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Understanding International Prices: Customers as Capital

Technical Appendix

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1 Definition of Aggregate Price Indices

The real export (import) price has been constructed by dividing the nominal deflator price of exports¹ (imports) by the all-items CPI,

$$p_x = \frac{EPI}{CPI} \quad (1)$$

$$p_m = \frac{IPI}{CPI}, \quad (2)$$

where EPI (IPI) denotes the nominal deflator prices of exports (imports) constructed by dividing the value of exports in current prices by the value of export is constant prices. p_x^T (p_m^T) has been constructed from the formula stated in Section 2A in the paper, using the CPI for housing and services to measure the prices of non-tradables P^N .

In the case of Table 2, the real exchange rate has been constructed by dividing the trade-weighted foreign price level index by the corresponding domestic price level index, after prior conversion to a common numeraire (using nominal exchange rate),

$$x_i \equiv \Pi_{j=1}^N (e_{ij} P_j)^{\omega_{ij}} / P_i, \quad (3)$$

where x_i denotes the real exchange rate of country i , e_{ij} denotes bilateral nominal exchange rate between country i and country j (j currency units in terms of domestic currency), ω_{ij} denotes the weight of country j in total trade ($\sum_j^N \omega_j = 1$) of country i , and P_i is the price index used to measured the overall price level. In all other cases we used the trade weighted time-series from the IMF-IFS database.

¹The nominal deflator price of exports (imports) is defined as the ratio of value of exports (imports) in current prices to the value of exports (imports) in constant prices.

The *terms of trade* has been constructed as follows

$$p = \frac{IPI}{EPI} = \frac{p_m}{p_x}. \quad (4)$$

2 Description of the Solution Method

We solve the model by taking a second order approximation to the equilibrium conditions around the deterministic steady state, and transforming the problem to a non-explosive difference equation as in Schmitt-Grohe & Uribe (2004). We assume that the solution is interior and that all inequalities are binding. After solving the model, we verify that this is the case. The codes are available upon request.

3 Robustness of Export-Import Correlation Puzzle

Here we show that our results do not come from price deflation using aggregate indices, tables 1-2 report analogous statistics to the paper but for nominal export and import prices. We report the results for both H-P-filtered and linearly detrended data.

4 Measurement of Long-run Price Elasticity of Trade Flows

Here we derive analytically the long-run price elasticity of trade flows in our model, and relate it to the measurement of the long-run elasticity in the data. The long-run price elasticity is interpreted as the long-run impact of a permanent change in the tariff rate T on the steady state product mix ratio $\frac{f}{d}$ or expenditure ratio $\frac{p_f f}{p_d d}$. Below, we show that such steady state response in our model is equal to γ , and show how it relates to the measurement of this elasticity in the trade literature.

For the purpose of this exercise, we must first modify our setup to include a T percent tariff rate charged by the government on the value of imported goods by the retailer (T percent out of the dock value). The tariff is assumed to be symmetric across countries, and the revenue from the tariff is assumed to be lump-sum rebated to the local households. Without loss of generality, we assume that the retailer pays the tariff.

The problem of the producer is unchanged. Therefore, given symmetry of the deterministic steady state, the producer's first order conditions imply²

$$p_d = p_d^*. \quad (5)$$

With positive tariff rate, the bargaining problem must be modified. In a generic match, the steady state bargaining problem is now given by

$$\max_p W(p)^\theta J(p)^{1-\theta}, \quad (6)$$

²In the steady state the producer must be indifferent where to sell, at home or abroad.

where

$$\begin{aligned} W(p) &= p - v(s^t) + (1 - \delta)W, \\ J(p) &= P - (1 + T)p + (1 - \delta)J, \end{aligned}$$

and W and J are steady state values of the surplus which goes to producer and retailer, respectively. Following the same steps as in the proof of Proposition 1, we obtain

$$p = \frac{\theta P}{(1 + T)} + (1 - \theta)v. \quad (7)$$

Applying the above generic solution to prices p_d, p_d^* , we obtain

$$\begin{aligned} p_d &= \theta P_d + (1 - \theta)v, \\ p_d^* &= \theta \frac{P_d^*}{1 + T} + (1 - \theta)\frac{v}{x}. \end{aligned} \quad (8)$$

Since in the symmetric steady state $p_d = p_d^*$, we have

$$P_d = \frac{P_d^*}{1 + T},$$

and by symmetry

$$P_d = \frac{P_f}{1 + T}, \quad (9)$$

and

$$p_d = p_f. \quad (10)$$

Plugging in for consumer prices from equation (14-15) in the paper, and using (9) and (10) above, we obtain

$$\frac{p_f f}{p_d d} = \frac{f}{d} = (1 + T)^{-\gamma} \left(\frac{\omega}{1 - \omega} \right)^{-\gamma}, \quad (11)$$

Rewriting the above in logarithms³, we have

$$\Delta \log \frac{f}{d} = -\gamma \Delta T. \quad (12)$$

From the above expression we observe that a percentage point change in the tariff rate T , approximately changes the import ratio and the import expenditure ratio by γ —just like in the frictionless Armington model.

The above equation is analogous to the one commonly used in trade literature to back out the long-run elasticity of trade flows (product mix ratio). For example, Head & Ries (2001) use 3-digit industry data for

³ $\ln(1 + x) \approx x$ (for x small)

the Canadian and the US expenditure share of import to domestic shipments for the time period 1990–1995, from which they construct industry level import expenditure ratios, p_{ff}/p_{dd} , to combine this information with a detailed schedule of tariff rates by industry. The regression equation they estimate, restated in terms of our notation, is given by

$$\ln b_{it} \equiv \ln \frac{p_{fit}f_{it}}{p_{dit}d_{it}} = (1 - \gamma) \ln(1 + T_i) + \text{constant} + \text{year dummies} + \varepsilon, \quad (13)$$

where b_{it} denotes the import expenditure ratio constructed from a geometric average of the corresponding numbers for import shares from Canadian and American sides, i denotes industry, t year (1990-1995). Their estimates of the parameter γ range from 7.9 to 11.4 (depending on whether they run the above regression with additional industry dummies or pool the industry data together).

Note that this approach effectively combines the cross-sectional evidence on tariff rate dispersion across sectors and sectoral dispersion in import shares with the time series aspect of tariff changes following NAFTA. In addition, since in their regression equation Head et al. control for year dummies, estimates of these dummies additionally confirm the sluggishness of the underlying adjustment process.

Eaton & Kortum (2002) estimate a similar equation using cross-sectional evidence on price dispersion across countries measured from the United Nations retail price database and bilateral import shares. Their estimate of $\gamma = 7.3$ ($= \theta - 1$) is consistent with the findings of Head et al.

5 Mapping of National Accounting Procedures

In the data, we measure output by GDP in constant prices, consumption by the sum of private consumption expenditures and government final consumption expenditures in constant prices, investment by gross-fixed capital formation in constant prices, and employment by aggregate of civil employment in the case of the rest of the world, and by the total aggregate hours worked in the case of the US. We map this measurement methodology onto our model as follows. The GDP in constant prices is defined by

$$P_{d,0}d_t + P_{f,0}f_t + (x_0p_{d,0}^*d_t^* - p_{f,0}f_t), \quad (14)$$

consumption and investment in constant prices are defined by⁴

$$(P_{d,0}d_t + P_{f,0}f_t) \frac{c_t}{G(d_t, f_t)}, \quad (15)$$

$$(P_{d,0}d_t + P_{f,0}f_t) \frac{i_t}{G(d_t, f_t)}, \quad (16)$$

⁴Consumption and investment in period zero prices are not equal to c and i . The reason is that by the Euler's Law and equilibrium price relations, we have $G(d_t, f_t) = P_{d,t}d_t + P_{f,t}f_t$, which fails for period zero prices used instead of $P_{d,t}$ and $P_{f,t}$, i.e. $P_{d,0}d_t + P_{f,0}f_t \neq P_{d,t}d_t + P_{f,t}f_t$. Quantitatively the difference is negligible.

and employment index is defined by n_t .

Investment in marketing does not show up explicitly in the expenditure side measurement of the GDP⁵ in consistency with the methodology of national income accounting. In the national accounting system expenses on R&D, marketing, advertising are all treated as expenses on intermediate goods – see United Nations, System of National Accounts, 1993, Par. 1.49, 6.149, 6.163, 6.165, or refer to McGrattan & Prescott (2005).

Disaggregated Price Data from Japan

The dataset has been compiled by Bank of Japan from monthly survey of producer/wholesale prices: Yen based price indices for exports (f.o.b.) and domestic prices (wholesale or corporate level prices that include only domestically-produced and domestically-used goods). The quarterly series are constructed from two separate monthly compilations by Bank of Japan: 1995-2002 and 2000-2005 by taking averages and connecting the series so that the averages during the overlapping year coincide. The analysis includes 31 heavily traded manufacturing commodity categories over the time period 1995-2005. Final series have been seasonally adjusted (using Demetra 2.0, tramo-seats method), and H-P-filtered with a smoothing parameter 1600.

Real price indices have been calculated using a more refined level of disaggregation—whenever possible each subordinate category of the basic category has been divided by the corresponding domestic price index for this category, and then aggregated back using the same weights to construct the real prices reported for basic categories only.

The basic categories we include in our analysis are: (1) Engines, (2) Pumps, (3) Agricultural tractors, (4) Bearings, (5) Printing machines, (6) Copying machines, (7) Metal valves, (8) Computers, (9) Computer external memory, (10) Computer input-output devices, (11) Wire communications equipment (fax machines and telephones), (12) Radio communications equipment, (13) Color televisions, (14) Video recording and/or reproducing apparatus, (15) Home audio equipment, (16) Car audio equipment, (17) Household electrical equipment, (18) Passive components (electronic components), (19) Connecting components (electronic components), (20) Electron tubes, (21) Semiconductors, (22) Integrated circuits, (23) Electrical measuring instruments, (24) Silicon wafers, (25) Small passenger cars, (26) Other passenger cars, (27) Bicycles, (28) Photographic cameras, (29) Spectacle frames & ophthalmic lenses, (30) Medical equipment & systems, (31) Watches & clocks. ⁶

⁵There is however a small ambiguity on whether to include marketing in the trade balance from services. The real GDP would then have to include an additional term $a_f x_0 v_0^*$. Quantitatively the impact of this change on the statistical properties of the real GDP is negligible—and so we ignored it.

⁶For further details about the source data, refer to the publication of Bank of Japan: “Explanation of the 1995 Base Wholesale Price Index (Revised Version)”, Research and Statistics Department, Bank of Japan, May 2001.

6 Estimation of Productivity Shock Process

To construct the TFP residuals z from the data we follow a similar procedure to Heathcote & Perri (2002). To construct the time-series for physical capital from the time-series for gross-fixed capital formation, and the perpetual inventory method with exogenously assumed depreciation rate of $\delta = 0.025$. To measure labor input, in the case of the US we use total hours worked, and due to lack of such data, we use civil employment for the other countries. Given our quarterly dataset from 1980.1 to 2004.3 for the aggregate of main 15 European countries, Japan, Canada, Switzerland, and Australia, we construct the time-series of z from the following equation

$$\log(z) = \log(y) - 0.36 \log(k) - 0.64 \log(n), \quad (17)$$

where y denotes GDP in constant prices, and the coefficient 0.64 denotes the share of labor income in GDP—in consistency with the parameterization of our model, and the values estimated in the literature for the developed countries.

From the linearly detrended time-series of $\log(z)$ and $\log(z^*)$, we estimate the parameters of the shock process with an imposed symmetry restriction. Consequently, we obtain the value for ψ equal to 0.91, and calibration targets for international correlation of z 's of 0.3, and standard deviation of 0.79%.

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Table 1: Correlation of Nominal and PPI-deflated Real Export Price and Real Import Price (HP filtered data).

Country	Correlation					
	EPI, IPI	EPI, e	IPI, e	p_x^{ppi}, p_m^{ppi}	p_x^{ppi}, x	p_m^{ppi}, x
Belgium	0.96	0.77	0.76	0.64	0.72	0.74
Canada	0.65	0.20	0.71	0.42	0.50	0.92
Switzerland	0.72	0.59	0.80	0.40	0.51	0.83
France	0.95	0.71	0.72	0.58	0.61	0.66
Germany	0.87	0.63	0.80	-0.16	0.50	0.85
Italy	0.89	0.62	0.72	0.67	0.68	0.72
Japan	0.88	0.88	0.76	0.77	0.92	0.85
Netherlands	0.95	0.72	0.76	0.90	0.76	0.80
US	0.82	0.13	0.44	0.47	0.46	0.69
Australia	0.53	0.35	0.91	0.56	0.45	0.95
Sweden	0.91	0.54	0.67	0.38	0.60	0.74
UK	0.87	0.34	0.61	0.83	0.61	0.79
MEDIAN	0.88	0.60	0.74	0.57	0.61	0.80

Notes: EPI denotes nominal export price index, IPI denotes nominal import price index, e denotes trade-weighted nominal exchange rate (from IMF-IFS database), x denotes analogous real exchange rate. All statistics based on logged & Hodrick-Prescott filtered (with $\lambda = 1600$) quarterly time series for the period 1980:1-2004:2 except for CPI of tradables series which ends in 2000. Sources are listed at the end of the paper.

Table 2: Correlation of Nominal and PPI-deflated Real Export Price and Real Import Price (HP filtered data).

Country	Correlation					
	EPI, IPI	EPI, e	IPI, e	p_x^{ppi}, p_m^{ppi}	p_x^{ppi}, x	p_m^{ppi}, x
Belgium	0.95	0.59	0.62	0.56	0.58	0.55
Canada	0.82	0.26	0.53	0.62	0.31	0.52
Switzerland	0.47	0.23	0.75	0.54	0.36	0.56
France	0.93	0.32	0.53	0.67	0.43	0.53
Germany	0.53	0.33	0.68	-0.09	0.29	0.66
Italy	0.71	0.36	0.65	0.87	0.36	0.37
Japan	0.68	0.79	0.45	0.66	0.65	0.42
Netherlands	0.98	0.50	0.55	0.97	0.58	0.64
US	0.81	0.12	0.41	0.62	0.47	0.64
Australia	0.83	0.21	0.47	0.43	0.38	0.89
Sweden	0.90	0.22	0.45	-0.22	0.46	0.45
UK	0.97	0.21	0.30	0.78	0.60	0.70
MEDIAN	0.83	0.29	0.53	0.62	0.45	0.55

Notes: EPI denotes nominal export price index, IPI denotes nominal import price index, e denotes trade-weighted nominal exchange rate (from IMF-IFS database), x denotes analogous real exchange rate. All statistics based on logged & linearly detrended quarterly time series for the period 1980:1-2004:2 except for CPI of tradables series which ends in 2000. Sources are listed at the end of the paper.