Estimating the effect of exchange rate changes on total exports[1]

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BIS Workshop

[1] The views expressed in this paper are those of the authors and do not necessarily reflect those of the Banque de France, the Eurosystem or the Bank of Canada.

Main question

How to estimate the response of aggregate exports to exchange rate changes?

- Standard approach: Real Effective Exchange Rate (REER) regression (McGuirk (1986))

$$d \ln E_{it} = \beta_1 d \ln REER_{it} + \beta_2 \sum_{n \neq i} \omega_{nit} d \ln X_{nt} + e_{it} \tag{1}$$

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Can we reconnect this "macro-level" REER regressions with "micro-level" foundations of bilateral trade (i.e. gravity)?

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1. We re-visit the theoretical foundations of "macro-level" Real Effective Exchange Rate (REER) regression
2. We calibrate a standard gravity model to quantify estimation biases in different models used in "marco-level" applied work
3. Can our new REER regression explain differences in elasticties estimated from bilateral and aggregate data?

Main results

- Structural gravity models with a unique elasticity of substitution permit aggregation from the bilateral level without bias.
- Simulations show the main sources of bias in specifications used in applied work:
  1. Functional form assumptions
  2. Omitted variables
  3. Differences in the weighting scheme
- Estimation biases in the exchange rate elasticity appear to be a minor concern.
  - Bias seems to be mainly on the demand elasticity

Literature

- Theoretical foundations of Real Effective Exchange Rate (REER)
  - Armington (1969), McGuirk (1986), Chinn (2006), Bayoumi et al. (2013), Patel et al. (2017), Bems Johnson (2017)
  - Bayoumi et al. (2005), Klau Fung (2006), Bennett Zarnic (2009), Schmitz et al. (2011), Barnett et al. (2016)
- Empirical macroeconomic literature on exchange rate and demand elasticities :
  - Orcutt (1950), Houthakker Magee (1969), Goldstein et al. (1985), Spilimbergo Vamvakidis (2003), Freund Pierola (2012), Imbs Méjean (2015), Bussiere et al. (2014), Ahmed et al. (2016)
  - Campa Goldberg (2005), Vigfusson et al. (2009), Bussière et al. (2014)
- Gravity literature and exchange rate
  - Anderson Vesselovsky Yotov (2016)

Theoretical framework (Dekle, Eaton and Korum (2007))

- Total exports of country i in international currency

$$E_i = \sum_{n \neq i} X_{ni} = \sum_{n \neq i} \pi_{ni} X_n$$

  - X_n ... total expenditure of importer n, π_{ni} ... expenditure share of n on goods from i

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  - X_n ... total expenditure of importer n, π_{ni} ... expenditure share of n on goods from i

- With CES preferences

$$\pi_{ni} = \frac{(r_i P_{ni})^{-\theta}}{(r_n P_n)^{-\theta}}$$

  - r_n ... nominal exchange rate of n, P_n ... price index in local currency, θ ... trade elasticity
  - $P_{ni} = P_{ii}\tau_{ni}$ ... producer price of exporter i (P_{ii}), trade costs (τ_{ni})

Counterfactual analysis: change in total exports

- Exact hat notation (ACR (2012))

$$\widehat{X}_{ni} \equiv \frac{X_{ni}^{'}}{X_{ni}}$$

  - $X_{ni}^{'}$ ... bilateral trade after the change

- Change in total exports

$$\widehat{E}_i = \sum_{n \neq i} \omega_{ni} \widehat{\pi}_{ni} \widehat{X}_n = \sum_{n \neq i} \omega_{ni} \frac{\left(\hat{r}_i \widehat{P}_{ii}\right)^{-\theta}}{\left(\hat{r}_n \widehat{P}_n\right)^{-\theta}} \widehat{X_n}$$

  - $\omega_{ni} \equiv X_{ni} / E_i$ denotes the export share

"Macro-level" Real Exchange Rate (RER) regression

- Taking logs, **the aggregate exchange rate regression:**

$$\ln \widehat{E}_i = -\theta \ln \widehat{RER_i} + \ln \sum_{n \neq i} \omega_{ni} \frac{\widehat{X_n}}{\left(\hat{r}_n \widehat{P}_n\right)^{-\theta}} \quad (2)$$

  - where the real exchange rate (RER_i) is defined as:

$$\ln \widehat{RER_i} = \ln \hat{r}_i \widehat{P}_{ii} \quad (3)$$

- **No aggregation bias ... if equation (2) is run**

Which regressions do people run?

McGuirk (1986) derives the standard aggregate exchange rate regression:

1. Start from changes in bilateral trade flows:

$$\hat{X}_{ni} = \hat{\pi}_{ni}\hat{X}_n$$

   - Use functional form of trade shares and take log :

$$\ln \hat{X}_{ni} = -\theta \ln \left(\frac{\hat{r}_i \widehat{P}_{ii}}{\hat{r}_n \hat{P}_n} \right) + \ln \hat{X}_n$$

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$$\ln \hat{X}_{ni} = -\theta \ln \left(\frac{\hat{r}_i \widehat{P}_{ii}}{\hat{r}_n \hat{P}_n} \right) + \ln \hat{X}_n$$

2. Sum the bilateral changes across all importers

$$\ln \hat{E}_i = -\theta \sum_{n \neq i} \omega_{ni} \sum_{k \neq i} \pi_{nk} \ln \left(\frac{\hat{r}_i \widehat{P}_{ii}}{\hat{r}_k \hat{P}_{kk}} \right) + \sum_{n \neq i} \omega_{ni} \ln \hat{X}_n$$

   - using the fact that $\ln \hat{P}_n = \sum_{k=1}^{K} \pi_{nk} \ln \left(\frac{\hat{r}_k}{\hat{r}_n} \hat{P}_{kk} \right)$

Double-weighted REER à la McGuirk (1986)

- **Standard aggregate exchange rate regression**

$$\ln \hat{E}_i = -\theta \ln \widehat{REER}_i + \sum_{n \neq i} \omega_{ni} \ln \hat{X}_n \quad (4)$$

  - $\ln REER_i$ is the double-weighted Real Effective Exchange Rate

$$\ln \widehat{REER}_i = \sum_{n \neq i} \sum_{k \neq i} \omega_{ni} \pi_{nk} \ln \left(\frac{\hat{r}_i \widehat{P}_{ii}}{\hat{r}_k \hat{P}_{kk}} \right) \quad (5)$$

  - Changes in the unit cost of production ($\widehat{P}_{ii} = \hat{w}_i^{\beta} \hat{p}_i^{1-\beta}$) of exporter i relative to other exporter price changes ($\hat{P}_{kk}$) times the changes in the bilateral exchange rate $\left(\frac{\hat{r}_i}{\hat{r}_k}\right)$.

Comparing Structural Gravity and McGuirk (1986)

- We can re-write the REER equation of McGuirk:

$$\ln \hat{E}_i = \underbrace{-\theta \ln \left(\widehat{RER_i}\right) - \sum_{n \neq i} \omega_{ni} \ln \left(\hat{P}_n \hat{r}_n\right)^{-\theta}}_{-\theta \ln \widehat{REER_i}} + \sum_{k \neq i} \omega_{ni} \ln \hat{X}_n$$

  - and compare with gravity

$$\ln \widehat{E_i} = -\theta \ln \widehat{RER_i} + \ln \sum_{n \neq i} \omega_{ni} \left(\frac{\widehat{X_n}}{\left(\hat{P}_n \hat{r}_n\right)^{-\theta}} \right)$$

  - by Jensen's inequality:

$$\ln \sum_{n \neq i} \omega_{ni} \left(\frac{\widehat{X_n}}{\left(\hat{P}_n \hat{r}_n\right)^{-\theta}} \right) \geq \sum_{n \neq i} \omega_{ni} \ln \hat{X}_n - \sum_{n \neq i} \omega_{ni} \ln \left(\hat{P}_n \hat{r}_n\right)^{-\theta}$$

- **Larger exchange rate shocks will induce larger bias.**

Simulation - Dekle, Eaton and Kortum (2007) approach

- Goal of simulation:
  - **How large is aggregation bias?**

- Data from Dekle, Eaton and Kortum (2007)
  - Trade and GDP data for 39 countries + ROW in the year 2004
  - Calibration: trade elasticity $\theta = 4$

- Simulation:
  - One country receives a random exchange rate shocks.
  - Repeat 100 times with different exchange rate shocks for all 39 countries.

Quantifying the bias: nominal exchange rate shock ($\hat{r}_i$)

- Partial equilibrium (wages are fixed, good prices adjust)
  - Changes : $\widehat{RER}_i = \widehat{r}_i \left(\widehat{p}_i^{1-\beta}\right)$ and $\widehat{X}_i = 1$

Quantifying the bias: nominal exchange rate shock ($\hat{r}_i$)

- Partial equilibrium (wages are fixed, good prices adjust)
  - Changes : $\widehat{RER}_i = \widehat{r}_i \left(\widehat{p}_i^{1-\beta}\right)$ and $\widehat{X}_i = 1$
- General equilibrium (wages and prices adjust)
  - Goods market clearing condition for given trade deficit (D_i)

$$\hat{r}_i \hat{w}_i Y_i + D_i = \sum_n \frac{\pi_{ni} \left(\hat{r}_i \hat{w}_i^{\beta} \hat{p}_i^{1-\beta}\right)^{-\theta}}{\sum_\ell \pi_{n\ell} \left(\hat{r}_l \hat{w}_l^{\beta} \hat{p}_l^{1-\beta}\right)^{-\theta}} \left(\hat{r}_n \hat{w}_n Y_n + D_n\right). \qquad (6)$$

  - Changes : $\widehat{RER}_i = \widehat{r}_i \left(\widehat{w}_i^{\beta} \widehat{p}_i^{1-\beta}\right)$ and $\widehat{X}_n = \hat{r}_n \hat{w}_n Y_n + D_n$
  - Hypothesis : the deficit is fixed in international currency units

Simulation

5 specifications to evaluate the aggregation bias:

1. Baseline (exact hat algebra)
   - produces unbiased estimates
2. Gold medal mistake
   - omitting the unobserved Multilateral Resistance Term (MRT)
3. Approximation via log changes
4. REER à la McGuirk (1986)
5. Log approximation with IMF weights
   - this is the standard method used in applied empirical work

Exchange Rate Regression in specification 1

- **Specification 1:** Baseline (exact hat algebra)

$$\ln \widehat{E}_i = \beta^1_{RER} \ln \widehat{RER_i} + \beta^1_X \ln \sum_{n \neq i} \omega_{ni} \left(\frac{\widehat{X}_n}{\left(\hat{r}_n \widehat{P}_n\right)^{\beta^1_{RER}}} \right) + \epsilon_i$$

- This is the Structural Gravity model implied regression that results in unbiased estimates for the exchange rate elasticity $\left(\beta^1_{RER} = -4\right)$ and the demand elasticity $\left(\beta^1_X = 1\right)$.

Exchange Rate Regression in specification 2

- **Specification 2:** Gold Medal mistake: omitting the Multilateral Resistance Term (MRT)

$$\ln \widehat{E}_i = \beta^2_{RER} \ln \widehat{RER_i} + \beta^2_X \ln \sum_{n \neq i} \omega_{ni} \widehat{X_n} + \epsilon_i$$

- This regression evaluates the bias when omitting the Multilateral Resistance Term ($(r_n P_n)^{-\theta}$) from the theory implied exchange rate equation in specification 1.

Exchange Rate Regression in specification 3

- **Specification 3:** Approximation via log changes

$$\ln \hat{E}_i = \beta^3_{RER} \ln \widehat{RER_i} + \beta^3_X \sum_{n \neq i} \omega_{ni} \left(\frac{\ln \hat{X}_n}{\ln \left(\hat{r}_n \widehat{P}_n \right)^{\beta^3_{RER}}} \right) + \epsilon_i$$

- Motivation: one might be tempted to approximate the baseline regression with changes in logs rather than the log of the change.

Exchange Rate Regression in specification 4

- **Specification 4:** REER à la McGuirk (1986)

$$\ln \hat{E}_i = \beta^4_{RER} \ln \widehat{REER}_i + \beta^4_X \sum_{k \neq i} \omega_{ni} \ln \hat{X}_n + \epsilon_i$$

- The main difference with the baseline specification 1 is:
  - we use the Real Effective Exchange Rate (REER) rather than the (RER) in the baseline specification

Exchange Rate Regression in specification 5

- **Specification 5:** log approximation with IMF weights

$$\ln \hat{E}_i = \beta^5_{RER} \ln \widehat{REER_i^{IMF}} + \beta^5_X \sum_{k \neq i} \omega_{ni} \ln \hat{X}_n + \epsilon_i$$

- The difference with specification 4 is that we use the IMF weighting scheme in constructing the Real Effective Exchange Rate.
- **This is the standard method used in applied empirical work**
  - Note: IMF weights differ from the theoretical implied weights used in specification 4. ▸ IMF

General equilibrium regression results

	Baseline (ideal-REER) (1)	GM mistake (2)	$d\ln$ approx. (3)	REER McGuirk (real-REER) (4)	IMF weights (5)
Exchange rate					
Mean	-4	-3.74	-4.001	-4	-3.918
Bias	0	.26	.001	0	.082
Std dev.	0	.045	.032	.019	.022
MSE $^{1/2}$	0	.264	.032	.019	.085
Foreign demand					
Mean	1	.988	1.004	1.004	1.002
Bias	0	.012	.004	.004	.002
Std dev.	0	.023	.053	.053	.053
MSE $^{1/2}$	0	.026	.053	.053	.053

Notes: The sample consists of 39 countries and each country receives 100 random exchange rate shocks. The total number of estimated exchange rate and demand elasticities is 3900 for each of the 5 different specfciations.

- Significant bias in both elasticities in all specifications. ▸ MTI

Summary of simulation results

- On average, bias in demand and exchange rate elasticity are small.
  - The size of the bias depends on the magnitude and the type of the exchange rate shock here.
- Bias does not depend on the level of the trade elasticity (θ)
  - Results with $\theta = 0.8$ here.
- Model does not perfectly explain bilateral flows.
  - Assume stochastic trade costs, see here.
  - Biases are amplified (bias in exchange rate elasticity is close to 1%, in demand elasticity is close to 20%)

Empirical part

- **Do ideal-REER regressions reduce the difference between bilateral and aggregate elasticities?**
  - construct empirical counterparts of the 5 regression specifications above.
- We use annual bilateral trade flows of 25 countries over the period 1964-2011.
  - RER is Nominal Exchange Rate deflated by CPI.
  - REER is BIS Narrow REER deflated by the CPI.
  - Foreign Demand is nominal GDP from Penn World Table.
  - Bilateral trade flows from CEPII.

Empirical regressions

- We run exchange rate regressions at different level of aggregation
  - Bilateral Regression:

$$\triangle \ln E_{nit} = \alpha_0 - \alpha_1 \triangle \ln RER_{nit} + \alpha_2 \triangle \ln X_{nt} + e_{nit}$$

  - Aggregate Regression:
    - the same 5 regression specifications as in the simulation
- Test: do exchange rate elasticities and demand elasticities differ?
  - in pooled and country-specific sample

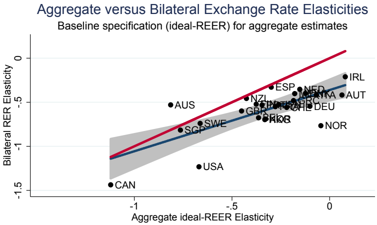
Empirical estimates of pooled regressions

	Bilateral	Aggregate				
		Baseline	GM mistake	*d* ln app.	McGuirk	IMF
	(1)	(2)	(3)	(4)	(5)	(6)
Exchange rate						
Point estimate	-.459	-.409	-.380	-.291	-.584	-.254
Std. error	(0.024)	(0.06)	(0.059)	(0.057)	(0.066)	(0.067)
Foreign demand						
Point estimate	1.184	1.199	.758	1.207	1.092	1.122
Std. error.	(0.019)	(0.106)	(0.076)	(0.096)	(0.038)	(0.042)
Observations	27940	1077	1077	1142	1077	1198
R2	.157	.567	.570	.579	.612	.516

Notes: The sample consists of 25 countries over the period 1964-2011.

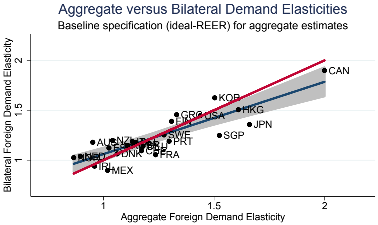
- No significant differences between bilateral and aggregate elasticities when using ideal-REER (baseline).
  - significant differences in all other specifications

Empirical estimates of country-by-country regressions



Red line corresponds to 45 degree line;

Blue line is best linear fit with 95 perc. confidence interval



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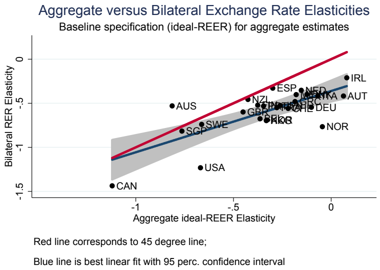

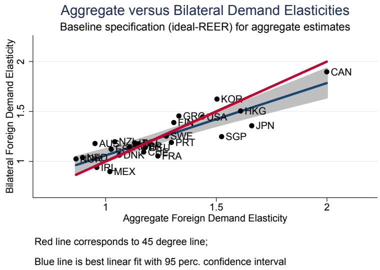

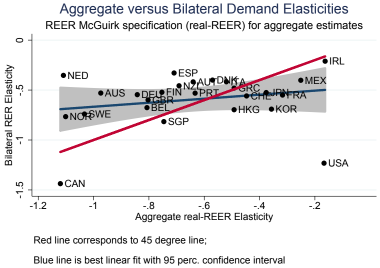

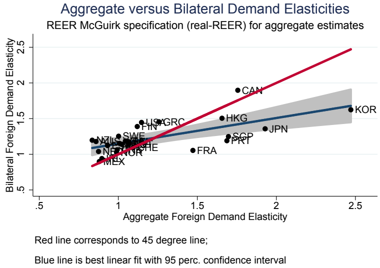

Conclusion

- We reconnect “macro-level” Real Effective Exchange Rate (REER) regressions with “micro-founded” bilateral trade equations (gravity)
  - with unique elasticity of substitution aggregation without bias possible
- We quantify estimation biases of specfciations used in empirical macro-literautre.
  - bias for exchange rate and demand elasticity can be significant (up to 20%)
- Our empirical evidence confirms analytical (simulated) results.
  - our “ideal-REER” reduces differences between aggregate and bilateral elasticities
- Policy institutions may revisit their projection models...

Appendix

EER calculated by policy institutions (IMF)

- Effective Exchange Rate (EER) based on McGuirk (1986)

$$\ln REER_i = \sum_{k \neq i} TW_{ik} \ln \left(\frac{r_i P_i}{r_k P_k} \right)$$

  - where: $TW_{ik} = \sum_{n \neq i} \omega_{ni} \pi_{nk}$
  - IMF calculate weights for the effect on production (not exports)

$$TW_{ik}^{IMF} = \sum_{n=1}^{N} \psi_{ni} \pi_{nk}$$

    - where $\psi_{ni} = \frac{X_{ni}}{\sum_{k=1}^{N} X_{ki}}$ includes the home market share
  - These weights are normalized to 1

$$TW_{ik}^{IMF} = \frac{\sum_{n=1}^{N} \psi_{ni} \pi_{nk}}{\sum_{n=1}^{N} \psi_{ni} (1 - \pi_{ni})}$$

    - which leads to a bias in export equations. Back

Partial equilibrium regression results

	Baseline ("ideal-REER") (1)	GM mistake (2)	$d \ln$ approx. (3)	REER McGuirk ("real-REER") (4)	IMF weights (5)
Exchange rate					
Mean	-4	-3.872	-4	-4	-3.957
Bias	0	.128	0	0	.043
Std dev.	0	.247	.003	.004	.08
MSE $^{1/2}$	0	.278	.003	.004	.091
Foreign demand					
Mean	1	0	1.002	0	0
Bias	0	0	.002	0	0
Std dev.	0	0	.039	0	0
MSE $^{1/2}$	0	0	.039	0	0

Notes: The sample consists of 39 countries and each country receives 100 random exchange rate shocks. The total number of estimated exchange rate and demand elasticities is 3900 for each of the 5 different specifciations.

- Small significant bias in exchange rate elasticities. Back

GETI regression results with stochastic trade costs

	Baseline (ideal-REER) (1)	GM mistake (2)	*d* ln approx. (3)	REER McGuirk (real-REER) (4)	IMF weights (5)
Exchange rate					
Mean	-4	-3.951	-4.041	-4.022	-3.997
Bias	0	.049	.041	.022	.003
Std dev.	0	.141	.166	.186	.178
MSE $^{1/2}$	0	.149	.171	.187	.178
Foreign demand					
Mean	1	1.28	1.092	1.151	1.224
Bias	0	.28	.092	.151	.224
Std dev.	0	.28	.262	.347	.344
MSE $^{1/2}$	0	.396	.278	.378	.411

Notes: The sample consists of 39 countries and each country receives 100 random exchange rate shocks. The total number of estimated exchange rate and demand elasticities is 3900 for each of the 5 different specfciations.

- Significant bias in both elasticities in all specifications. Bias in demand elasticity larger than in exchange rate elasticity. Back

GETI regression results with $\theta = 0.8$

	Baseline (ideal-REER) (1)	GM mistake (2)	$d\ln$ approx. (3)	REER McGuirk (real-REER) (4)	IMF weights (5)
Exchange rate					
Mean	-.8	-.716	-.8	-.8	-.777
Bias	0	0	0	0	.023
Std dev.	0	.01	.022	.01	.011
MSE $^{1/2}$	0	.085	.022	.01	.025
Foreign demand					
Mean	1	.995	1.004	1.004	1.003
Bias	0	.005	.004	.004	.003
Std dev.	0	.011	.053	.053	.053
MSE $^{1/2}$	0	.012	.053	.053	.053

Notes: The sample consists of 39 countries and each country receives 100 random exchange rate shocks. The total number of estimated exchange rate and demand elasticities is 3900 for each of the 5 different specfciations.

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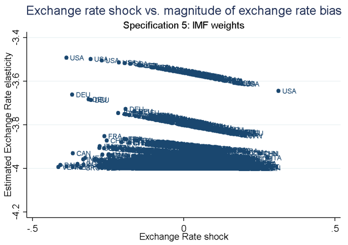
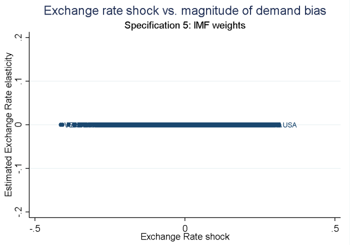
Bias in exchange rate and demand elasticity in MTI

- Plot the magnitude of the exchange rate shock against the estimated elasticities in the IMF specification

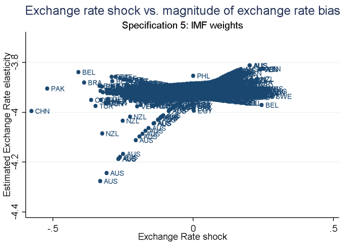


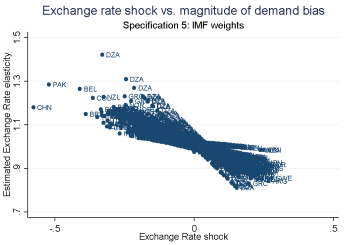


  - Bias depends on economic size.

Bias in exchange rate and demand elasticity in GETI

- Plot the magnitude of the exchange rate shock against the estimated elasticities in the IMF specification





- Bias depends on remoteness. ▸ Back