Long-Run Price Elasticity of Trade and the Trade-Comovement Puzzle *

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ABSTRACT

Recent studies have found significant support for the positive link between bilateral trade intensity and business cycle comovement of output and TFP in a cross-section of industrialized country pairs. Since this feature of the data is not reproduced by the workhorse model of international business cycle, it is referred to as the *trade-comovement puzzle*. In the paper, we show that the puzzle is intimately related to the failure of the standard theory to account for the high long-run price elasticity of trade flows. We do so by enriching the standard theory with frictions of building market shares and establishing trade relations, which generate low short-run price elasticity of trade coexisting with the high long-run price elasticity. We show that when the low short-run elasticity is generated by explicitly modeled frictions of building market shares, the theory can account for 50% and 78% of the trade-comovement relation in the data for output and TFP, respectively.

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1. Introduction

The conventional wisdom about the international comovement of business cycles is that countries which trade more with each other should have more synchronized output fluctuations. The logic behind this assertion is that shocks in one country, by *demand complementarity*, spillover to demand for goods produced in major trade partner countries, and in effect lead to an increased correlation of their GDPs. The link suggested by this intuition has been extensively studied empirically, and shown to be consistent with the data. By running cross-country regressions Frankel & Rose (1998), Clark & van Wincoop (2001), Calderon, Chong & Stein (2002), Otto, Voss & Willard (2001), Baxter & Kouparitsas (2005), Kose & Yi (2006) all find that, among industrialized bilateral country pairs, more trade is associated with more synchronized business cycle fluctuations.

In a series of papers, Kose and Yi (2001, 2006) show that the conventional wisdom and the above pattern in the data are at odds with the standard model of international macroeconomics (Backus, Kehoe & Kydland (1995))[1]. Kose and Yi show that in the standard model there is an additional opposing force to the complementarity effect, potent enough to reverse the relationship between trade and comovement. This force is the *resource-shifting effect*, which in this model environment makes productive resources (capital and labor) shift over the business cycle towards the most productive country, and thereby tends to reduce international correlation of output.

The reason why resource-shifting effect affects the trade-comovement relation implied by the standard model is because its intensity varies with trade. The mechanism behind it is as follows. When countries trade little with each other, which in the model corresponds to high assumed bilateral trade barriers in the long-run, it is costly to produce goods in a country different from the one in which these goods are eventually consumed. This effect acts as a counterforce to the resource shifting motive because shifting resources (production) towards the most productive country implies that either vast amount of resources are wasted in transportation (due to high trade barriers) or there is a departure from international

[1] Even in the best scenario of financial autarky and exogenously assumed correlation of the primitive productivity shocks increasing with trade intensity as in the data, the standard model accounts for merely 30% of the relationship. Under complete markets, the standard model gives the opposite prediction to the data.

consumption smoothing (and risk sharing). As a result, when trade barriers are high, the resource-shifting effect is weak. On the other hand, when countries trade more and trade barriers are lower, resource shifting intensifies and lowers business cycle synchronization. In the standard model this effect quantitatively dominates and we observe a negative correlation between trade and comovement of business cycles.

To address this puzzle, in this paper we keep the complete asset market assumption intact, and model trade frictions which lead to a disconnect between the short-run and the long-run price elasticity of trade flows. These frictions allow us to be consistent with the long-run oriented trade literature in assuming that domestic and foreign goods are intrinsically closely substitutable *and* still have a low short-run elasticity in consistency with the business cycle literature[2]. Our main finding is that such explicit modeling of the disconnect between the long-run and short-run price elasticity of trade, even under the worst case scenario of complete asset markets, can account for about half of the trade-comovement relation in the data. We conjecture that a mild restriction on asset market incompleteness would be enough in our model to match the data exactly.

The reason why our theory successfully accounts for the trade-comovement pattern is twofold. First, short-run search and matching frictions involved in trade in goods generate an additional complementarity effect similar to the one generated by the Armington aggregation with low elasticity of substitution between the domestic and foreign goods. Second, the high intrinsic elasticity of substitution between domestic and foreign goods effectively dampens the influence of the resource shifting effect on the trade-comovement relation predicted by the theory. This is because when domestic and foreign goods are closely substitutable in the long-run, much smaller variation in the assumed bilateral trade barriers is required to replicate *in the model*[3] the differences of trade intensities seen in the cross-section of bilateral country pairs. A smaller variation of trade barriers across bilateral country pairs leads to a smaller variation of the motive to produce goods in the country where they are consumed, and a smaller variation of the intensity of the resource-shifting effect. As a result, in the cross-section of bilateral country pairs simulated *from our model,* the resource shifting motive varies

[2]See Ruhl (2005) for more details.
[3] In our simulations, tariffs vary from 0% to 64%.

much less, and the still present complementarity effect then dominates.

The additional complementarity effect in our framework is implied by search and matching frictions involved in trade in goods. Unlike in frictionless environments, in our model producers need to first establish long-lasting trade relations with their customers in order to sell their goods, and the build-up of such relationships is time consuming. This introduces sluggishness in market shares of producers and thus sluggishness in the consumed ratio of domestic products and imports. As a result, after a positive productivity shock, a larger number of searching customers in the domestic country increases the demand for imported goods in the short-run in proportion to the initial market share of foreign importers – just like in a model with complementarity built into preferences.

The high intrinsic elasticity of substitution between domestic and foreign goods, crucial for our results, finds strong support in the long-run oriented trade literature. Numerous studies confirm that long-run elasticity of trade with respect to permanent tariff changes is very large (see for example Head & Ries (2001), Eaton & Kortum (2002), Clausing (2001)), and large values of elasticity are needed to account for the evolution of world trade in the last century (Yi (2003)). The measurement of long-run elasticity in the literature exactly aligns with the type of exercise performed to account for the trade-comovement relation, which further reinforces the need to use a high value of elasticity.

The rest of the paper is organized as follows. In Section 2 we present an overview of empirical evidence reported in the literature. Section 3 presents the setup and discusses the features of the model. Calibration and results are presented in Section 3. Section 5 presents the results. Section 6 concludes.

2. Link Between Trade and Comovement in the Data

In this section, we set a quantitative target for the model. For this purpose, we explore the empirical relation between trade and comovement of business cycles in a sample of 20 industrialized countries over the period 1980Q1 - 2004Q2. Countries in our sample constitute about 79% of world GDP and 62% of world trade (as of year 1994).

More specifically, we perform a simple data study that we will later mimic in the model. The result of this study gives us the estimates of the regression coefficients between bilateral trade intensity and bilateral correlations of output and TFP. We find that coefficients for both output and TFP are positive and statistically significant. The robustness of these results to the use of instrumental variables and various controls has been widely documented in the literature (see for example Kose & Yi (2006), Baxter & Kouparitsas (2005) or the extensive analysis in Clark & van Wincoop (2001)), and so we will not repeat it here.

In Table 1, we report results from simple regressions of correlations of GDP and TFP on trade intensity, in a cross-section of bilateral country pairs. In the exercise, we use quarterly data from 20 industrialized countries for the years 1980Q1 - 2004Q2, divided into 2 subperiods[4]: 1980Q1-1993Q4 and 1994Q1-2004Q4. The list of countries included in our sample is: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States. The reported statistic is the estimated β_x coefficient of the equation

$$corr(x_i, x_j)_\tau = \alpha + \beta_x trade_{ij,\tau} + \varepsilon_{ij,\tau}, \tag{1}$$

where, $corr(x_i, x_j)_\tau$ is the correlation between countries i and j in subperiod τ of the logged and HP-filtered series of real GDP or Solow residuals.The variable $trade_{ij,\tau}$ is a measure of bilateral trade intensity of countries i and j in subperiod τ, given by the log of

$$\frac{IM_{ij,\tau} + IM_{ji,\tau}}{GDP_{i,\tau} + GDP_{j,\tau}},$$

where $IM_{ij,\tau}$ are nominal imports (in US dollars) by country i from country j at the beginning of subperiod τ, and $GDP_{i,\tau}$ is the nominal GDP (in US dollars) of country i at the beginning[5] of subperiod τ. Bilateral trade intensity in our sample ranges from 0.019% to 7.37%. In total, we have 392 observations.

Table 1 reports regression coefficients together with 5% significance intervals. As we can see, both coefficients are statistically significant and indicate a positive relationship

[4]Not all years of data are available for all countries. For a detailed description of the data we use, see Appendix.

[5]The coefficients do not change significantly when we use end of subperiod statistics of trade intensity. They both remain significant on a 95% level, the coefficient for GDP increases to 0.0708, and the coefficient for Solow residuals decreases to 0.0269.

Table 1: OLS estimates of β

x	β_x
Gross Domestic Product	0.0616 $(0.0332, 0.09)$
Total Factor Productivity	0.0297 $(0.0035, 0.0559)$

between trade intensity and correlation of GDPs and TFPs, consistent with results reported by other authors. These values imply that doubling trade intensity is associated with an increase of correlation of GDP of about 0.043, and correlation of TFP of about 0.021. Given the dispersion of trade intensities in our dataset, this implies that the difference in correlation of output between 10th and 90th percentile of bilateral trade intensities is about 0.2. We now proceed with the presentation of the model.

3. Model

Time is discrete, $t = 0, 1, 2...$, and horizon infinite. The world is comprised of three countries. The first two countries, labeled *domestic* (D) and *foreign* (F), are symmetric and of equal size, and the third country, labeled *rest of the world* (W), is allowed to differ in size. The size of a country is determined by the population size of atomless households residing in the country. Labor and capital, supplied by the households are assumed to be immobile across countries, and are used by local producers to produce goods. Goods are differentiated by the country of origin and tradable. The good produced in the domestic country is labeled D, the good produced in the foreign country is labeled F, and the good produced in the rest of the world is labeled W. Households in each country use these goods for consumption and investment in physical capital. Their preferences are characterized by imperfect substitutability between each type of good, and a preference bias towards the locally produced good. Financial markets are assumed to be complete.

As far as trade in goods is concerned, we follow here Drozd & Nosal (2008) and introduce search and matching frictions involved in trade in goods. These frictions are critical to our analysis. The detailed description of these frictions is as follows. In each country we introduce a sector of local retailers who purchase tradable goods from domestic and foreign producers and locally resell them to the households. Retailers search for producers of goods (foreign and domestic), and producers accumulate *marketing capital* to attract searching retailers. Trade between households and retailers is assumed perfectly competitive and frictionless. Trade between producers and retailers is subject to the matching friction and prices are determined by bargaining.

A. Technology and Notation

The source of uncertainty in the model is the random productivity shock affecting the production technology in each country. The history of shocks up to and including period t is denoted by $s^t = (s_0, s_1, ...s_t)$, where $s_t \equiv (\varepsilon_{it})_{i\in\{D,F,W\}}$ and ε_{it} is an iid random variable. The initial realization s_0, as well as time invariant probability measure μ over the three dimensional shock space S are given.

Each country $i = D, F, W$ has access to a constant returns to scale production technology $z_i(s^t)F_i\left(k_i(s^t), l_i(s^t)\right)$, which uses country-specific capital and labor, and is subject to country-specific technology shock z_i. The technology shock z_i is given by an exogenous AR(1) process

$$\log(z_i(s^t)) = \psi \log(z_i(s^{t-1})) + \varepsilon_{it},$$

where $0 < \psi < 1$ is the shock persistence parameter, and ε_{it} is Normally distributed i.i.d. random variable with zero mean.

Since the production function is assumed to be constant returns to scale, we summarize production constraints by an economy-wide marginal cost $v_i(s^t)$. Given factor prices $w_i\left(s^t\right), r_i\left(s^t\right)$ and the shock $z_i\left(s^t\right)$, the marginal cost in each country can be defined as follows

$$v_i\left(s^t\right) \equiv \min_{k,l} \left\{w_i\left(s^t\right) l + r_i\left(s^t\right) k \;\middle|\; z_i\left(s^t\right) F\left(k,l\right) = 1\right\}. \tag{2}$$

B. Households

The problem of the households is standard. Each country $i = D, F, W$ is populated by a fixed measure L_i of identical and infinitely lived households. Households supply production factors to firms, accumulate physical capital, and consume. After each history s^t, the households choose their allocation, which consist of the level of consumption $c_i(s^t)$, investment in physical capital $i_i(s^t)$, labor supply $l_i(s^t)$, purchases of tradable goods $D_i(s^t)$, $F_i(s^t)$, $W_i(s^t)$, and purchases of a set of one period state-contingent bonds $b_i(s_{t+1}|s^t)$, to maximize their expected discounted lifetime utility given by

$$\sum_{t=0}^{\infty} \beta^t \int_{S^t} u_i\left(c_i\left(s^t\right), 1 - l_i\left(s^t\right)\right) \mu\left(ds^t\right), \tag{3}$$

where the instantaneous utility function u is parameterized by

$$u_i(c,l) = \frac{(c^{\eta}(1-l)^{1-\eta})^{1-\sigma}}{1-\sigma}, \ \sigma > 0, \ 0 \leq \eta \leq 1.$$

The preferences towards D, F, and W goods are described by a CES aggregator G_i with the elasticity of substitution γ and home bias parameters ω_i^j,

$$G_i(D,F,W) = \left(\omega_i^D D^{\frac{\gamma-1}{\gamma}} + \omega_i^F F^{\frac{\gamma-1}{\gamma}} + \omega_i^W W^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}, \ \gamma \geq 0, \ \sum_{j=D,F,W} \omega_i^j = 1. \tag{4}$$

The composite output is used for consumption and investment in physical capital,

$$c_i\left(s^t\right) + i_i\left(s^t\right) = G_i\left(D_i\left(s^t\right), F_i\left(s^t\right), W_i\left(s^t\right)\right). \tag{5}$$

Given the sequence of investment $i_i(s^t)$, physical capital in country i follows the standard law of motion with a constant depreciation rate δ

$$k_i\left(s^t\right) = (1-\delta)\, k_i\left(s^{t-1}\right) + i_i\left(s^t\right), \ 0 < \delta \leq 1. \tag{6}$$

The budget constraint of the household can be defined sequentially. After each history

s^t, households in each country face a budget constraint given by

$$\begin{aligned} & P_i^D\left(s^t\right) D_i\left(s^t\right) + P_i^F\left(s^t\right) F_i\left(s^t\right) + P_i^W\left(s^t\right) W_i\left(s^t\right) \\ & + \int_S Q_i(s_{t+1}|s^t) b_i(s_{t+1}|s^t) \mu(ds_{t+1}) \\ = \; & b_i\left(s^t\right) + w_i\left(s^t\right) l_i\left(s^t\right) + r_i\left(s^t\right) k_i\left(s^{t-1}\right) + \Pi_i\left(s^t\right), \; i = D, F, W \end{aligned} \tag{7}$$

On the expenditure side, the budget constraint includes purchases of goods in the retail market at retail prices P_j^i, and purchases of the set of one-period state contingent bonds $b_i(s_{t+1}|s^t)$ traded at state contingent prices given by $Q_i(s_{t+1}|s^t)$. On the income side, it includes income from maturing bonds $b_i\left(s^t\right)$ purchased in the previous period, labor income $w_i\left(s^t\right) l_i\left(s^t\right)$, physical capital rental income $r_i\left(s^t\right) k_i\left(s^{t-1}\right)$, and profits paid by the domestic firms $\Pi_i(s^t)$.

In the formulation of the household problem we normalize the prices at each s^t so that the composite consumption good c_i is the numeraire in each country. We do so by setting the level of CPI[6] price index in each country equal to 1.

In addition, because the world asset market is assumed to be fully integrated, there is a spot price which translates country i's numeraire to country j's numeraire $x_i^j(s^t)$, and must satisfy the following non-arbitrage condition

$$Q_j(s_{t+1}|s^t) = \frac{x_i^j(s^{t+1})}{x_i^j(s^t)} Q_i(s_{t+1}|s^t). \tag{8}$$

This price is the real exchange rate as the numeraire in each country are the consumption baskets. The above condition is standard under complete markets and says that one cannot profit by trading assets denominated in the other country numeraire unit.

Summarizing, given the initial values for $k_i(s^{-1})$ and $b_i(s^{-1})$, households choose their

[6] The CPI_i is defined as the lowest cost of acquiring a unit of consumption, and thus solves

$$CPI_i = \min_{D,F,W} P_i^D D + P_i^F F + P_i^G W$$

subject to

$$G_i(D, F, W) = 1.$$

allocations to maximize (3) subject to the aggregation constraint (5), the law of motion for physical capital (6), the budget constraints (7), the no-Ponzi scheme condition, and the numeraire normalization. The following necessary conditions characterize the household's problem:

(i) consumption/leisure choice

$$\frac{u_{il}\left(s^t\right)}{u_{ic}\left(s^t\right)} = -w_i\left(s^t\right), \tag{9}$$

(ii) Euler equation

$$u_{ic}\left(s^t\right) = \beta E_{s^t}[u_{ic}\left(s^{t+1}\right)\left((1-\delta_k) + r_i\left(s^{t+1}\right)\right)],$$

(iii) demand equations

$$P_i^j\left(s^t\right) = G_{ij}\left(s^t\right), \tag{10}$$

(iv) pricing kernels

$$Q_i(s_{t+1}|s^t) = \beta\frac{u_{ic}\left(s^{t+1}\right)}{u_{ic}\left(s^t\right)}, \tag{11}$$

(v) non-arbitrage condition

$$Q_j(s_{t+1}|s^t) = \frac{x_i^j(s^{t+1})}{x_i^j(s^t)}Q_i(s_{t+1}|s^t)$$

where $u_{il}\left(s^t\right)$, $u_{ic}\left(s^t\right)$, $G_{iD}\left(s^t\right)$ denote derivatives of the instantaneous utility function and the Armington aggregator function with respect to the subscripted arguments[7].

C. Producers

Tradeable goods are country specific and are produced by a unit measure of atomless competitive producers residing in each country. Producers employ local capital and labor to produce these goods using the production technology available in their country of residence. In order to sell the goods, producers must match with retailers who become their customers. This

[7]By comparing side-by-side (iv) and iterating backwards to state s^0, one can obtain a simpler condition for the real exchange rate

$$x_i^j\left(s^t\right) = \frac{u_{jc}\left(s^t\right)}{u_{ic}\left(s^t\right)}x_i^j\left(s^0\right).$$

The above equation is referred to as the *efficient risk sharing equation.*

feature is central to our analysis and is described below in detail. At the end of this section we summarize the producer's problem with the profit maximization problem they solve.

Marketing friction. The novel feature introduced in this paper is that producers actively match with the retailers. Specifically, the producers have access to an explicitly formulated *marketing technology,* and accumulate what we term *marketing capital* m. Marketing capital must be separately accumulated in each country where the producer wants to sell the goods. The marketing capital accumulated by a given producer relative to the marketing capital held by other producers determines the fraction of searching retailers that meet with this producer. More specifically, a producer from country i with marketing capital $m_i^j(s^t)$ in country j attracts a fraction

$$\frac{m_i^j\left(s^t\right)}{\sum_{i=D,F,W} \bar{m}_i^j\left(s^t\right)} \tag{12}$$

of searching retailers in any given period, where $\bar{m}_i^j(s^t)$ denotes the average level of marketing capital held by the producers from country i in country j. In the above formulation, notice the following two features. First, it is the *relative* marketing capital that is assumed to matter for the matching probability. Second, because each producer is atomless, their choice of marketing capital level m does not affect the average level $\bar{m}$, which is thus taken by them as given. Clearly, in equilibrium $\bar{m}$ and m coincide as there is measure one of producers in each country.

The shares given by (12) play a crucial role for each producer in their customer capital build-up problem, as they determine the arrival rate of new customers to the list of customers with whom a given producer is already matched. More specifically, given that there is mass $h_j(s^t)$ of searching retailers (potential customers) in country j, the mass of new customers to the list of the producer from country i selling in country j is equal to

$$\frac{m_i^j\left(s^t\right)}{\sum_{i=D,F,W} \bar{m}_i^j\left(s^t\right)} h_j\left(s^t\right). \tag{13}$$

Each match is long-lasting and subject to an exogenous destruction rate $\delta_{h,}$, which gives rise the law of motion for the customer list H_i^j of a given producer

$$H_i^j(s^t) = (1-\delta_H)H_i^j(s^{t-1}) + \frac{m_i^j\left(s^t\right)}{\sum_{i=D,F,W}\bar{m}_i^j\left(s^t\right)}h_j\left(s^t\right), \tag{14}$$

The size of this list is critical for the producer as it puts a limit on the amount of good they can sell in each country. Specifically, in each match we assumed that one unit of the good can be traded in per period. Thus, sales cannot be larger than the customer list. The *sales constraint* of the producer of good D in country j is given by[8]

$$D_j(s^t) \leq H_D^j(s^t). \tag{15}$$

Analogous equations hold for other goods and all countries.

Marketing capital accumulation. Producers in the model attract searching customers by accumulating a form of capital, called marketing capital m. Given last period's level of marketing capital $m_i^j(s^{t-1})$ and the current level of instantaneous marketing input $a_i^j\left(s^t\right)$, current period's marketing capital is given by

$$m_i^j(s^t) = (1-\delta_m)\, m_i^j(s^{t-1}) + a_i^j(s^t) - \phi m_i^j\left(s^{t-1}\right)\left(\frac{a_i^j\left(s^t\right)}{m_i^j\left(s^{t-1}\right)} - \delta_m\right)^2. \tag{16}$$

This specification nests decreasing returns from the instantaneous marketing input $a_i^j(s^t)$ and the capital-theoretic specification of marketing. Decreasing instantaneous returns from a, parameterized by the *market expansion friction parameter* ϕ, are intended to capture the fact that the build-up of marketing related assets, like brand awareness, reputation or distribution network takes time.**??** show that this specification, together with the assumption that country specific goods are closely substitutable, is consistent with the high long-run and low short-run price elasticity of trade flows – a feature confirmed by numerous studies of the data. We follow their motivation to incorporate this feature, and later use the same methodology to calibrate the value of the parameter ϕ.

[8]Due to positive markups, this condition always binds in our model (on the simulation path).

Profit maximization. Producers from country $i = D, F, W$ sell goods in country $j = D, F, W$ for the wholesale prices $x_i^j p_i^j$ (assume $x_i^i \equiv 1$). These prices are determined by bargaining with the retailer, which will be described in detail in the next section. For the purpose of this section, note that since for every contingency s^t the producer can perfectly anticipate what the outcome of the bargaining will be, and cannot strategically influence it beforehand, in the profit maximization problem we can consider these prices as given.

The instantaneous profit function Π of the producer is given by difference between the profit from sales in each market

$$\sum_{j=D,F,W} (x_i^j p_j^i \left(s^t\right) - v_i \left(s^t\right)) D_j,$$

and the total cost of marketing these goods

$$\sum_{j=D,F,W} x_i^j v_j a_i^j.$$

Thus, the instantaneous profit function is given by the following expression

$$\Pi \left((d_i^j)^j, (a_{id}^j)^j, s^t\right) = \sum_{j=D,F,W} (x_i^j p_j^i \left(s^t\right) - v_i \left(s^t\right)) D_j - \sum_{j=D,F,W} x_i^j v_j a_i^j. \tag{17}$$

Summarizing, our representative producer from country $i = D, F, W$, who enters period t in state s^t with the customer list $\left(H_i^j \left(s^{t-1}\right), m_i^j \left(s^{t-1}\right)\right)^j$, chooses the allocation

$$\left(a_i^j \left(s^t\right), m_i^j \left(s^t\right), D_i^j \left(s^t\right), H_i^j \left(s^t\right)\right)^j$$

to satisfy the following Bellman equation

$$\begin{aligned} & V\left(\left(H_i^j \left(s^{t-1}\right), m_i^j \left(s^{t-1}\right)\right)^j ; s^t\right) \\ = \; & \max \left\{\Pi \left((d_i^j)^j, (a_{id}^j)^j ; s^t\right) + E_t Q_i \left(s_{t+1} | s^t\right) V\left(\left(H_i^j \left(s^t\right), m_i^j \left(s^t\right)\right)^j ; s^{t+1}\right)\right\} \end{aligned}$$

subject to the marketing technology constraints (16), sales constraints (15), and the laws of motion for customer lists (14).

D. Retailers

In each country there is a sector of atomless retailers, who purchase goods from producers and resell them to local households. Retailers who enter into the sector must incur an initial search cost χv in order to find a producer with whom they can match and trade. Each match lasts until it is exogenously dissolves with per-period probability δ_h. As long as the match lasts, the parties involved have an option to trade 1 unit of the good per period. In equilibrium, the industry dynamics is governed by a free entry and exit condition, which endogenously determines the measure h of searching retailers at each date and state. Trade between consumers and retailers in country i takes place in a competitive market at prices P_i^D for good D, P_i^F for good F and P_i^W for good W. In equilibrium these prices are given by (10), and throughout the paper we refer to them as *retail prices* (in contrast to *wholesale prices* denoted by small caps).

In each period, there is a mass of retailers already matched with the producers, H_i^j, and a mass of new entrants h_i. A new entrant in country i, upon paying the up-front search cost χv_i, meets with probability π_i^j a producer from country j. The entrant takes this probability as given, but in equilibrium it is determined by the marketing capitals accumulated by the producers

$$\pi_i^j(s^t) = \frac{\bar{m}_j^i\left(s^t\right)}{\sum_{j=D,F,W} \bar{m}_j^i\left(s^t\right)},$$

where π_i^j denotes here the probability of meeting a producer from country j in country i.

We proceed to the discussion of the bargaining problem between the producer and the retailer, and then set up the zero profit condition governing the size of entry into the retail sector, h_i.

Bargaining and price determination. An important feature of this environment is how the prices at which retailers and producers trade (wholesale prices) are determined. In this respect, we depart from the competitive pricing assumption and assume that in each period, after matching takes place, each retailer bargains with their producer over the total surplus from the match. We assume that the surplus is split in consistency with Nash bargaining solution with continual renegotiation.

To set the stage for the Nash bargaining problem, we first need to define the value function from the match for the producer and for the retailer, given that they trade at s^t at some arbitrary wholesale price p. For the producer from country i selling in country j these value functions (measured in country j numeraire) are given by

$$U_i^j\left(p; s^t\right) = \max\left\{0,\, p - x_i^j(s^t)v_i\left(s^t\right)\right\} + \left(1-\delta_h\right) E_t Q_j\left(s_{t+1}|s^t\right) U_i^j\left(p(s^{t+1}); s^{t+1}\right),$$

and for the retailer in country i matched with producer from country i by

$$J_i^j\left(p; s^t\right) = \max\left\{0,\; P_i^j\left(s^t\right) - p\right\} + \left(1-\delta_h\right) E_t Q_i\left(s_{t+1}|s^t\right) J_i^j\left(p(s^{t+1}); s^{t+1}\right),$$

where $p(s^t)$ is the equilibrium (given) schedule of wholesale prices.

The flow part of the Bellman equation for the producer is the difference between the wholesale price and the cost of producing the good, whereas for the retailer it is the difference between the retail price (resell price) and the wholesale price paid to the producer.

Given the above value functions, we are now ready to set up the bargaining problem, which imposes the following requirement on the equilibrium schedule of the wholesale prices $p_i^j(s^t)$

$$p_i^j(s^t) \in \arg\max_p \{J_i^j(p; s^t)^{1-\theta} W_j^i\left(p; s^t\right)^{\theta}\},\; \text{all } s^t, \tag{18}$$

where θ denotes the bargaining power of the producer[9].

The following proposition establishes that with continual renegotiation at every history the pricing formulas resulting from the above bargaining problem simply allocate θ fraction of the total instantaneous (static) trade surplus given by $P_i^j - x_i^j v_j$ to the producer and $1-\theta$ to the distributor.

Proposition 1. *Assume trade takes place at s^t. The solution to the bargaining problem stated in (18) is given by*

[9]Note that since the search cost and the marketing cost are sunk from the perspecitve of any given match and cannot be used to form another match in the same period. This is to say that the outside options of both sides in the bargaining problem are zero.

$$p_i^j(s^t) = \theta P_i^j(s^t) + (1-\theta)x_i^j(s^t)v_j(s^t). \tag{19}$$

Proof. To simplify notation suppress i, j from the above formulas, and consider a generic matched pair. Define the total surplus from the match as $S = J + W$. Note that (18) implies at every s^t

$$W(s^t) = \theta S(s^t),$$

where

$$S(s^t) = \max\{\theta(P(s^t) - v(s^t)), 0\} + (1-\delta_H)E_t\{Q(s_{t+1}|s^t)\theta S(s^{t+1})\}.$$

Thus,

$$\begin{aligned}
W(s^t) &= \max\{p(s^t) - v(s^t), 0\} + (1-\delta_H)E_t\{Q(s_{t+1}|s^t)W(s^{t+1})\}, \\
W(s^t) &= \theta S(s^t) = \max\{\theta(P(s^t) - v(s^t), 0\} + \theta(1-\delta_H)E_t\{Q(s_{t+1}|s^t)S(s^{t+1})\} = \\
&= \max\{\theta(P(s^t) - v(s^t)), 0\} + (1-\delta_H)E_t\{Q(s_{t+1}|s^t)W(s^{t+1})\}.
\end{aligned}$$

Subtracting side by side, and assuming that trade surplus is positive (trade takes place), we obtain the fixed-surplus-splitting rule given by

$$p(s^t) - v(s^t) = \theta(P(s^t) - v(s^t)).$$

□

The intuition behind the above result is straightforward. Given the continual renegotiation of the price, Nash Bargaining implies that in every period the total present discounted value from the match S is split in proportion θ,$1-\theta$ between the producer and the retailer. In particular, from today on this is the case, and for any contingency, from tomorrow on as well. Therefore, since it is impossible to split the surplus from tomorrow onwards in any other proportion, the surplus today has to be split in that proportion as well. Since this reasoning holds for all dates and states, the proposition follows.

Free entry and exit condition. We are now ready to formulate the equilibrium free entry and exit condition governing the measures of searching distributors in each country, h_i. This condition requires that the expected profit from entry covers the up-front search cost $\chi v_i(s^t)$, and is given by

$$\sum_{j=D,F,W} \pi_i^j(s^t) J_i^j \left(p(s^t); s^t\right) = \chi v_i(s^t),\ i = D, F, W. \tag{20}$$

The left hand side of the this equation is the expected surplus for the distributor from matching with a producer of good D, F or W and the right hand side is the search cost paid to find this producer.

Positive markups and the binding pattern of sales constraints. Note from the bargaining problem that because of the search cost χv, in the steady state producers trade the goods at a strictly positive markup, i.e. $p_i > v_i$. As a result, the producer always wants to sell goods to all of his customers, and the sales contraints (15) are binding. In the stochastic equilibrium, however, the binding pattern of sales constraints depends on the relative magnitude of shocks and equilibrium markups. It is conceivable that for shocks large enough so that trade surplus is negative, the producer and retailer would choose not to trade. This, however, does not happen for our calibrated values of the parameters, and in the simulation path the sales contraints always bind. Later we will explain the intuition behind our results assuming that sales constraints always bind.

E. Equilibrium

Equilibrium requires several market clearing conditions and feasibility constraints. The main resource constraint of the domestic country (other countries by analogy) is given by

$$\sum_{i=D,W,F} D_i\left(s^t\right) + \sum_{j=D,F,W} a_D^j\left(s^t\right) + h_D\left(s^t\right)\chi = z_D\left(s^t\right) F\left(k_D\left(s^{t-1}\right), l_D\left(s^t\right)\right),\ \text{all } s^t. \tag{21}$$

The left hand side of the above expression consists of the amount of goods sold in the domestic market or exported, amount used up in marketing, and the amount used up for the distribution of goods (search cost). The right hand side is the total production of good D.

In addition, representativeness assumption requires that the average marketing capitals are determined by the representative producer

$$m_i^j(s^t) = \bar{m}_i^j(s^t), \text{ all } s^t. \tag{22}$$

The probability $\pi(s^t)$ is determined through the marketing capitals,

$$\pi(s^t) = \frac{\bar{m}_d(s^t)}{\bar{m}_d(s^t) + \bar{m}_f(s^t)}, \text{ all } s^t \tag{23}$$

and the world asset market clears

$$\sum_{j=D,F,W} x_i^j\left(s^t\right) b_j\left(s^t\right) = 0. \tag{24}$$

The equilibrium of this economy is defined as $(i, j = D, F, W)$: value functions for producers and retailers V_i^j, U_i^j, J_i^j in each country, the sequence of allocations for households $c_i\left(s^t\right)$, $i_i\left(s^t\right)$, $l_i\left(s^t\right)$, $D_i\left(s^t\right)$, $F_i\left(s^t\right)$, $W_i\left(s^t\right)$, $b_i\left(s^{t+1}\right)$, producers $a_j^i\left(s^t\right)$, $j_i\left(s^t\right)$, $j_i\left(s^t\right)$, $m_j^i\left(s^t\right)$, $m_j^i\left(s^t\right)$, $H_j^i(s^t)$, $H_j^i\left(s^t\right)$, measure of searching retailers $h_i\left(s^t\right)$, average levels of marketing capitals $\bar{m}_i^j\left(s^t\right)$; and the sequence of consumer prices $P_i^j\left(s^t\right)$, wholesale prices $p_i^j\left(s^t\right)$, wages $w_i\left(s^t\right)$, interest rates $r_i\left(s^t\right)$, marginal costs $v_i\left(s^t\right)$, bilateral real exchange rates $x_i^j\left(s^t\right)$, bond prices $Q_i\left(s^{t+1}|s^t\right)$ such that: (i) allocations solve household's utility maximization problem, (ii) the zero profit condition (20) of the retail sector is satisfied, (iii) the producer allocations and value functions are consistent with the producers' Bellman equation given prices, (iv) retailer's value functions are consistent with Bellman equations and allocation given prices, (v) all market clearing conditions and feasibility conditions are satisfied, (v) prices and value functions are consistent with (2), (8), (19), and $x_i^i(s^t) \equiv 1$, all s^t.

4. Parameterization

In this section we describe how we choose functional forms and parameter values. First, we motivate our choice of targets for the elasticity of substitution γ and the market expansion friction ϕ. Then, we describe the choice of the remaining parameters. The baseline period length in the model and in the data is one quarter. Unless otherwise stated, we choose the same parameters for all three countries. Whenever possible, we make sure that the targets are obtained in all three economies, otherwise they are obtained exactly for the domestic economy.

Short-run - long-run elasticity and the marketing frictions. In the model, the long-run response of the product mix ratio[10] $\frac{F}{D}$ to the relative price of the domestic good versus the foreign good is equal to the Armington elasticity γ. After a permanent tariff reduction of ΔT percent[11], the product mix ratio in the model changes by

$$\Delta \log \frac{F}{D} \approx -\gamma \Delta T.$$

Intuitively, in the long-run the marketing friction is slack, and the response of trade depends only on the elasticity of substitution between domestic and foreign good. Since an analogous equation has been estimated in the trade literature to measure the elasticity parameter, we can directly adopt these estimates. We set γ equal to 15, which is close to the upper limit of the values reported in the literature.

Over the business cycle, the long-run relation between relative prices and trade flows is severed in our model. In the short-run, the marketing frictions limit the instantaneous response of quantities to price fluctuations, leading to a low estimated short-run elasticity of substitution. A similar discrepancy between short-run and long-run estimates has also been identified in the data[12]. We use this fact to quantitatively discipline the choice of the of the market expansion friction parameter ϕ. To set the target short-run elasticity, we propose our own measurement from the aggregate time series. More specifically, we compute the business cycle volatility of the ratio of imports to domestic absorption ($\approx \frac{F+W}{D}$ in the model) relative to the volatility of the ratio of their underlying price deflators. We label the ratio of these volatilities the *volatility ratio*[13] and compute it for a cross-section of 16 major OECD

[10]In the model, the same relationship holds for $\frac{g}{d}$ and also for aggregate imports $\frac{imports}{d}$. We use only $\frac{f}{d}$ for expositional simplicity.

[11]Which is equivalent to a permanent change of the the price of d relative to f.

[12]For more information see Ruhl (2008).

[13]To construct the *volatility ratio* we use series on constant and current price values of imports and domestic absorption, where domestic absorption is the sum of domestic expenditures less imports, $DA = (C+G)+I-IM$. We next identify the corresponding prices of imports and domestic absorption with their corresponding

countries. The motivation for this methodology is that for a large class of models in which the domestic and foreign goods are aggregated using a CES aggregator, the volatility ratio places an upper bound on the value of the true elasticity of trade flows γ. In particular, in the standard model, when ωs are assumed constant, the volatility ration is *exactly equal* γ.

Table 2 presents estimates of the volatility ratio in our sample. We can see that the implied short-run elasticity is low, with the median volatility ratio equal to 0.81, which is the number we adopt as one of our targets.

Table 2: Volatility ratio in a cross-section of major industrialized countries

	Detrending method	
Country	HP-1600	Linear
Australia	0.94	0.93
Belgium	0.57	0.50
Canada	1.27	0.64
Denmark	1.45	2.08
Finland	1.33	0.97
France	0.54	0.73
Germany	0.90	1.16
Italy	0.69	0.46
Japan	0.60	0.43
Netherlands	0.44	0.72
Portugal	1.37	1.39
Spain	0.65	0.60
Switzerland	0.71	1.16
Sweden	0.95	0.95
UK	0.65	0.61
US	1.23	1.02
Median	0.81	0.83

price deflators (deflators are defined as the ratio of current to constant price values). Denoting the deflator price of domestic absorption by P_{DA} and the deflator price of imports by P_{IM}, the *volatility ratio* is then defined as $\sigma(\frac{IM}{DA})/\sigma(\frac{P_{DA}}{P_{IM}})$, where σ refers to the standard deviation of the logged and Hodrick-Prescott filtered quarterly time series. Notice that the *volatility ratio* places an upper bound on the regression coefficient between the two variables underlying its construction. This is because the regression coefficient, typically used in short-run studies, is the *volatility ratio* rescaled by the correlation coefficient ($\text{reg}(x,y) = \frac{\sigma_y}{\sigma_x}\rho_{x,y}$, $\rho_{x,y} \in [-1,1]$).

Independently calibrated parameters. Here we describe the choice of parameters which can be independently calibrated. They are (i) the discount factor β chosen to reproduce the average annual risk free real interest rate of 4.1%, (ii) Cobb-Douglas production function $k^{\alpha}l^{1-\alpha}$ with parameter α chosen to reproduce the constant labor share of 64%, (iii) depreciation of physical capital of 2.5% (quarterly) from Backus, Kehoe & Kydland (1995)[14], and finally, (iv) the standard value for the intertemporal elasticity of substitution/risk aversion parameter σ of 2. We arbitrarily fix $\delta_h = 0.1$, implying that the matches in the economy last on average 2.5 years (10 quarters). For the details on national accounting in the model, see Appendix at the end.

Productivity shock process. The country-specific productivity shock $z(s^t)$ is assumed to follow an AR(1) process with no cross-country spillovers

$$\log(z_i(s^t)) = \psi \log(z_i(s^{t-1})) + \varepsilon_i(s_t),$$

where the residuals ε_i are assumed to be normally distributed with zero mean, standard deviation σ^2, and correlation coefficients ρ_{ij}. We assume that the persistence terms ψ are the same in all countries and equal to 0.89. The volatility σ of the shocks is also assumed to be the same in all countries and equal to 0.22. We give the details of the estimation in the Appendix.

We also vary the assumptions about correlations ρ_{ij} across numerical exercises, to best mimic the conditions in the data. In the *Bilateral Pairs* exercise, we assume that all cross correlations are equal, and chosen so that at 15% tariffs all three GDP correlations are equal to 0.35, which is the median bilateral output correlation in our cross-section, and also equal to the median correlation of countries with total rest of the world in the data. In the *European Case Study* exercises, we choose the correlation of shocks between ROW and rest of Europe so that their output correlation is 0.4, which is the median in the data. As for the correlation of shocks between the small country and the two blocs, we set them equal to each other and

[14] It implies investment to GDP ratio of 25%. In the recent data we find 20% in US, 28% Japan, 22% Germany, 21% France. The OECD median is close to 20%. We adopt this number to make the model implications more comparable to the literature.

choose the level to reproduce the output correlation of the small country with ROW in *Case Study: European Country*, and with Europe in *Case Study: ROW Country*[15].

Jointly calibrated parameters. The group of parameters jointly calibrated include the marketing friction parameter ϕ, depreciation of marketing capital δ_m, the up-front search cost χ, the bargaining power θ, home-bias parameters ω_i^k, consumption share parameter η, and the population sizes L_i. Because each parameter influences more than one target at the same time, the calibration must be joint using the General Method of Moments method. We calibrate their values simultaneously using the following calibration targets. (i) L-R Armington elasticity of 15, which is towards the upper limit reported in the trade literature (see Ruhl (2008)), (ii) producer markups of 10% as estimated by Basu & Fernald (1995), (iii) volatility ratio of 0.81 equal to the median value in the sample of OECD countries as in **?**, (iv) relative volatility of the real export price p_x to the real exchange rate x of 37% consistent with the data for the US, (v) marketing to GDP ratio of 4.5%,, which is half way between estimates of marketing/sales of 7% reported by Lilien & Little (1976) and advertising/GDP of around 2% reported in Coen (June 2007), (vi) the standard value for the share of market activities in the total time endowment of households equal to 30% (Cooley (1995)) and finally (vii) the trade intensity pattern in the data, depending on the exercise, (viii) different sizes of steady state real GDP, depending on the exercise.

For the trade patterns in the steady state of the economies in the two reported exercises we do the following

1. In the *Bilateral Pairs* exercise, we set tariffs between Domestic and Foreign of 15% and then choose the home bias parameters for the three countries to reproduce the steady state import/GDP ratio of 18%, the median in the data. We choose population sizes so that the World steady state GDP is 20 times bigger that the single country real GDP. We then vary tariffs from 11% to 64% in order to reproduce the variation in bilateral trade in the data. At the same time, we vary tariffs with the rest of the world from 14% to 30% to mimic the behavior of countries in the data - the more countries trade with each other, the more they trade with the rest of the world.

[15] Our results are not sensitive to the choice of the correlation between the two big blocs.

2. In the *European Case* exercise, we choose home bias parameters for the three countries to reproduce imports/gdp of a median European country (Domestic country) from the ROW (World) of 2.7%, and from the rest of Europe (Foreign country) 15.7%. We choose population sizes so that steady state real GDP of the Domestic country is 20 times smaller than World or Foreign.

Table 3: Parameter values in the benchmark calibration

Parameter		Value
	Preference Parameters	
γ	elasticity of substitution	15
$\omega_1^D, \omega_1^F, \omega_1^W$	preference weights country 1	0.3469, 0.3345, 0.3185
$\omega_2^D, \omega_2^F, \omega_2^W$	preference weights country 2	0.3345, 0.3469, 0.3185
$\omega_3^D, \omega_3^F, \omega_3^W$	preference weights country 3	0.3185, 0.3185, 0.3265
η	leisure weight in utility	0.35
σ	risk aversion	2
β	time discount factor	0.99
	Technology Parameters	
α	capital share	0.36
δ	depreciation of physical capital	0.025
δ_H	mach destruction rate	0.1
χ	search cost	1.15
δ_m	depreciation of marketing capital	0.0159
ϕ	adjustment cost of marketing capital	5.07
θ	bargaining power of producers	0.455
	Other Parameters	
ψ	persistence of the productivity shock	0.89
ρ_{ij}	Cross-correlation of productivity shocks	in text
$\bar{l}_1, \bar{l}_2, \bar{l}_3$	population sizes	$1, 1, 20$

5. Quantitative Analysis

This section presents numerical exercises performed on the model and compares the results to the relevant statistics from the data. We perform two exercises. In the first one, labeled *Bilateral Pairs,* we model two small countries (Domestic and Foreign), and one big rest-of-the-world country (World). This exercise is intended to mimic the bilateral pairs data study presented in Section 2.of the paper. In the second numerical exercise, which we label

European Case, we model one small European country and two big countries,rest of the world excluding Europe (ROW) and rest of Europe. This exercise is intended to mimic the case of Europe, which is often given as an example to support the common wisdom about the positive relationship between trade and comovment in the data. In this context, we want to ask how much of this pattern our theory can account for.

A. Bilateral Pairs

In this exercise, we choose the home bias parameters such that at 15% tariffs, the steady state import/GDP ratio is 18%, which is the median in our sample. We then vary tariffs from 11% to 64% in order to generate the bilateral trade intensity and correlations observations. At the same time, we vary tariffs with the rest of the world from 14% to 30% to mimic the behavior of countries in the data - the more countries trade with each other, the more they trade with the rest of the world[16]. For this variation in tariffs, bilateral trade intensity in the model varies from 0.02% to 7.3% just like in the data.

Table 4 presents results from regressions that we run on model-generated data. The model implies a regression coefficient both for GDP and TFP correlations that is close to the data estimates. It accounts for 48% of the slope for GDP and 78% of the slope for TFP.

Table 4: Data and Model: regression coefficients

Coefficient for	Data	Model	Standard Model with complete markets[17]
GDP Correlation	0.0616	0.0297	negative
TFP Correlation	0.0297	0.0233	0

We would also like to allow for the possibility that for reasons exogenous to the model the primitive shocks to the economies become more correlated when countries trade more[18]. Thus, we repeat the previous exercise with one difference: while changing tariffs, we are also changing the correlation of exogenous shocks of Domestic and Foreign so that the model

[16] This variation of tariffs with the rest of the world is chosen to replicate the regression coefficient of trade intensity with the rest of the world on bilateral trade.

[17] For all parameterizations of the standard model, the implied coeffcient for GDP is negative, and there is no effect on the coefficient for TFP.

[18] Kose & Yi (2006) perform an analogous exercise with the standard model.

reproduces exactly the regression coefficient for TFP. Table 5 reports the results. Note that even though the model still falls short of reproducing the full effect from the data, the coefficient for output increases significantly.

Table 5: Data and Model: Regression coefficients when the shocks' correlation changes

Coefficient for	Data	Model	Standard Model with complete markets[19]
GDP Correlation	0.0616	0.0371	negative
TFP Correlation	0.0297	0.0297	0

For all parameterizations of the standard model, the implied coeffcient for GDP is negative, and there is no effect on the coefficient for TFP.

B. European Case

In this exercise, we choose the home bias parameters in order to match the median pattern of imports/GDP of a European country with the rest of Europe and the rest of the world excluding Europe (ROW). We also choose the correlations of the shocks to match the correlation of the median European country with the ROW[20]. Our calibrated economies give the ratio of correlations that is 41% of the statistic from the data. The results are reported in Table 6.

Table 6: Model versus European country data.

	Data	Model
Imports/GDP from rest of Europe	16.42%	16.42%
Imports/GDP from ROW (excluding Europe)	2.73%	2.73%
Correlation with rest of Europe	0.62	0.46
Correlation with ROW (excluding Europe)	0.35	0.35

C. Explanation of the Results

The reason why our model implies a positive trade-comovement relationship is twofold. First, we have a novel search-implied motive for the demand complementarity effect—absent from the standard model. Second, in our environment the elasticity of substitution γ, which governs

[20]Here and in the next exercise, we still require all cross-country correlations of exogenous shocks to be the same.

the responsiveness of long-run trade patterns to permanent tariff[21] changes, is very high—consistently with the data. As mentioned in the introduction to the paper, the second effect substatially supresses the influence of the resource-shifting effect on the trade comovement relation, while the first one gives rise to complementarity effect unrelated to the assumed elasticity of substitution γ—thus largely unaffected by the choice of this parameter.

Where does our novel search-implied compelementarity effect come from? First, marketing capitals, and thus relative marketing capitals, adjusts sluggishly to shocks because matches are persistent and there is a market expansion friction ϕ. Second, the specification of the matching function (13) implies that the arrival rate of new customers not only depends on the relative marketing capital, but also on the *search intensity* of the customer side of the market h (*thick market externality).* This is the key reason why output increases in our model when the other country is hit by a positive productivity shock, and why the strength of this effect depends on the initial shares of marketing capital (12). More precisely, following a positive productivity shock, local retailers search harder (h increases) because they have a positive probability of meeting the now cheaper home producers. Given their higher search intensity, by the logic of thick market externality, the productivity of each unit of marketing capital held by the importers goes up, as well as the arrival rate of new customers to them. Since this effect is for free from their perspective and affects the future, despite lower markups today, importers sell more and increase output. Since the effect is stronger for importers with larger market share, thus trade-comvement pattern follows.

The effect on TFP is more subtle, and comes solely from the specifics of the national accounting procedures. In the data the TFP residuals are measured by subtracting from the log of final output (real GDP), the log of payments to labor and capital. Since final output excludes intermediate inputs, and marketing expenditures are classified this way by the national accounting procedures (*System of National Accounts 1993* (1993)), TFP goes up when less marketing is needed for a given level of production/sales.

[21]Interpreted as equivalence units of trade barriers in general.

6. Conclusion

This paper proposes a mechanism of international transmission of business cycles through international trade. We introduce a search and matching frictions into a standard international real business cycle model and asses quantitatively the effect such friction has on the trade-comovement relationship. The results of the numerical exercises indicate that our model can reproduce half of the positive relationship between trade and comovement seen in the data for output, and about two thirds for the TFP. This conclusion applies both to the cross-section of countries as well as the European case.

Appendix

A1. National Accounts in the Model

GDP in constant prices (≡steady state prices) is measured by

$$P_{i,0}^{D}D_{i,t} + P_{i,0}^{F}F_{i,t} + P_{i,0}^{W}W_{i,t} + (\sum x_{D}^{j}p_{j,0}^{D}D_{j,t} - p_{i,0}^{F}F_{i,t} - p_{i,0}^{W}W_{i,t}), \tag{A1}$$

consumption and investment in constant prices is measured by[22]

$$(P_{i,0}^{D}D_{i,t} + P_{i,0}^{F}F_{i,t} + P_{i,0}^{W}W_{i,t})\frac{c_{i,t}}{G(D_{i,t}, F_{i,t}, W_{i,t})}, \tag{A2}$$

$$(P_{i,0}^{D}D_{i,t} + P_{i,0}^{F}F_{i,t} + P_{i,0}^{W}W_{i,t})\frac{i_{i,t}}{G(D_{i,t}, F_{i,t}, W_{i,t})}, \tag{A3}$$

and employment index is measured by $l_{i,t}$. Notice that investment in marketing does not show up explicitly in the expenditure side measurement of GDP[23]. This assumption is consistent with the methodology of national income accounting, in which expenses on R&D, marketing, advertising are all treated as intermediate inputs – see *System of National Accounts 1993* (1993) Par. 1.49, 6.149, 6.163, 6.165.

A2. Estimation of the Productivity Shock Process

To construct the TFP residuals z from the data we follow a similar procedure to Heathcote & Perri (2004), and include physical capital. Physical capital has been constructed from the gross-fixed capital formation series using perpetual inventory method with exogenously assumed depreciation rate of $\delta = 0.025$. For the US we have used total hours worked, and for the rest of the world civil employment index instead. Given the quarterly dataset from 1980.1 to 2004.3 for the aggregate of main 15 European countries, Japan, Canada, Switzerland, and Australia, we have constructed the series of z from the following equation

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

where y denotes GDP in constant prices, and the coefficient 0.64 denotes the assumed share of labor income in GDP - consistent with the parameterization of the model and the values estimated for the developed countries. We linearly detrend the series for $\log(z)$, and estimate the parameters of the underlying productivity process.

A3. Data Sources

Bilateral trade statistics from International Monetary Fund, Direction Of Trade Statistics, 2005. Nominal GDP from World Development Indicators, World Bank. Gross Fixed Capital Formation, GDP in constant prices and Civil Employment from Source OECD.org, Quarterly National Accounts. Series for physical capital have been constructed using the perpetual inventory method with a constant depreciation of 2.5%. Aggregate GDP for blocks of countries has been computed

[22] Consumption and investment in period zero prices are not equal to c and i. The reason is that the Euler's Law does not apply for period zero (steady state) prices. However, quantitatively the difference turns out small.

[23] There 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 $a_j x_i^j v_j$. Quantitatively the impact of this change on the statistical properties of the real GDP is negligible.

from growth rates of GDP in constant prices (recent years, varies by country) weighted by the nominal GDP of each country in 2004 (we applied the growth rates backwards).

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