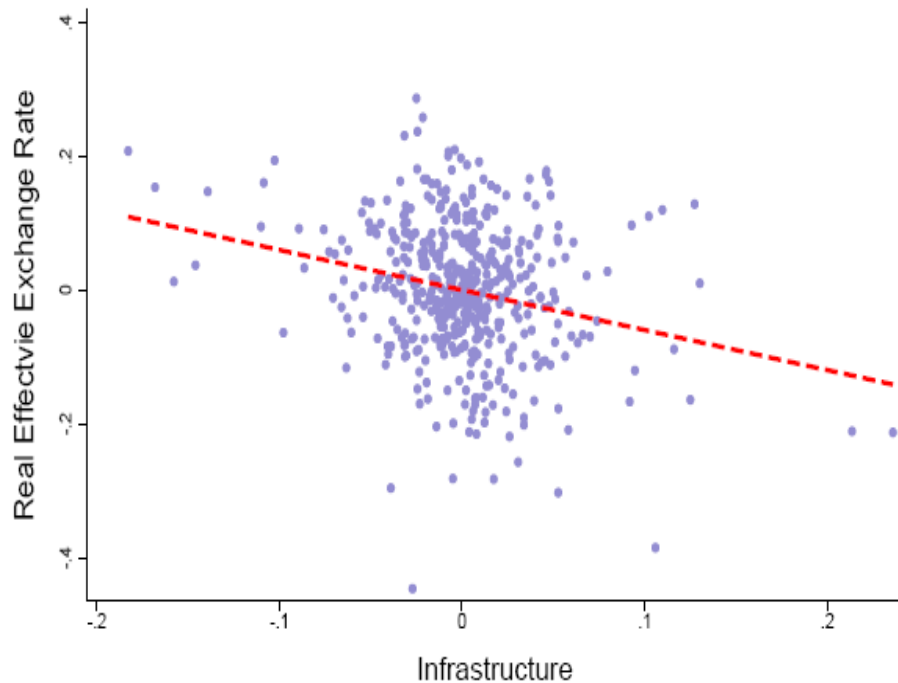
(1) Robust standard errors are in parentheses * p < 0.1, ** p < 0.05, and *** p < 0.01.

(2) The last four regressions use a sample that covers 10 3- year periods: 1981, 1984, 1987, 1990, 1993, 1996, 1999, 2002, 2005, and 2008.

(3) The 39 countries that are included in Column 4 of Table 2 are: Algeria Armenia Australia Austria Belgium Bulgaria Chile China Costa Rica Croatia Czech Republic Denmark France Georgia Germany Hungary Ireland Italy Japan Macedonia, FYR Malaysia Mexico Morocco Netherlands New Zealand Pakistan Philippines Poland Portugal Romania Russian Federation Slovak Republic South Africa Sweden Switzerland Ukraine United Kingdom United States Uruguay

Roads and RER

- Conditional scatter plots: RER vs. infrastructure



Notes:

- (1) The left graph presents the raw scatter plot of log REER against log infrastructure, conditional on all other regressors in Column 4 of Table 2.
- (2) The right graph is a noise-filtered version of the left graph. Specifically, we divide the scatter points in the left graph into 50 equal-width boxes based on the values on the x axis. Within each box, we compute the mean value of REER. The resulting mean REER is plotted against the mid-value of infrastructure for all boxes in the right graph.

Selecting robust determinants by a Bayesian Model
Averaging (BMA) procedure

A relatively demanding way to check for robustness

Horse race among various potential determinants

Bayesian Model Averaging

- Nominal Linear Regression Model

Consider a linear regression structure

$$y = \alpha_r + X_r \beta_r + \varepsilon \quad \varepsilon \sim N(0, \sigma^2 I)$$

β_r is a subset of β

$k_r = \dim(\beta_r)$ and $K = \dim(\beta)$

Variable selection:

Find the 'Best' model

Bayesian Model Averaging:

Average over all subset sets of model (out of 2^K possible models)

Bayesian Model Averaging

• Cross Country Bayesian Estimation 1

Prior Model Size=4 Prior Inclusion Probability=4/8		Dependent Variable: log Real Effective Exchange Rate(Index 2005=100) Model Number: $2^8=256$			
Variable	Posterior Inclusion Probability (1)	Posterior Mean Conditional on Inclusion (2)	Posterior S.D. Conditional on Inclusion (3)	Positive Sign Certainty Conditional on Inclusion (4)	Negative Sign Certainty Conditional on Inclusion (5)
Log GDP/capita	1.00 ⁺	0.62	0.08	1.00	0.00
Log Infrastructure	1.00⁺	-0.55	0.11	0.00	1.00
GOV/GVN	0.95 ⁺	0.07	0.02	1.00	0.00
Real Interest Rate	0.93 ⁺	0.03	0.01	1.00	0.00
Tariff rate	0.39	0.006	0.004	1.00	0.00
Terms of Trade	0.32	0.02	0.02	1.00	0.00
Relative Productivity	0.30	-0.02	0.01	0.00	1.00
Net Foreign Asset/GDP	0.20	0.01	0.05	0.98	0.02

Notes:

(1) ⁺ indicates posterior inclusion probability is larger than prior inclusion probability.

(2) The left-hand-side variable in all regression is the log Real Effective Exchange Rate. The sample period is 1980-2009. Country and year means of all variables are purged before the BMA procedure is applied.

(3) All regressors are ranked by the first column, the posterior inclusion probability (PIP). This is the sum of the posterior probabilities of all models containing the variable. The next two columns reflect the posterior mean and standard deviations for the linear marginal effect of the variable. The conditional mean and standard deviation for a variable are conditional on its inclusion in the model. "Positive sign certainty" is the posterior probability that the coefficient is positive conditional on inclusion; it is a measure of posterior confidence on the sign of the coefficient. Similar definition is used for "negative sign certainty".

(4) We use 'Empirical Bayes g', as advocated by George and Foster (2000) and Hansen and Yu (2001), and a Binomial Model Prior suggested by Sala-I-Martin et al. (2004). The prior model size is set to be 4 in this table; the next table verifies that this is a reasonable prior.

(5) The sample in this table is the same as in Column 4 of Table 2.

Bayesian Model Averaging

• Robustness Check: PIP with Different Prior Model Size (Cross-Country)

		Model Number: $2^8=256$					
Dependent Variable	Log Real Effective Exchange Rate(Index 2005=100)						
Prior Model Size	K=2	K=3	K=4	K=5	K=6	K=7	
Variable	Prior Inclusion Prob.	0.25	0.375	0.5	0.625	0.75	0.875
Log GDP/capita		1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺
Log Infrastructure		1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺
GOV/GVN		0.88 ⁺	0.92 ⁺	0.95 ⁺	0.97 ⁺	0.98 ⁺	0.99 ⁺
Real Interest Rate		0.81 ⁺	0.89 ⁺	0.93 ⁺	0.96 ⁺	0.98 ⁺	0.99 ⁺
Tariff rate		0.16	0.27	0.39	0.52	0.67	0.83
Terms of Trade		0.13	0.22	0.32	0.45	0.60	0.78
Relative Productivity		0.13	0.21	0.30	0.42	0.56	0.75
Net Foreign Asset/GDP		0.07	0.13	0.20	0.30	0.44	0.66

Notes:

(1) ⁺ indicates that the posterior inclusion probability is greater than the prior inclusion probability.

(2) The observations in this BMA test are the same with the sample in Column 4 of Table 2.

Instrument variable approach

Evidence on mechanism:

- **Infrastructure and firm profit margins:**
- **Chinese firm-level data provides evidence on the mechanism**

Endogeneity Problem

Infrastructure could be endogenous:

- mis-measured



- RER and infrastructure could be collinear with other variables



IV Idea1: Natural Disasters and Infrastructure

(Exogenous) natural disasters could temporarily reduce the stock of infrastructure



IV Idea2: Roads Building Difficulty and Infrastructure

Ruggedness and cost of construction materials could affect the Infrastructure Improvement



IV Idea: Natural Disaster and Infrastructure

• Cross Country Regression of Infrastructure on Disasters

Dependent Variable	Log Infrastructure								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Lag 1: (Severity* Area)^2	-0.02 [*] (0.009)	0.30 ^{**} (0.15)	0.31 [*] (0.17)				-0.01 (0.01)	0.30 ^{**} (0.15)	0.29 [*] (0.16)
Lag 1: (Severity* Area)^3	0.02 ^{**} (0.009)	-3.17 ^{**} (1.32)	-3.22 ^{**} (1.48)				0.01 (0.01)	-3.08 ^{**} (1.27)	-3.02 ^{**} (1.39)
Lag 3: (Rugged*Cost)^2				-0.03 (0.79)	-7.53 ^{***} (1.50)	-6.71 ^{***} (1.74)	-0.07 (0.78)	-7.57 ^{***} (1.49)	-6.76 ^{***} (1.73)
Lag 3: (Rugged* Cost)^3				7.28 ^{**} (3.66)	42.5 ^{***} (7.57)	40.7 ^{***} (8.61)	6.99 [*] (3.58)	42.5 ^{***} (7.54)	40.9 ^{***} (8.56)
Lag 3: (Rugged* Cost)^4				-21.8 ^{***} (6.79)	-89.3 ^{***} (15.5)	-87.5 ^{***} (17.5)	-20.7 ^{***} (6.66)	-89.4 ^{***} (15.5)	-87.6 ^{***} (17.5)
Lag 3: (Rugged* Cost)^5				18.0 ^{***} (4.58)	65.7 ^{***} (11.5)	64.7 ^{***} (13.1)	17.1 ^{***} (4.49)	65.6 ^{***} (11.5)	64.7 ^{***} (13.0)
Country FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
R^2	0.13	0.14	0.12	0.21	0.20	0.22	0.25	0.21	0.24
Max Year #	29	20	20	24	20	20	24	20	20
Country #	53	47	38	53	47	39	53	47	38
N	1270	631	480	1091	632	481	1090	631	480

Notes:

(1) Standard errors clustered by country are in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

(2) Disaster severity = total number of people affected by earthquake in a year /total population.

(3) Rugged is the geometric mean of 5 different Terrain Ruggedness Index.

(4) Cost is the roads built material cost, comprised of sand and gravel, crushed stone, cement, and steel, etc.



Are the instrumental variables good for the purpose?

Relevance: Are they “weak instruments”?

Stock Yogo test

Exogeneity: Are they correlated with the error term in the main regression?

Over-identification test

IV Idea

- 2SLS: 2nd Stage RER on Infrastructure

Dependent Variable IV List	Log Real Effective Exchange Rate(Index 2005=100)								
	A=			B=			C=		
	Lag1: (Severity* Area)^(2,3)			Lag3: [Ruggedness* Cost]^(2-5)			A+B		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log Infrastructure	-0.76 ^{***} (0.20)	-0.95 ^{***} (0.37)	-1.24 ^{***} (0.37)	-0.96 ^{***} (0.36)	-0.57 ^{**} (0.28)	-0.86 ^{***} (0.24)	-0.82 ^{***} (0.28)	-0.59 ^{**} (0.26)	-0.87 ^{***} (0.23)
Log GDP/capita	0.43 ^{***} (0.08)	0.59 ^{***} (0.11)	0.84 ^{***} (0.15)	0.49 ^{***} (0.08)	0.52 ^{***} (0.09)	0.74 ^{***} (0.11)	0.47 ^{***} (0.08)	0.52 ^{***} (0.09)	0.75 ^{***} (0.11)
GOV/GDP	0.06 [*] (0.03)	0.08 ^{***} (0.03)	0.07 (0.04)	0.06 ^{**} (0.03)	0.08 ^{***} (0.03)	0.07 [*] (0.04)	0.06 ^{**} (0.03)	0.08 ^{***} (0.03)	0.07 [*] (0.04)
Terms of Trade		0.01 (0.01)	0.02 (0.02)		0.006 (0.009)	0.02 (0.02)		0.006 (0.008)	0.02 (0.02)
Net Foreign Asset/GDP		0.15 ^{**} (0.06)	0.05 (0.05)		0.14 ^{**} (0.06)	0.03 (0.05)		0.14 ^{**} (0.06)	0.03 (0.05)
Real Interest Rate		0.03 (0.02)	0.04 (0.03)		0.03 (0.02)	0.04 (0.03)		0.03 (0.02)	0.04 (0.03)
Tariff Rate		0.005 (0.004)	0.004 (0.003)		0.006 (0.005)	0.006 (0.003)		0.006 (0.005)	0.005 (0.003)
Relative Productivity			-0.03 [*] (0.02)			-0.02 (0.02)			-0.02 (0.02)
Country-Specific Effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-Specific Effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sargan N*R-sq test P value	0.78	0.71	0.75	0.64	0.11	0.22	0.44	0.24	0.45
Durbin-Wu-Hausman chi^2 test P value	0.68	0.35	0.31	0.33	0.77	0.22	0.49	0.72	0.18
Weak IV F test	53.0 ⁺⁺	11.9 ⁺	11.6 ⁺	21.3 ⁺⁺	12.8 ⁺	16.1 ⁺	40.0 ⁺⁺	15.7 ⁺	18.5 ⁺
R^2	0.55	0.60	0.58	0.52	0.61	0.61	0.52	0.61	0.60
N	1270	631	480	1091	632	481	1090	631	480

Notes:

(1) Standard errors clustered by country are in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01

(2) The critical values for Stock-Yogo (2005) weak IV test are 11.59 at the 10% and 19.93 at the 5% (Regression 1-3), 10.27 at the 10% and 16.85 at the 5% (Regression 4-6), and 11.12 at the 10% and 19.28 at the 5% (Regression 7-9).

Map on Robustness Checks:

- **Alternative Measure of the Real Exchange Rate - Bilateral RER against the US dollar**
- **Alternative Measure of Transport Infrastructure by Log Volume of Goods Transported**
- **Excluding Small Economies, Major Oil Producers, and Potential Extreme Outliers**
- **Subsamples by income groups and different time periods**
- **Roads and RER across regions within a single country**

Robustness Check

Alternative Measure of RER: Cross Country Panel Regression of BRER on Infrastructure

Dependent Variable Variable Form	Log Bilateral Exchange Rate vis-a-vis the United States							
	Annual Frequency				Every Third Year			
Log Infrastructure	-0.66** (0.28)	-0.44 (0.28)	-0.77*** (0.20)	-0.89*** (0.25)	-0.63** (0.26)	-0.46 (0.31)	-0.79*** (0.29)	-1.03*** (0.33)
Log GDP/capita	0.49*** (0.14)	0.24* (0.14)	0.85*** (0.19)	1.08*** (0.26)	0.51*** (0.14)	0.32** (0.16)	0.90*** (0.25)	1.14*** (0.33)
GOV/GDP	0.02 (0.06)	0.01 (0.05)	0.04 (0.05)	0.07 (0.07)	0.002 (0.06)	0.06 (0.06)	0.02 (0.07)	0.09 (0.10)
Terms of Trade		-0.03 (0.02)	0.01 (0.01)	-0.001 (0.04)		-0.06** (0.03)	0.01 (0.01)	-0.03 (0.05)
Net Foreign Asset/GDP		0.32*** (0.07)	0.21* (0.12)	-0.02 (0.12)		0.25** (0.11)	0.10 (0.08)	0.07 (0.18)
Real Interest Rate		0.07** (0.02)	0.06* (0.02)	0.05 (0.04)		0.06 (0.04)	0.01 (0.05)	0.02 (0.06)
Dummy for Trade Liberalization		-0.07 (0.09)				-0.07 (0.08)		
Tariff rate			0.01 (0.01)	0.005 (0.005)			0.004 (0.004)	0.001 (0.003)
Relative Productivity				-0.008 (0.02)				-0.02 (0.018)
Country FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
R ² (within)	0.22	0.29	0.38	0.47	0.23	0.28	0.38	0.45
Max # Years	30	24	20	20	10	8	6	6
# Countries	81	64	63	47	80	63	62	45
# non-missing obs.	1721	993	802	557	578	329	250	177

Notes:

(1) Standard errors clustered by country are in parentheses; * p < 0.1, ** p < 0.05, and *** p < 0.01.

(2) The last four regressions use a sample that covers 10 3- year periods: 1981, 1984, 1987, 1990, 1993, 1996, 1999, 2002, 2005, 2008.

(3) The 47 countries that are included in Column 4 of Table A4 are: Algeria Argentina Armenia Australia Austria Azerbaijan Bangladesh Bulgaria China Costa Rica Croatia Czech Republic Denmark Estonia France Georgia Germany Hungary India Italy Japan Korea, Rep. Latvia Macedonia, FYR Malaysia Mexico Morocco Netherlands New Zealand Pakistan Peru Philippines Poland Portugal Romania Russian Federation Slovak Republic Slovenia South Africa Sri Lanka Sweden Switzerland Syrian Arab Republic Thailand Ukraine United Kingdom Uruguay.

Robustness Check

- Alternative Measure of RER: Cross Country Bayesian Estimation 2

Prior Model Size=4 Prior Inclusion Probability=4/8		Dependent Variable: Log Bilateral Real Exchange Rate vis-a-vis the United States Model Number: $2^8=256$				
Variable	Posterior Inclusion Probability (1)	Posterior Mean Conditional on Inclusion (2)	Posterior S.D. Conditional on Inclusion (3)	Positive Sign Certainty Conditional on Inclusion (4)	Negative Sign Certainty Conditional on Inclusion (5)	
Log GDP/capita	1.00 ⁺	1.04	0.08	1.00	0.00	
Log Infrastructure	1.00 ⁺	-0.88	0.12	0.00	1.00	
Real Interest Rate	0.99 ⁺	0.05	0.01	1.00	0.00	
GOV/GDP	0.82 ⁺	0.07	0.03	1.00	0.00	
Tariff rate	0.19	0.005	0.005	1.00	0.00	
Relative Productivity	0.17	-0.01	0.01	0.00	1.00	
Net Foreign Asset/GDP	0.14	-0.02	0.06	0.03	0.97	
Terms of Trade	0.14	-0.0003	0.02	0.67	0.33	

Notes:

(1) See notes to Table 3.

(2) The sample includes 557 (non-missing) observations in 47 countries across 20 years.

Robustness Check

• Alternative Measure of Transport Infrastructure: Cross Country Bayesian Estimation 3

Prior Model Size=5 Prior Inclusion Probability=5/8		Dependent Variable: log Real Effective Exchange Rate(Index 2005=100) Model Number: $2^8=256$			
Variable	Posterior Inclusion Probability (1)	Posterior Mean Conditional on Inclusion (2)	Posterior S.D. Conditional on Inclusion (3)	Positive Sign Certainty Conditional on Inclusion (4)	Negative Sign Certainty Conditional on Inclusion (5)
Log GDP/capita	1.00 ⁺	0.49	0.08	1.00	0.00
Log Goods Transported	0.91 ⁺	-0.11	0.04	0.00	1.00
Real Interest Rate	0.82 ⁺	0.03	0.01	1.00	0.00
GOV/GDP	0.76 ⁺	0.05	0.02	1.00	0.00
Terms of Trade	0.59	0.04	0.02	1.00	0.00
Tariff rate	0.47	0.006	0.004	1.00	0.00
Relative Productivity	0.26	-0.007	0.02	0.03	0.97
Net Foreign Asset/GDP	0.23	-0.001	0.05	0.30	0.70

Notes:

(1) See notes to Table 3.

(2) The sample includes 410 (non-missing) observations in 33 countries across 20 years.

Robustness Check: Excluding Small Economies, Major Oil Producers, Transition Economies, Outliers

• Cross Country Bayesian Estimation 4

Dependent Variable	Log Real Effective Exchange Rate(Index 2005=100) Model Number: 2 ⁸ =256							
Different Group	Excl. Small Economies		Excl. Major Oil Exporters		Excl. Transition Economies		Excl. Outliers (Residual>3*std deviation)	
Variable	PIP	Conditional Posterior Mean	PIP	Conditional Posterior Mean	PIP	Conditional Posterior Mean	PIP	Conditional Posterior Mean
Log GDP/capita	1.00⁺	0.62	1.00⁺	0.62	1.00⁺	0.87	1.00⁺	0.62
Log Infrastructure	1.00⁺	-0.55	1.00⁺	-0.55	0.55⁺	-0.31	1.00⁺	-0.56
GOV/GDP	0.95⁺	0.07	0.94⁺	0.07	0.99⁺	0.24	0.71⁺	0.05
Real Interest Rate	0.93⁺	0.03	0.93⁺	0.03	0.69⁺	0.05	0.99⁺	0.07
Tariff rate	0.39	0.006	0.38	0.006	0.19	0.002	0.30	0.005
Terms of Trade	0.32	0.02	0.35	0.02	0.19	0.01	0.43	0.03
Relative Productivity	0.30	-0.02	0.31	-0.02	0.19	0.008	0.44	-0.02
Net Foreign Asset/GDP	0.20	0.009	0.20	0.01	0.20	-0.31	0.18	-0.004
Max # Years	20		20		20		20	
# Countries	37		36		26		37	
# non-missing obs.	479		475		323		476	

Notes:

(1) PIP = Posterior Inclusion Probability. + indicates PIP is larger than prior inclusion probability (or 50% in this case).

(2) "Small economies" follow the definition of the World Bank as those with less than 1.5 million people. A list of 45 small economies can be found at:

<http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/0,,contentMDK:21512464~pagePK:41367~piPK:51533~theSitePK:40941,00.html>.

(3) "Major oil exporters" are OPEC members.

(4) A transition economy or transitional economy is an economy which is changing from a centrally planned economy to a free market. List of transition economies refers to: http://en.wikipedia.org/wiki/Transition_economy#cite_note-imf2000-5.

(5) Outliers in the last column are defined as observations whose residuals from regression 4 in Table 2 are greater than 3 times the standard deviations.

Robustness Check: Different Subsamples by Income and Time Periods

• Cross Country Bayesian Estimation 5

Dependent Variable	Log Real Effective Exchange Rate(Index 2005=100)							
	Model Number: $2^8=256$							
Different Group	Developing Countries		High-Income Countries		1988-1997		1997-2007	
Variable	PIP	Conditional Posterior Mean	PIP	Conditional Posterior Mean	PIP	Conditional Posterior Mean	PIP	Conditional Posterior Mean
Log GDP/capita	0.99 ⁺	0.38	1.00 ⁺	1.01	0.99 ⁺	0.62	1.00 ⁺	0.62
Log Infrastructure	0.82 ⁺	-0.32	0.57 ⁺	-0.27	0.95 ⁺	-0.62	0.99 ⁺	-0.45
GOV/GDP	0.99 ⁺	0.14	0.33	0.02	0.92 ⁺	0.11	0.86 ⁺	0.07
Real Interest Rate	0.71 ⁺	0.03	0.99 ⁺	0.13	0.31	-0.002	0.99 ⁺	0.08
Tariff rate	0.96 ⁺	0.06	0.33	0.001	0.34	0.002	0.96 ⁺	0.06
Terms of Trade	0.54 ⁺	0.03	0.93 ⁺	-0.16	0.57 ⁺	-0.07	0.56 ⁺	0.03
Relative Productivity	0.36	-0.02	0.35	-0.02	0.32	-0.01	0.45	-0.03
Net Foreign Asset/GDP	0.31	-0.09	0.32	0.01	0.55 ⁺	0.12	0.29	-0.06
Max # Year		20		20		9		12
# Countries		18		19		28		37
N		204		275		157		350

Notes:

(1) PIP = Posterior Inclusion Probability. + indicates PIP is larger than prior inclusion probability (or 50% in this case).

(2) "High income economies" follow the definition of the World Bank

[http://data.worldbank.org/about/country-classifications/country-and-lending-groups#High income](http://data.worldbank.org/about/country-classifications/country-and-lending-groups#High%20income).

and include: Andorra Aruba Australia Austria The Bahamas Bahrain Barbados Belgium Bermuda Brunei Canada Cayman Islands Channel Islands Croatia Curaçao Cyprus Czech Republic Denmark Equatorial Guinea Estonia Faroe Islands Finland France French Polynesia Germany Greece Greenland Guam Hong Kong Hungary Iceland Ireland Isle of Man Israel Italy Japan South Korea Kuwait Liechtenstein Luxembourg Macao Malta Monaco Netherlands New Caledonia New Zealand Northern Mariana Islands Norway Oman Poland Portugal Puerto Rico Qatar Saint Kitts and Nevis Saint Martin San Marino Saudi Arabia Singapore Sint Maarten Slovakia Slovenia Spain Sweden Switzerland Trinidad and Tobago Turks and Caicos Islands United Arab Emirates United Kingdom United States and U.S. Virgin Islands. All other countries are in the "Developing Countries" group.

One more robustness check using intra-country data

Examine the relationship between local RER and local transport infrastructure across regions (provinces) with China 2001-2009

Local RER = a region's price level for the CPI basket relative to that of Beijing

Local transport = same road density definition as in the cross country context

- As there is more information on road quality, we can do more quality adjusted measure of transport infrastructure

Bayesian Model Averaging

- With-in China Sample Bayesian Estimation for 5 Variables

Prior Model Size=4 Prior Inclusion Probability=4/5		Dependent Variable: Log Bilateral Real Exchange Rate with Beijing Model Number: $2^5=32$				
Variable	Posterior Inclusion Probability (1)	Posterior Mean Conditional on Inclusion (2)	Posterior S.D. Conditional on Inclusion (3)	Positive Sign Certainty Conditional on Inclusion (4)	Negative Sign Certainty Conditional on Inclusion (5)	
GOV/GDP	1.00 ⁺	0.02	0.003	1	0	
Log Product Market Development Index	0.99 ⁺	-0.006	0.001	0	1	
Log Factor Market Development Index	0.99 ⁺	0.008	0.002	1	0	
Log GDP/capita	0.99 ⁺	0.02	0.006	1	0	
Log Infrastructure	0.91 ⁺	-0.02	0.007	0	1	

Notes:

(1) ⁺ indicates that the posterior inclusion probability is greater than prior inclusion probability (=4/5).

(2) For details on the implementation of the BMA procedure and definitions of the terms, please see the footnotes to Table 3.

(3) The observations in this BMA test are the same with the sample in Column 3 of Table 12.

Bayesian Model Averaging

- Robustness Check: PIP with Different Prior Model Size (With-in China)

Dependent Variable: Log Bilateral Real Exchange Rate with Beijing				
Model Number: $2^5=32$				
Prior Model Size	K=1	K=2	K=3	K=4
Variable	Prior Inclusion Probability			
GOV/GDP	1.00 ⁺	1.00 ⁺	1.00 ⁺	1.00 ⁺
Log Product Market Development Index	0.99 ⁺	0.99 ⁺	0.99 ⁺	0.99 ⁺
Log Factor Market Development Index	0.99 ⁺	0.99 ⁺	0.99 ⁺	0.99 ⁺
Log GDP/capita	0.76 ⁺	0.92 ⁺	0.97 ⁺	0.99 ⁺
Log Infrastructure	0.35 ⁺	0.62 ⁺	0.79 ⁺	0.91 ⁺

Notes:

(1) See footnotes to Table 4.

(2) The observations in this BMA test are the same with the sample in Column 3 of Table 12.

Evidence on mechanism

Roads and Firm Profits

Proxies for markup

Return on asset

Return on equity

Profit rate (profit/sale)

Mechanism: Profitability and Infrastructure

- Regression of Profitability on Infrastructure including Firm and Industry*Year Fixed Effect

Dependent Var.	Log Return on Owner's Equity			Log Return on Asset			Log Profit Margin		
Log Infrastructure	-0.03** (0.01)	-0.02* (0.01)		-0.07** (0.03)	-0.05* (0.03)		-0.01** (0.005)	-0.006 (0.005)	
Export*Log Infrastructure	-0.0003 (0.0004)	-0.0002 (0.0003)		-0.0003 (0.001)	-0.0002 (0.001)		-0.0001 (0.0001)	-0.0001 (0.0001)	
Log Total Employment	0.01*** (0.001)	0.01*** (0.001)	0.01*** (0.001)	0.03*** (0.002)	0.03*** (0.002)	0.03*** (0.002)	0.006*** (0.0002)	0.006*** (0.0002)	0.006*** (0.0002)
Long term debt/Asset	-0.02*** (0.001)	-0.02*** (0.001)	-0.02*** (0.001)	0.08*** (0.01)	0.08*** (0.01)	0.08*** (0.01)	-0.01*** (0.001)	-0.01*** (0.001)	-0.01*** (0.001)
Long term Invest/Main Business Revenue	-0.04*** (0.003)	-0.04*** (0.003)	-0.04*** (0.003)	-0.10*** (0.01)	-0.10*** (0.01)	-0.10*** (0.01)	-0.03*** (0.002)	-0.03*** (0.002)	-0.03*** (0.002)
Revenue Growth Rate	1e-05*** (3e-06)	1e-05*** (3e-06)	1e-05*** (3e-06)	3e-05*** (1e-05)	3e-05*** (1e-05)	3e-05*** (1e-05)	-1e-07 (2e-06)	-1e-06 (2e-06)	-1e-06 (2e-06)
Log GDP/capita	0.03*** (0.01)	0.05*** (0.01)	0.03*** (0.01)	0.07*** (0.02)	0.08*** (0.02)	0.05*** (0.01)	0.007* (0.004)	0.01** (0.004)	0.004* (0.002)
Log Population		-0.001 (0.001)	-0.001** (0.001)		-0.002 (0.002)	-0.004** (0.001)		-0.001*** (0.0003)	-0.001*** (0.0003)
GOV/GDP		-0.10*** (0.02)	-0.11*** (0.02)		-0.20*** (0.04)	-0.23*** (0.04)		-0.04*** (0.01)	-0.05*** (0.01)
Log Product Market Development Index		0.0004 (0.01)	0.002 (0.01)		-0.01 (0.02)	-0.01 (0.02)		-0.002 (0.004)	-0.002 (0.004)
Log Factor Market Development Index		-0.01* (0.01)	-0.01 (0.01)		-0.01 (0.02)	-0.01 (0.02)		-0.00001 (0.003)	0.001 (0.003)
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry*Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cluster S.E. on province*year	Y	Y	Y	Y	Y	Y	Y	Y	Y
R^2	0.008	0.01	0.01	0.006	0.007	0.007	0.005	0.007	0.007
N	980778	980778	1003068	980778	980778	1003068	980778	980778	1003068

Notes: Standard errors Cluster by Province-Year are in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01

Transport infrastructure is an important determinant of the RER

Better roads and transport networks -> lower RER

Quantitatively, the effect of infrastructure on RER is almost as strong as the Balassa-Samuelson effect, and much stronger than the Froot-Rogoff effect.

Without taking into account transport infrastructure, the RER of a country with a faster-than-average expansion of infrastructure could appear too low

- IMF exchange rate misalignment analysis
- Countries in a currency union

- 감사합니다.
- ありがとう.
- 谢谢。
- आप श्रीमान धन्यवाद
- ขอบคุณ[มาก.
- Merci.
- Thank you.



Bayesian Model Averaging

• Contribution to Bilateral Real Exchanger Rate Change

- Compare the economic significance of the infrastructure with the Balassa-Samuelson effect and the Froot-Rogoff effect, etc
- Example: 1988-2007

Cross Country (1988-2007)

