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Abstract

In an extended Ricardian model of trade, we study the effects of improving trade deficits on relative prices, and the relation between growth rates and real exchange rates. An improvement in the trade balance induces relative wages to overshoot their long-run value, placing downward pressure on the terms of trade of the same order of magnitude found in Armington type models. Once the pattern of specialization changes, some of the decline is reversed with a smaller value of long-run depreciation. We find that divergent growth rates do not cause distinct trends in the terms of trade. The result depends on the size of the non-tradable sector and the variability of industry-specific efficiencies. We also find that self-selection into export markets causes the relative price of non-traded goods to respond to demand re-balancing, giving birth to an endogenous Balassa-Samuelson effect. The model also suggests that in the long-run the stochastic variation of the real exchange rate is dominated by the volatility of the terms of trade.

JEL classification: F10; F32; F41; F43

Keywords: Trade re-balancing; Relative prices; Ricardian trade; Growth

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1. Introduction

What is the degree of real exchange rate depreciation associated with closing large trade deficits? Do the terms of trade of faster growing economies decline? This paper re-addresses the connection between the trade balance, economic growth, and relative prices in a Ricardian model of trade.

In 1991 the United States was running a trade deficit of 28 billion, less than a percent of GDP. In 2006 the deficit was 757 billion, or 5.7 percent of GDP. The sheer magnitude and the unsustainable path of the deficit suggest an inevitable decline in the real value of the dollar. This depreciation might be an unwelcome development for the rest of the world, particularly if its magnitude is relatively large.

While the literature on trade re-balancing has attracted considerable attention, the link between beneficial supply-side developments and the terms of trade continues to occupy a central stage in international macroeconomics. Consistently-divergent growth rates between trading partners imply distinct trends in the terms of trade. Downward trends, for instance, not only price competitors out of the market but also affect the value of domestic exports. These trends, however, are hard to find in the data.

The literature on trade re-balancing has advanced along two paths, not necessarily contradictory. One path studies the effects of an improvement in trade deficits on relative prices under the assumption of fixed international specialization. This line of thought finds that closing the United States trade deficit requires a large real exchange rate depreciation. The distinguishing feature of the second strand of research is the assumption of monopolistic competition and increasing returns. Followers of this path show that the real exchange rate adjustment is much more modest compared with models that assume a specialization by origin.

Existing frameworks for linking the supply-side developments with the terms of trade have also followed two streams. The specialization-by-origin approach suggests that supply-side improvements lead to deteriorating terms of trade. Meanwhile, the second line of research, assuming monopolistic competition and increasing returns, suggests that if countries grow by expanding the range of goods available for both domestic and foreign consumption, the terms of trade does not face pressure to deteriorate. The latter thesis is supported by the recent empirical research in international trade that distinguishes between trade along the intensive margin and the extensive margin.[1]

This paper offers an alternative explanation. Our theoretical framework builds on the work of Dornbusch et al (1977) and Eaton and Kortum (2002). In our model, closing

[1] See Hummels and Klenow (2005).

the United States trade deficit is associated with a 26 percent deterioration of the conventional terms of trade in the medium run, where the pattern of specialization is held fixed. Meanwhile in the long run, in which the specialization pattern changes, terms of trade of the transfer giving country decline by 2.2 percent.

For a given pattern of international specialization, higher relative aggregate productivity simultaneously raises relative wages and reduces the unit labor requirement by the same amount. These two effects counteract, leaving the relative marginal cost of production and, consequently, the terms of trade, unaffected in the medium run. In turn, higher relative wages push the domestic trade balance into deficit, restoring equilibrium in the goods market. The terms of trade and the real exchange rate remain unaffected. Re-establishing balanced trade requires a decline in relative wages. This adjustment can be minuscule if the size of the non-tradable sector is large or the variability of industry specific efficiencies is low. In our calibration, the relative wage declines by 0.9 percent after an initial increase of 10 percent.

Finally, endogenous tradability, giving rise to self-selection into export markets, induces endogenous movements in the relative price of non-tradables. This endogenous Balassa-Samuelson effect is consistent with the findings of Ghironi and Melitz (2003). We also observe that the long-run variation in the real exchange rate is dominated by the variation in the terms of trade, a result in line with that of Engel (1999).

Our study complements the already vast literature on trade re-balancing. Obstfeld and Rogoff (1995), in a model of a small country with monopoly power, show that a financial transfer to Home from the rest of the world decreases domestic labor supply and, consequently, the supply of domestic goods. The lower supply puts upward pressure on the terms of trade. Lane and Milesi-Ferretti (2004) build a small country model with an exogenous tradable and a monopolistically competitive non-tradable sector. They demonstrate that a wealth transfer to Home from the rest of the world contracts the supply of non-tradables and engenders an increase in its relative price.[2] Galstyan (2010) examines elasticities of relative prices with respect to the trade balance, and finds that a reduction in the trade deficit to GDP ratio requires larger countries to experience a greater depreciation than smaller ones.

Dornbusch et al (1977) show that in a Ricardian trade model a positive Home transfer lowers domestic relative wages and increases the range of domestically produced goods, culminating in a deterioration of both the real exchange rate and the terms of trade. Corsetti et al (2009) study the consequence of trade re-balancing on relative prices in a model with monopolistic competition and endogenous creation of firms. They report

[2] An endogenous tradable sector eliminates this result.

that the adjustment of the terms of trade and the real exchange rate is overstated in models with the specialization-by-origin assumption.

Scrutinizing the relation between the growth rates and the terms of trade, Acemoglu and Ventura (2002) find support for the thesis that faster growing countries experience worsening terms of trade. Benigno and Thoenissen (2003), in a two-country sticky price and sticky wage model, show that improvements in total factor productivity result in a weakening of the terms of trade. On the other hand, Krugman (1989), revisiting the findings of Houthakker and Magee (1969), suggests that if countries grow by expanding production along the extensive margin, the terms of trade does not face pressure to deteriorate.

Our findings imply that demand re-balancing might initially cause a large depreciation of the United States real exchange rate. In the long run though, the real exchange rate depreciation is more modest. Meanwhile, the absence of trending terms of trade can be explained reasonably well without product creation and love for variety effects. We find that for a plausible parametrization of the model, a 10 percent growth rate of real GDP requires less than a percentage point adjustment in the terms of trade. Finally, the model suggests that a significant chunk of movements in the terms of trade over 1998-2006 is a reflection of demand side factors.

The rest of the paper is organized as follows. Section two describes the theoretical framework; section three the results of our calibration exercise; and section four yields some conclusions.

2. The model

This section extends the Ricardian trade model of Dornbusch et al (1977) by incorporating productivity draws from a Type II Extreme value distribution a la Eaton and Kortum (2002).

2.1. Technology

There are two countries, Home and Foreign. The world economy is able to produce and consume a continuum of goods indexed on a unit interval. As in Ricardo, each country has only one factor of production, labor. There are no restrictions on inter-sectoral labor mobility, but very high frictions at the international level forbid any cross-border labor re-allocation.

The technology in each country is captured by the efficiency of labor in each industry. This efficiency is a composite of industry-specific productivity and aggregate productiv-

ity, $A_k a_k(z)$, where A_k is an exogenous productivity shifter in country k common to all sectors, while $a_k(z)$ is the technology specific to industry z. Following Samuelson (1954), trade barriers take a form of iceberg costs such that delivering one unit of a good from country k to country n requires producing $d_{nk} > 1$ units of the good in country k. Perfect competition implies that the price of a good produced and consumed in country k is equal to the marginal cost of production, $p_{kk}(z) = w_k/(A_k a_k(z))$, where w_k is the nominal wage. On the other hand, international trade costs force consumers in country n to pay more for the same good, $p_{nk}(z) = p_{kk}(z)d_{nk} = w_k d_{nk}/(A_k a_k(z))$.

As in Dornbusch et al (1977), we introduce the relative Home productivity schedule $A(z) = A_h a_h(z)/(A_f a_f(z))$, where subscripts h and f refer to Home and Foreign variables. Then the sectors are ordered according to their relative productivities such that $A(z) > A(z')$ for any index $z < z'$. These assumptions imply a downward sloping relative productivity schedule, $dA(z)/dz < 0$.

Relative production costs determine the pattern of international specialization. A good is produced at Home if the cost of domestic production is lower than the total cost of imports, $w_h/(A_h a_h(z)) < w_f d_{hf}/(A_f a_f(z))$. Similarly, a good is produced abroad if the cost of Foreign production is below the domestic cost of exports, $w_f/(A_f a_f(z)) < w_h d_{fh}/(A_h a_h(z))$. Meanwhile, trade frictions give rise to goods that are too expensive to trade internationally and, therefore, are produced by both countries (the non-tradable goods sector). Figure 1 depicts the pattern of international specialization. For a relative wage rate ω_0, Home exports goods on the interval $(0, z_f^0)$ and imports Foreign produced goods on the interval $(z_h^0, 1)$. The non-tradable sector is captured by the interval (z_f^0, z_h^0).

Consumers in both countries, searching for the best bargain, choose to buy a good from the seller with the lower price. Therefore, the actual price that a consumer in country n pays for good z is

$$p_n(z) = \min\{p_{nk}(z); k = h, f\} \tag{1}$$

Following the seminal work of Eaton and Kortum (2002), we assume that industry-specific labor efficiency is drawn from the Fréchet distribution with a probability distribution function $F(a_k) = \exp\left[-T_k a_k^{-\mu}\right]$.[3] Parameter T_k governs the location of the distribution and reflects country k's state of absolute advantage, while parameter μ regulates heterogeneity in relative productivities.

The law of large numbers ensures that the fraction of goods bought by country n from country k is also the probability π_{nk} that country k supplies a particular good to country n at the lowest possible price. To find this probability, we first observe that the

[3]For any variable x appearing directly in the text we use $\exp[x] = e^x$.

probability distribution function of prices from k to n is

$$G_{nk}(p) = Pr[p_{nk}(z) \leq p] = 1 - F(a_k) = 1 - e^{-T_k\left(\frac{w_k}{A_k p} d_{nk}\right)^{-\mu}} \tag{2}$$

Hence, the probability of at least one country supplying a good to country n with a price below p is equal to $1-(1-G_{nk}(p))(1-G_{nn}(p))$. The latter expression also describes the distribution function of prices in country n

$$G_n(p) = 1 - e^{-\left\{T_k\left(\frac{w_k}{A_k} d_{nk}\right)^{-\mu} + T_n\left(\frac{w_n}{A_n}\right)^{-\mu}\right\} p^{\mu}} \tag{3}$$

Finally, the probability that country k provides a good at the lowest price is also the probability that country n charges a price above p

$$\pi_{nk} = \Pr\left(p_{nk}(z) \leq \min\left\{p_{ns}(z); s \neq k\right\}\right) = \int_0^{\infty} e^{-T_n\left(\frac{w_n}{A_n p} d_{nn}\right)^{-\mu}} dG_n(p) \tag{4}$$

Therefore, the probability that Home provides a good in the domestic market is

$$\pi_{hh} = \left(1 + \left(\frac{T_h}{T_f}\right)^{-1} \left(\frac{A_h}{A_f}\right)^{-\mu} \varpi^{\mu} d_{hf}^{-\mu}\right)^{-1} \tag{5}$$

while the probability that it supplies a good to foreigners is

$$\pi_{fh} = \left(1 + \left(\frac{T_h}{T_f}\right)^{-1} \left(\frac{A_h}{A_f}\right)^{-\mu} \varpi^{\mu} d_{fh}^{\mu}\right)^{-1} \tag{6}$$

where $\omega = w_h/w_f$ is the relative wage.

These probabilities also capture the shares of goods produced for domestic as well as foreign markets, $z_f = \pi_{fh}$ and $z_h = \pi_{hh}$. For an arbitrary relative wage rate, the range of Home produced goods increases when Home aggregate productivity rises relative to that of Foreign; Home absolute advantage improves; or Foreign export costs rise. Similarly, the array of goods that Home exports expands when relative Home aggregate productivity rises; Home absolute advantage improves; or Home export costs decline.

The cut-off condition for the domestic specialization pattern combined with equation

(5) implies the following expression for the relative productivity schedule[4]

$$A(z) = \frac{A_h}{A_f}\left(\frac{T_h}{T_f}\right)^{\frac{1}{\mu}}\left(\frac{1-z}{z}\right)^{\frac{1}{\mu}} \tag{7}$$

The schedule shifts upwards when relative aggregate productivity A_h/A_f rises, leaving the distribution of industry-specific productivities unaltered. This rise, ceteris paribus, induces an increase in relative wages of an equivalent magnitude. On the other hand, an improvement in the state of domestic absolute advantage, while raising the relative productivity schedule, calls for a redistribution of industry-specific productivities, resulting in a re-classification of industries.[5]

2.2. Consumers

The representative agent in country k consumes a basket of goods C_k defined over a unit interval, $C_k = \exp\left[\int_0^1 \ln c_k(z)dz\right]$. Two factors drive the choice of this utility function. First, the empirical findings of Bergin (2006) suggest a unitary elasticity of substitution between home and foreign tradable goods. Second, an elasticity greater than one requires a grid search procedure over the bounds of the definite integral. The assumption of unitary elasticity eliminates this requirement, considerably simplifying the numerical solution methodology.

The domestic agent's demand for a Home produced good is $c_h(i) = (p_h(i)/P_h)^{-1} C_h$ while the demand for a Foreign produced good is $c_h(j) = (p_f(j)d_{hf}/P_h)^{-1} C_h$. We define price indices of domestically produced tradable and non-tradable goods as $P_h^T = \exp\left[\frac{1}{z_f}\int_0^{z_f} \ln p_h(i)di\right]$ and $P_h^N = \exp\left[\frac{1}{z_h - z_f}\int_{z_f}^{z_h} \ln p_h(i)di\right]$. The crux here is the possibility of changing average prices in the face of constant individual prices, the compositional effect.[6] Combining these prices together, the average and the welfare-based price index that Home consumers face is

$$P_h = \left(P_h^T\right)^{z_f}\left(P_h^N\right)^{z_h - z_f}\left(d_{hf}P_f^T\right)^{1-z_h} \tag{8}$$

In line with the sectoral prices, the average productivities in the Home tradable and

[4]The same expression can be derived if one combines the cut-off condition for the foreign specialization pattern with equation (6)

[5]Our estimations of Ts for different time periods reveal a relatively stable pattern of absolute advantage. For this reason we do not consider movements in Ts.

[6]It is important to mention that throughout the text we deal with average price levels as defined in the text. These are different from the prices, where the increased availability of goods drives down the price index due to the love for variety effect. See for instance Feenstra (1994), Broda and Weinstein (2006), Galstyan and Lane (2008), Corsetti et al (2009) to mention a few.

non-tradable sectors are characterized by $A_h^T = A_h \exp\left[\frac{1}{z_f}\int_0^{z_f} \ln a_h(i)di\right]$ and $A_h^N = A_h \exp\left[\frac{1}{z_h - z_f}\int_{z_f}^{z_h} \ln a_h(i)di\right]$ respectively. These productivities change proportionally to the aggregate productivity for any given composition. At the same time, the compositional effects will prove to be non-negligible in driving the average productivities.

The relative prices of interest are (i) the terms of trade, defined as the price of Home produced tradables relative to Foreign produced tradables, $\tau = P_h^T/P_f^T$; (ii) the relative price of non-tradables in terms of tradables, $\rho_h = P_h^N/P_h^T$; and (iii) the real exchange rate, measured as the price of the Home consumption basket relative to its Foreign counterpart, $\varrho = P_h/P_f$.[7]

The relation between average prices and productivities indicates that the terms of trade is proportional to relative wages and inversely proportional to relative productivities in the tradable sector

$$\tau = \frac{P_h^T}{P_f^T} = \frac{w_h}{w_f}\left(\frac{A_h^T}{A_f^T}\right)^{-1} \tag{9}$$

The relative price of the non-tradables is inversely proportional to the inter-sectoral productivity differential, which, driven by self-selection into export markets, gives rise to an endogenous Balassa-Samuelson effect

$$\rho_h = \frac{P_h^N}{P_h^T} = \left(\frac{A_h^N}{A_h^T}\right)^{-1} \tag{10}$$

Finally, the real exchange rate is a function of the terms of trade and Home and Foreign relative prices of non-tradables

$$\varrho = \frac{P_h}{P_f} = \left(\tau\frac{\rho_h}{\rho_f}\right)^{z_h - z_f}\frac{d_{hf}^{1-z_h}}{d_{fh}^{z_f}} \tag{11}$$

which can be transformed into[8]

$$\varrho = \frac{d_{hf}^{1-z_h}}{d_{fh}^{z_f}}\left(\frac{A_f}{A_h}\right)^{z_h - z_f}\left(\frac{T_f}{T_h}\right)^{\frac{z_h - z_f}{\mu}}\left(\frac{z_h^{z_h}(1-z_h)^{1-z_h}}{z_f^{z_f}(1-z_f)^{1-z_f}}\right)^{\frac{1}{\mu}}\left(\frac{w_h}{w_f}\right)^{z_h - z_f} \tag{12}$$

Other things equal, the real exchange rate depreciates when relative aggregate pro-

[7] We have also constructed the real exchange rate based on GDP deflators. The response of this exchange rate is similar to the response of the CPI based real exchange rate. For this reason the GDP deflator based real exchange rate has been omitted from the text.

[8] To show this, use the relative productivity schedule $A(z)$ to substitute for $a_h(i)$ in the average productivity of the non-tradable sector, then integrate. The rest follows from the definition of relative prices.

ductivity rises; the state of domestic absolute advantage improves; or relative wages decline. Obviously, the changing pattern of international specialization can also influence the real exchange rate via compositional effects. For a fixed pattern of specialization though, higher relative aggregate productivity raises the relative marginal product of labor, pushing relative wages up by the same amount. On the other hand, the increase in relative aggregate productivity reduces unit labor requirements for a given wage. These two effects, working in opposite directions, cancel out. The terms of trade and the real exchange rate, in turn, do not move. Once changes in composition take place, the real exchange rate does change. The magnitude of this change depends on the demand side.

2.3. Equilibrium

In equilibrium, total Home output of good i is equal to the world demand for it

$$y_h(i) = L_h c_h(i) + d_{fh} L_f c_f(i) \tag{13}$$

while equilibrium in the domestic non-tradable sector is given by

$$y_h(i) = L_h c_h(i) \tag{14}$$

After substituting in static demand and pricing conditions, the equilibrium equations above generalize to

$$w_h L_h^T = z_f L_h P_h C_h + z_f L_f P_f C_f \tag{15}$$

and

$$w_h L_h^N = (z_h - z_f)\, L_h P_h C_h \tag{16}$$

where $L_h^T = \int_0^{z_f} l_h(i)di$ and $L_h^N = \int_{z_f}^{z_h} l_h(i)di$ are employment in the Home tradable and non-tradable sectors respectively.

Home goods market clearing therefore requires

$$w_h L_h = z_h L_h P_h C_h + z_f L_f P_f C_f \tag{17}$$

while the global equilibrium requires

$$L_h P_h C_h + L_f P_f C_f = w_h L_h + w_f L_f \tag{18}$$

The $B(z)$ schedule follows from the combination of the Home market equilibrium

condition with the global equilibrium

$$B(z) = \frac{L_f}{L_h} \frac{z_f}{(1 - z_h) + (z_h - z_f)\, tb} \tag{19}$$

and specifies the relative wage required to achieve world goods market equilibrium, while $tb = TB/w_h L_h$ and $TB = w_h L_h - L_h P_h C_h$.[9]

Finally, Figure 1 suggests a functional relation between z_f and z_h

$$\frac{A(z_f)}{d_{fh}} = A\left(z_h\right) d_{hf} \tag{20}$$

Equations (7), (19), and (20) determine the pattern of international specialization and relative wages.

2.4. Margins of trade

Shifts in fundamentals take the form of movements in either the $A(z)$ or $B(z)$ curves to the right.[10] In what follows x is the initial equilibrium value of a variable, while x' corresponds to the new equilibrium value.

The intensive margin in the Home tradable sector is defined as

$$int^T = \frac{\int_0^{z_f} w_h' l_h'(i) di}{\int_0^{z_f'} w_h' l_h'(i) di} = \frac{z_f}{z_f'} \tag{21}$$

where $z_f' > z_f$. The formula above measures the post-adjustment tradable output share of domestic sectors that maintain their tradable status. The extensive margin in the tradable sector is then simply $ext^T = 1 - z_f/z_f'$.

Likewise, the intensive margin in the Home non-tradable sector is defined as

$$int^N = \frac{\int_{z_f'}^{z_h} w_h' l_h'(i) di}{\int_{z_f'}^{z_h'} w_h' l_h'(i) di} = \frac{z_h - z_f'}{z_h' - z_f'} \tag{22}$$

and measures the post-adjustment non-tradable output share of sectors that keep their non-tradable status. While the tradable sector experiences only "creation", the non-tradable sector undergoes both "creation" and "destruction". The destruction is measured as the pre-adjustment non-tradable output share of sectors that lose their non-

[9] See Obstfeld and Rogoff (1996).

[10] Leftward shifts would require re-writing the formulas.

tradable status

$$ds^N = \frac{\int_{z_f}^{z'_f} w_h l_h(i)di}{\int_{z_f}^{z_h} w_h l_h(i)di} = \frac{z'_f - z_f}{z_h - z_f} \tag{23}$$

Creation, defined as

$$cr^N = \frac{\int_{z_h}^{z'_h} w'_h l'_h(i)di}{\int_{z'_f}^{z'_h} w'_h l'_h(i)di} = \frac{z'_h - z_h}{z'_h - z'_f} \tag{24}$$

reflects the post-adjustment non-tradable output share of the Foreign tradable goods that have become non-tradable.

3. Calibration and Results

In our calibration, the United States is the Home country while its major trading partners, averaged with weights from Bayoumi et al (2005), constitute the Foreign country.[11]

The share of the Home labor force relative to that of Foreign is $L_h = 0.1$.[12] Correspondingly, L_f is set equal to 0.9. Eaton and Kortum (2002) estimate implied states of absolute advantage for the set of industrial countries in our sample. We use relative GDP ratios to fill in the missing T for the aggregate group of emerging markets. The weighted average of these parameters is set equal to $T_f = 0.5$, while $T_h = 1$.[13] Eaton and Kortum (2002) also estimate values for μ ranging from 3.6 to 12.9.[14] Trade costs data are taken from Anderson and van Wincoop (2004). The authors provide a rough estimate of trade barriers for industrialized countries: 21 percent transportation costs, 44 percent border-related trade barriers, and 55 percent retail and wholesale distribution costs. These numbers suggest a trade cost of 1.7 excluding the distribution costs, and 2.7 including the distribution costs. We pick $\mu = 5.7$ and $d_{fh} = d_{hf} = 1.7$ so that the GDP share of Home imports is 13 percent.[15] The calibration generates an 89 percent share of non-tradable output in total output, and an 11 percent share of tradable output.

Finally, to analyze shifts in fundamentals in an environment with and without com-

[11]The aggregate trade share of the countries is 83 percent. The set of countries with normalized trade weights in parentheses includes Canada (17.9), Japan (15.3), Mexico (14.1), Germany (8.2), China (8.0), United Kingdom (5.5), Korea, Rep. (4.6), France (4.5), Italy (3.3), Singapore (2.3), Malaysia (2.1), Brazil (2.1), Netherlands (1.9), Belgium (1.6), Thailand (1.5), Australia (1.3), Spain (1.2), Sweden (1.1), India (1.0), Austria (0.6), Finland (0.5), Denmark (0.5), Norway (0.3), Portugal (0.3), New Zealand (0.3), and Greece (0.2).

[12]The data are taken from the World Bank's *World Development Indicators*.

[13]This is regardless of the value of μ.

[14]They estimate the parameters equal to 3.6, 8.28 and 12.9. The estimates vary with data and methodology of estimation.

[15]We have also tried $\mu = 3.7$ and $d_{fh} = d_{hf} = 2.2$. The results are very similar.

positional effects, we consider two periods: the medium and long run.[16] In the medium run, nominal prices and wages are fully flexible, while the pattern of international specialization is fixed. In the long run, the pattern of international specialization is free to adjust. Therefore, some of the medium-run implications of the model are similar in spirit to models with the specialization-by-origin assumption of Armington (1969).

Of primary concern is the magnitude of the adjustment of relative prices in the medium and long run that corresponds to (i) an improvement of the United States trade deficit from the current 4 percent of GDP; and (ii) an increase in domestic aggregate productivity of 10 percent.

3.1. Trade re-balancing

Obstfeld and Rogoff (1996) describe the effect of an improvement in the trade surplus as follows:

> A positive Home trade balance, for example, implies that Home's production exceeds its consumption in value, so that Home is making a transfer of resources to Foreign. Suppose that TB rises from an initial value of zero, the effect is to lower the $B(z)$ schedule, lowering Home's relative wage and increasing the range of goods Home produces for export. Accompanying this change is a fall in Home's real wage, a fall in its real exchange rate, and, as Keynes asserted, a fall in its terms of trade.(p.255)

This effect is illustrated in Figure 1. Column 1 of Table 1 reports changes in relative prices that require closing the trade deficit. In the medium run, where the pattern of specialization is held fixed, a reduction of the trade deficit necessitates a 25.6 percent decline in relative wages and the terms of trade to restore equilibrium in the goods market. These results are similar to the ones obtained by Obstfeld and Rogoff (2007) in a specialization-by-origin model. Both the figure and the table suggest some overshooting, with relative wages in the medium run dropping far below their long-run values. Though the world economy is in equilibrium at ω^m wages, the pattern of specialization is inefficient. At the ongoing wage it is more efficient for Home to produce and export a wider range of goods. The resulting increase in domestic labor demand raises relative wages to ω^l from ω^m. The long-run effect is, therefore, a lower relative wage $\omega^0 < \omega^l < \omega^m$ and a wider range of domestically produced goods.

[16] The macroeconomic literature emphasizes three periods: (i) the short run, when prices are fixed and the stock of capital does not change; (ii) the medium run, when prices are fully flexible, but the stock of capital is fixed; and (iii) the long run, when both prices and capital are free to adjust (Carlin and Soskice, 2006).

In the new long-run equilibrium, relative wages are down by 2.5 percent relative to their initial long-run equilibrium value. The terms of trade that ignores compositional effects, the conventional terms of trade, still deteriorates by the same amount as the long-run fall in relative wages. However, the terms of trade based on average export and import prices improves. Addition of new industries that have on average lower productivity levels to the existing ones, reduces average domestic productivity in the tradable sector and increases average productivity in the foreign tradable sector. Column (1) of Table 2 shows that Home productivity in the tradable sector declines by 2.5 percent, while productivity in the Foreign tradable sector rises by 2.2 percent. The composite effect improves the terms of trade by 2.2 percent.

Next, we address the consequence of trade re-balancing for the relative price of non-tradables. In the medium run, the relative price is unaltered. In the long run, the changing pattern of international specialization induces a re-classification of industries. The relative price of non-tradables responds to endogenous movements in the productivity differential, in turn driven by self-selection into export markets. Columns 1 of Tables 1 and 2 present the quantitative effects of this re-balancing. A range of higher productivity industries in the non-tradable sector switch their status, pushing down productivity in the tradable sector by 2.5 percent. Meanwhile, some low productivity industries are added to the non-tradable sector. As the range of tradables is much smaller than the range of non-tradables, these new industries decrease average productivity in the tradable sector by more than in the non-tradable sector. Overall, productivity in the non-tradable sector declines by 0.4 percent, causing the relative price of non-tradables to fall by 2.1 percent. [17]

Finally, real exchange rate movements in the medium run are driven solely by movements in the terms of trade. An improvement in trade deficit that induces a decline in relative wages places downward pressure on the terms of trade, pushing the real exchange rate down by 22 percent.[18] Over the long run, the changing pattern of international specialization restores a portion of the initial decline in relative wages. Simultaneously, movements in the relative price of foreign non-tradables counteract improvements in the domestic terms of trade, while declining domestic non-tradable prices induce downward pressure on the real exchange rate. As column 1 of Table 1 illustrates, the real exchange rate deteriorates by 2.2 percent, whereas the conventional real exchange rate declines by 2.1 percent in the long run.

[17] The self-selection result is in line with the findings of Ghironi and Melitz (2003), but these authors do not analyze trade re-balancing.

[18] These results are similar to the ones obtained by Obstfeld and Rogoff (2007) in a specialization by origin model.

It appears that the sluggish movement of non-tradable prices is dominated by movements in the terms of trade. These movements, in turn, pass the variation of the terms of trade on to the variation of the real exchange rate, a result consistent with the findings of Engel (1999).

Finally Table 2 presents the effects that the improvement of trade deficit has on the margins of trade. The intensive margin in the tradable sector accounts for 86.7 percent of post-adjustment output, while the extensive margin represents 13.3 percent. Most of the action in the non-tradable sector is explained by the intensive margin. This is to be expected given the large size of the non-tradable sector.

3.2. Productivities

The traditional literature on equilibrium exchange rates suggests that countries experiencing relatively higher growth rates face declining terms of trade. A more recent study of a two-country sticky price and sticky wage model by Benigno and Thoenissen (2003) shows that improvements in total factor productivity result in a depreciation of the terms of trade. Distinct trends in terms of trade, however, are hard to find in the data.[19]

In 1969 Houthakker and Magee estimated import and export income elasticities of demand for a set of countries. They found that faster growing countries had higher export than import income elasticities of demand. The main implication of this 45 degree line is that relatively better performing countries might not experience large swings in the terms of trade. Krugman (1989) re-estimates these elasticities and finds a similar relation with less confidence. He argues that if countries grow by expanding the range of goods available for both domestic and foreign consumption, the terms of trade, driven by the love for variety effect, does not face pressure to deteriorate.

Our model suggests that the volume of exports rises with an increase in real foreign income and declines in the domestic price of exports: $Q_x = d_{fh}^{-1}(Y_f/\tau)\rho_f^{(z_h-z_f)/(1-z_f)}$, where income is deflated with the GDP deflator. The last term signifies the expenditure switching effect: an increase in the foreign relative price of non-tradables increases the demand for domestic exports. Likewise, the volume of imports depends on real domestic income, the terms of trade, and the relative price of local non-tradables: $Q_m = d_{hf}^{-1} Y_h \tau \rho_h^{(z_h-z_f)/z_h}$. In the empirical estimation of the elasticities above, the price of non-tradables has been largely ignored. This mis-specification induces a correlation between the error term and the regressors, yielding inconsistent estimates. Meanwhile, the issue of simultaneity that stems from the relative prices and quantities regression has

[19] Acemoglu and Ventura (2002) find some support for the thesis that faster growing countries experience worsening terms of trade.

been emphasized by Houthakker and Magee in 1969, casting doubt on the existence of the 45 degree line.

This subsection offers an alternative explanation of why the real exchange rate does not exhibit a declining trend when a country grows faster than its trading partners. Figure 2 illustrates the effects of an increase in domestic aggregate productivity. For a given pattern of international specialization, higher relative aggregate productivity simultaneously raises relative wages and reduces the unit labor requirement by the same amount. These two effects offset one another, leaving the relative marginal cost of production and, consequently, the terms of trade unaffected in the medium run.[20] The expanded version of the terms of trade equation makes this point

$$\tau = \frac{w_h}{w_f}\left(\frac{A_h}{A_f}\right)^{-1}\left(\frac{e^{\frac{1}{z_f}\int_0^{z_f}\ln a_h(i)di}}{e^{\frac{1}{z_h-z_f}\int_{z_f}^{z_h}\ln a_f(j)dj}}\right)^{-1} \tag{25}$$

Higher relative wages push the domestic trade balance into deficit, restoring equilibrium in the goods market. This effect is reflected in the leftward shift of the locus of goods market equilibrium points $B(z)$. In our calibration, a 10 percent improvement in domestic aggregate productivity raises relative wages by 10 percent, pushing trade into a 1.2 percent deficit as a share of output from the initial balance. The terms of trade and the real exchange rate remain unaffected.

Restoring balanced trade requires that the $B(z)$ curve shifts back to its initial position. The long-run adjustment follows the logic of an improving trade deficit. The decline in relative wages, however, depends on the slopes of the $B(z)$ and $A(z)$ curves. The log-linearized version of the relative productivity schedule

$$\hat{A}(z_f) = \hat{A}_h - \hat{A}_f - \frac{1}{\mu\left(1-z_f^0\right)}\hat{z}_f \tag{26}$$

and that of the world goods market equilibrium condition around a balanced trade

$$\hat{B}(z_f) = \frac{1+z_h^0-z_f^0}{1-z_f^0}\hat{z}_f \tag{27}$$

show that the $B(z)$ curve is relatively steeper than the $A(z)$ curve.

[20]The same effect works in a model of endogenous varieties. When the fixed cost is modeled in terms of labour, both wages and the terms of trade decline. When the fixed cost is modeled in terms of output, wages rise while the unit labour requirement declines. The composite effect is unaltered terms of trade. See Appendix A for details.

Equations 26 and 27 determine the equilibrium relative wage

$$\hat{\varpi} = \left(\hat{A}_h - \hat{A}_f\right) - \frac{1}{1+\mu\left(1+z_h^0-z_f^0\right)}\left(\hat{A}_h - \hat{A}_f\right) \tag{28}$$

The first part of the equation indicates that the initial increase in relative wages in the medium run corresponds to an increase in relative productivities. The second part of the equation signifies the decline of the relative wage from the medium to the long-run equilibrium. This adjustment can be minuscule if the size of the non-tradable sector is large or the variability of industry-specific efficiencies is low. In our calibration, relative wages decline by 0.9 percent after a 10 percent increase in the medium run. Both the conventional terms of trade and the real exchange rate decline by less than a percent. The average terms of trade improves by 0.7 percent.

Table 2 describes the effects of increasing aggregate productivity on the margins of trade. The intensive margin in the tradable sector accounts for 96.1 percent of tradable output while the share of the extensive margin is only 3.9 percent. The relatively small extensive margin in the tradable sector is the result of a relatively steep $B(z)$ schedule. Meanwhile, most of the trade in the non-tradable sector is still accounted for by the intensive margin.

3.3. A reflection on stylized facts

If changes in fundamentals are reflected in productivity shifts only, then the implication of the model is a possibly zero or a slight negative correlation between changes in the conventional terms of trade and relative wages. As Figure 3 illustrates, this is not the case in reality. For a sample of 30 industrial and developing countries we have constructed changes in the terms of trade and relative wages.[21] The vertical axes describes average change in relative manufacturing prices over the period 1998-2006. The horizontal axes indicates average change in relative manufacturing wages over the same period. The correlation coefficient between the conventional terms of trade and the relative wages is 0.62.

To address this issue, note that the equilibrium wage equation (28) is incomplete: demand side determinants are absent. Log-linearization of the equilibrium wage equation

[21] Authors calculations based on BACI (Base pour l'Analyse du Commerce International) and KILM (Key Indicators of the Labour Market) data.

around a balance trade results in

$$\hat{\varpi} = \frac{\mu\left(1+z_h^0-z_f^0\right)}{1+\mu\left(1+z_h^0-z_f^0\right)}\left(\hat{A}_h-\hat{A}_f\right) - \frac{z_h^0-z_f^0}{1-z_h^0}\frac{1}{1+\mu\left(1+z_h^0-z_f^0\right)}tb \tag{29}$$

Two components drive relative wages: shifts in supply side and shifts in demand (the trade balance is interpreted as capturing shifts in demand side determinants.)[22] The supply side predictions of the model are clear. Improving productivity raises relative wages by a equivalent order of magnitude, leaving a small negative impact on relative marginal cost. The latter translates into a marginal deterioration of the terms of trade, suggesting an existence of a slight negative correlation between relative wages and the terms of trade.

On the other hand, shifts in aggregate demand shift the $B(z)$ curve. As these movements leave relative aggregate productivities unaltered, relative wages swing by a similar magnitude. These movements, in turn, suggest an existence of a significantly positive correlation between relative wages and the terms of trade. Figure 4 plots the change in model generated terms of trade against the change in model generated wages. The coefficient of correlation is 0.88. To create the scatter plot, the relative productivity is calculated as $\hat{A}_h - \hat{A}_f = \hat{\omega} - \hat{\tau}_c$, while tby is captured with actual trade balance as a share of GDP in 2006. Due to lack of data, we have used the United States z_h^0 and z_f^0 for all of the countries.[23]

Table 3 describes the second order moments, as well as correlations between actual and fitted relative wages and the terms of trade. $\hat{\omega}$ and $\hat{\tau}_c$ indicate average changes in relative manufacturing wages and conventional manufacturing terms of trade over 1998-2006 for a sample of 30 industrial and developing countries, while $\tilde{\omega}$ and $\tilde{\tau}_c$ are model-generated variables. Elements on the main diagonal represent standard deviations, whereas Off-diagonal elements represent pairwise correlations. The volatility of manufacturing terms of trade is 0.01, compared to the simulated value of 0.05. On the other hand, the volatility of relative manufacturing wages over the sample period is 0.03, compared to a simulated value of 0.05. Correlation coefficient between actual and model generated relative wage is 0.6, while the one between actual and fitted terms of trade is 0.46.

Thought the relation is not perfect, it is not bad either. The model suggests that a significant chunk of movements in the terms of trade over 1998-2006 is a reflection of

[22] Alternatively, one can introduce demand side shifts directly into the model. See Galstyan and Lane (2009).

[23] No doubt, this will "over-fit" the scatter-plot.

demand side factors.

4. Conclusions

In an extended Ricardian model of trade this paper revisits the effects of improving trade deficits on relative prices, and the relation between growth rates and the real exchange rate.

We find that a terms of trade deterioration occurs when the prices of exports and imports ignore compositional effects. When compositional effects are allowed, a narrowing of the United States trade deficit is associated with a 2.2 percent improvement in the average terms of trade over the long run, while the conventional terms of trade declines by 2.5 percent. In the medium run, however, closing the trade deficit is associated with a 26 percent decline in the terms of trade and a 22 percent real depreciation of the exchange rate.

Looking at the relation between growth and the terms of trade, we observe that countries can grow without major declines in the latter. In our model, higher relative aggregate productivity raises the relative marginal product of labor increasing relative wages by the same amount. Meanwhile, an increase in relative aggregate productivity reduces the unit labor requirement for a given wage. These two effects translate into a constant level of the terms of trade. In the long run, declining relative wages, combined with compositional effects, contribute to changes in the terms of trade. The decline in turn depends on the size of the non-tradable sector and the variability of industry-specific efficiencies. A 10 percent increase in the United States GDP relative to that of the rest of the world is associated with a less than 1 percent movement in either the terms of trade or the real exchange rate.

We find that self-selection into export markets causes the relative price of non-tradable goods to respond to demand side changes, giving birth to an endogenous Balassa-Samuelson effect. Our calibration exercise also suggests that in the long run the variation of the real exchange rate is dominated by the variation of the terms of trade.

Finally, the model suggests that a significant chunk of movements in the terms of trade over 1998-2006 is a reflection of demand side factors.

Appendix: Increasing returns, productivity and the terms of trade

There are two countries, Home and Foreign. The number of goods produced in the world is endogenously determined. The representative agent in country k maximizes the utility function $C_k = \left(\sum_z c_k^{\frac{\eta-1}{\eta}}(z) \right)^{\frac{\eta}{\eta-1}}$. The domestic agent's demand for a Home produced good i is $c_h(i) = (p_h(i)/P_h)^{-\eta} C_h$, while the demand for a Foreign produced good j is $c_h(j) = (p_h(j)/P_h)^{-\eta} C_h$. Similar demand equations are derived for the foreign agent.

There exists a pool of firms that can produce and export. To produce, a potential entrant must incur fixed costs. Output is produced using labor as the only input in production: $y_k(z) = A_k (L_k(z) - \alpha_k)$. Under these assumptions, the monopolist charges a price that is marked-up over the marginal cost of production: $p_k(z) = \eta (\eta - 1)^{-1} w_k A_k^{-1}$, where w and A denote wages and productivity respectively.

The zero-profit condition pins down output per firm, $y_k(z) = \alpha_k A_k (\eta - 1)$. Moreover, equilibrium in the labor market identifies the number of firms producing in domestic and foreign countries, $n_k = L_k (\alpha_k \eta)^{-1}$. Finally, equilibrium in the goods market identifies relative wages, $\omega = (A_h/A_f)^{1-\eta} (\alpha_h/\alpha_f)^{-\eta}$. The terms of trade is then given by $\tau = \omega (A_h/A_f)^{-1}$.

Higher productivity raises average output per firm, leaving the number of firms unaltered. Following a hike in domestic productivity, wages decline by more than the fall in the relative unit labour requirement. The composite effect is a decline in relative marginal costs, and a deterioration in the terms of trade.

If fixed costs take a form of output instead of labour (that is $\alpha_k = \beta_k / A_k$ in the above), then higher domestic productivity increases the number of firms, leaving output per firm unaffected: $y_k(z) = \beta_k (\eta - 1)$, $n_k = A_k L_k (\eta \beta_k)^{-1}$. Rising productivity increases relative wages by the same amount, $\omega = (A_h/A_f) \left(\beta_h/\beta_f\right)^{-\eta}$. Furthermore, the unit labour requirement declines by the same magnitude. As a result, the terms of trade does not deteriorate: $\tau = \left(\beta_h/\beta_f\right)^{-\eta}$.

The addition of a non-tradable sector will influence the results as inter-sectoral labor reallocation will also tend to affect relative wages.

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Figure 1: Trade Re-Balancing

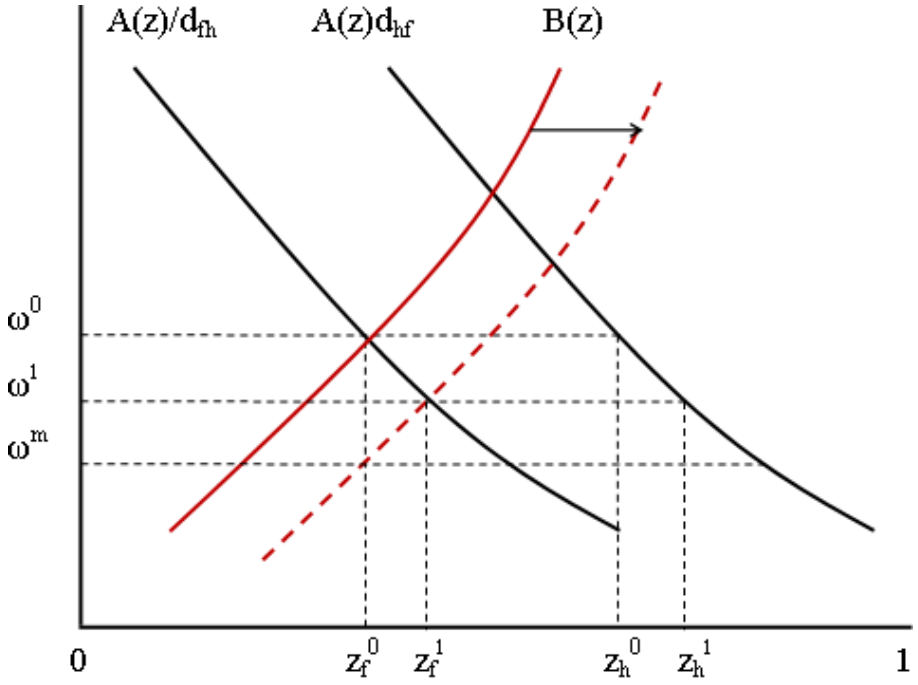


Figure 2: Productivity Increase

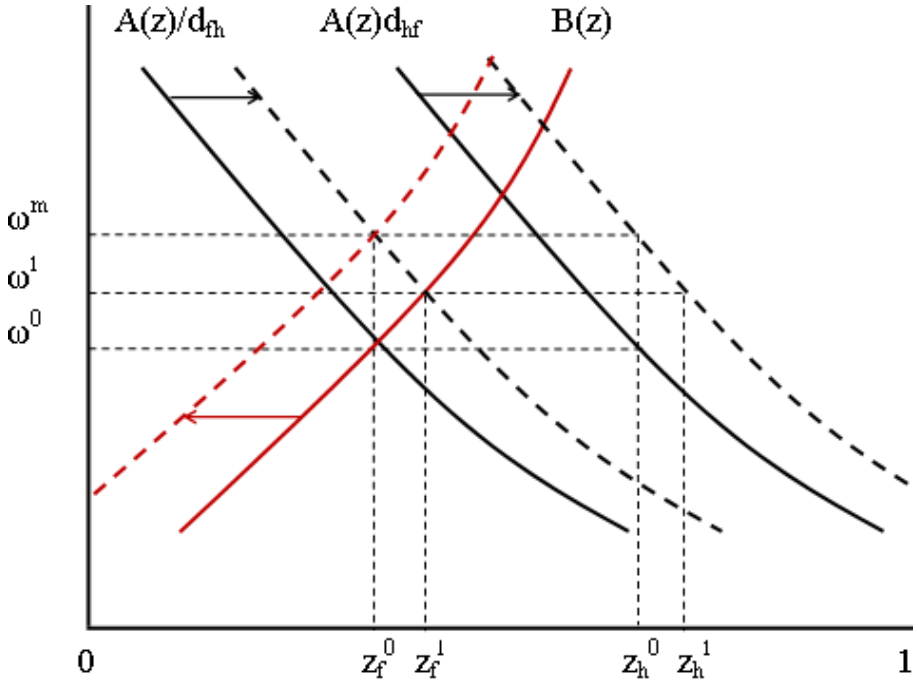
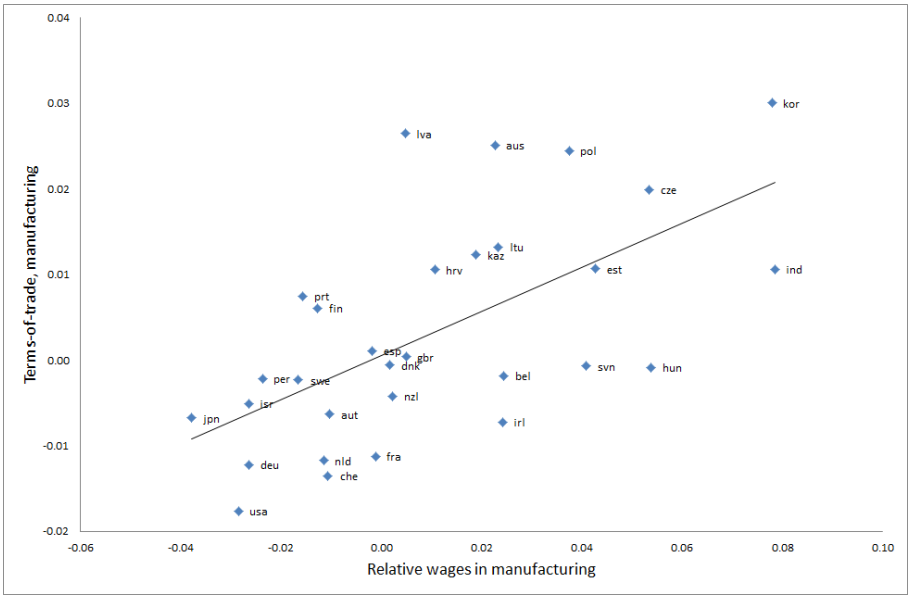
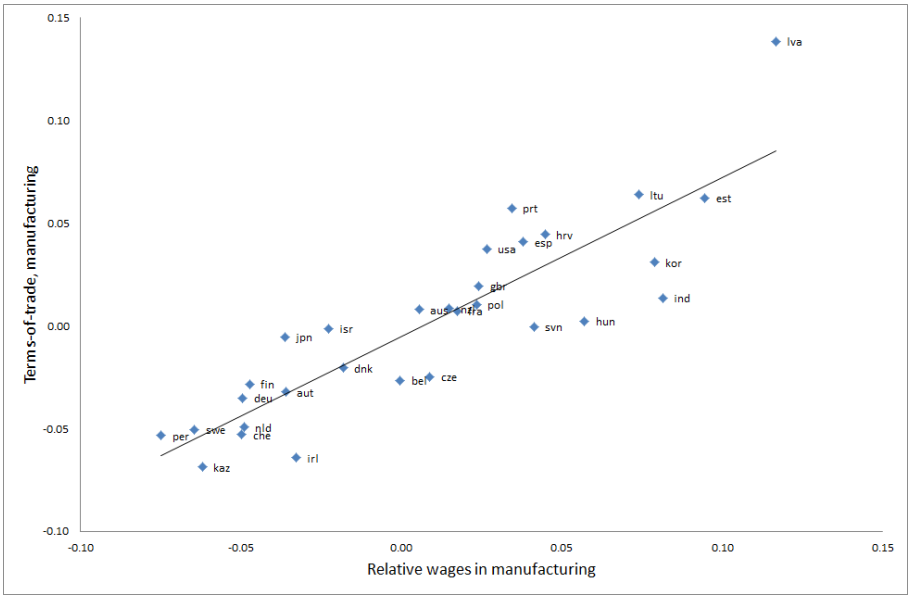


Figure 3: Terms of trade vs. relative wages



Note: The vertical axes indicates average change of relative prices in manufacturing over the period 1998-2006. The horizontal axes indicates the changes in relative manufacturing wages over the same period. Authors calculations based on BACI (Base pour l'Analyse du Commerce International) and KILM (Key Indicators of the Labour Market) data.

Figure 4: Terms of trade vs. relative wages, simulated



Note: The vertical axes indicates average simulated change of relative prices in manufacturing. The horizontal axes indicates simulated change in relative manufacturing wages.

Table 1: Relative prices

	(1)	(2)
Part A: Medium run		
$d \ln \omega$	-25.6	10
$d \ln \tau$	-25.6	0
$d \ln \varrho$	-22.3	0
$d \ln \rho_h$	0	0
$d \ln \rho_f$	0	0
Part B: Long run, average prices		
$d \ln \omega$	-2.5	9.1
$d \ln \tau$	2.2	0.7
$d \ln \varrho$	-2.2	-0.7
$d \ln \rho_h$	-2.1	-0.7
$d \ln \rho_f$	1.8	0.6
Part C: Long run, conventional prices		
$d \ln \tau_c$	-2.5	-0.9
$d \ln \varrho_c$	-2.1	-0.8
$d \ln \rho_{h,c}$	0	0
$d \ln \rho_{f,c}$	0	0

Note: Columns (1) indicate the response to a re-balancing of trade from 4 percent of GDP to a balanced position. Columns (2) indicate the response to a 10 percent increase in aggregate Home productivity.

Table 2: Productivities and trade margins

	(1)	(2)
Part A: Productivities		
$d \ln A_h^T$	-2.5	9.1
$d \ln A_h^N$	-0.4	9.8
$d \ln A_f^T$	2.2	0.7
$d \ln A_f^N$	0.5	0.1
Part B: Trade margins		
int^T	86.7	95.5
ext^T	13.3	4.5
int^N	98.2	99.5
ds^N	0.3	0.1
cr^N	1.8	0.5

Note: Columns (1) indicate the response to a re-balancing of trade from 4 percent of GDP to a balanced position. Columns (2) indicate the response to a 10 percent increase in aggregate Home productivity.

Table 3: Stylized facts

	$\hat{\omega}$	$\hat{\tau}_c$	$\tilde{\omega}$	$\tilde{\tau}_c$
$\hat{\omega}$	0.03	0.62	0.60	
$\hat{\tau}_c$		0.01		
$\tilde{\omega}$			0.05	
$\tilde{\tau}_c$		0.46	0.88	0.05

Note: $\hat{\omega}$ and $\hat{\tau}_c$ indicated average changes in relative manufacturing wages and conventional manufacturing terms of trade over 1998-2006 for a sample of 30 industrial and developing countries (authors calculations based on BACI (Base pour l'Analyse du Commerce International) and KILM (Key Indicators of the Labour Market) data). $\tilde{\omega}$ and $\tilde{\tau}_c$ are model-generated variables. Elements on the main diagonal represent standard deviations. Off-diagonal element represent cross-correlations.

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