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ARTICLE

Inter-industry trade and business cycle dynamics

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Abstract

Motivated by the increased importance of trade between industrialized and less-developed countries, we build a two-sector dynamic stochastic general equilibrium model featuring inter-industry trade as well as intra-industry trade to analyze the business cycle dynamics of industrialized countries. We find that import-competing sectors are more sensitive to domestic productivity shocks than exporting sectors, due to their stronger reliance on domestic demand. This generates pressure to adjust relative prices and to reallocate factors of production. It also propagates the international spillover effects of productivity shocks leading to stronger business cycle comovement across countries, relative to a traditional business cycle model that does not feature inter-industry trade.

Keywords: international business cycles; inter-industry trade

1. Introduction

Figure 1 shows the share of the two top US trading partners in total US trade. The figure illustrates that the trade share with China has been growing fast over the last couple of decades, while the trade share with Canada has been steadily declining. These trends are representative for other industrialized countries and mark a shift in the pattern of international trade since trade among industrialized countries, like the USA and Canada, is primarily driven by intra-industry trade, while trade between industrialized and less-developed countries, like the USA and China, is to a large degree inter-industry trade. This is illustrated by Figure 2 showing the importance of intra-industry trade, as measured by the Grubel Lloyd index, for manufacturing trade between the US and Canada resp. China.[1] Two facts stand out: i) the Grubel Lloyd index is remarkably stable over time for both countries; ii) trade with China is to a much lesser extent based on intra-industry trade. Put differently, trade with China is to a much larger extent inter-industry trade. In this paper, we explore the consequences of more pronounced inter-industry trade for business cycle dynamics.[2]

The potential consequences of the shift in the structure of international trade from intra- to inter-industry for business cycle dynamics are still under-explored, mainly due to the restriction of existing business cycle models to intra-industry trade. We aim to close this gap by developing a modern dynamic stochastic general equilibrium (DSGE) model that is based on comparative advantage as well as "love of variety" and thus features both inter- and intra-industry trade. We find that the structure of international trade is indeed important. Under inter-industry trade, productivity shocks (both foreign and domestic) lead to shifts in the relative demand of exporting and import-competing sectors, generating pressure to adjust relative prices (including wages) and/or to reallocate factors of production. This has consequences especially for the international comovement of business cycles.

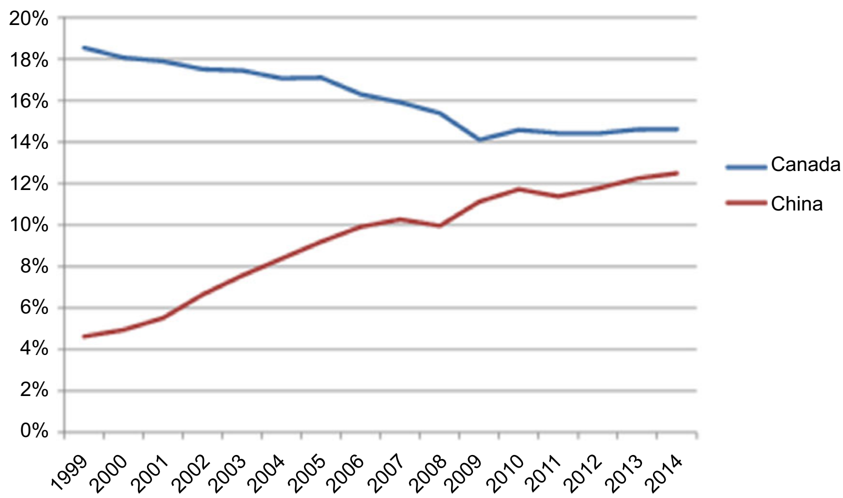

Figure 1. Trade shares of USA with Canada and China.

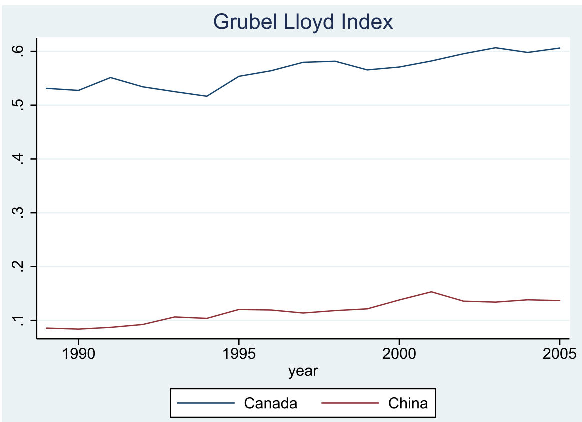

Figure 2. Grubel Lloyd index for manufacturing trade between the USA and Canada resp. China.

At the heart of our analysis lies the idea that sectors respond differently to aggregate productivity shocks, depending on whether they are exporting sectors (in which the USA has a comparative advantage) or import-competing sectors (in which the USA has a comparative disadvantage). To see whether this is indeed the case in the data, we regress output and revenue of exporting and import-competing sectors on a measure for aggregate productivity shocks (see section 2). Using US data, we find that there is indeed an economically and statistically significant difference in how strongly both types of sectors respond to aggregate productivity shocks: the response of output and revenue in import-competing sectors is on average 1.5 times stronger than in exporting sectors.

We proceed by developing a model that can replicate these stylized facts.[3] Our model is a dynamic version of the static model developed in Bernard et al. (2007) (BRS henceforth). BRS combine firm heterogeneity and endogenous firm entry a la Melitz (2003) with comparative advantage. Thus, they build a model that includes both inter- and intra-industry trade, which makes it suitable for our analysis.

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The model we use is a dynamic version of BRS, along the lines of Ghironi and Melitz (2005) (GM henceforth), and is based on Lechthaler and Mileva (2019) and Lechthaler and Mileva (2021), who study the effects of trade liberalization on wage inequality. It is a model with two countries, two sectors, and two factors of production, namely skilled and unskilled workers. The industrialized country has a relatively larger endowment of skilled workers and thus a comparative advantage in the skill-intensive sector. International trade induces both countries to specialize partly in producing their comparative advantage sector good. In contrast to Lechthaler and Mileva (2019), the model used here also features an intensive margin of labor supply (hours per worker) that can be adjusted at business cycle frequency as in most models of international macroeconomics.

We find that in response to temporary, negative shocks to aggregate productivity in the industrialized country, relative demand shifts from the import-competing sector toward the exporting sector, because the latter depends less on domestic demand. We show that in this context it plays an important role for the results whether workers are mobile across sectors or not. In a version of the model where workers can move freely across the two sectors, many workers move immediately to the exporting sector, implying a large contraction in the import-competing sector, a contraction that is much larger than what we observe in the data. In contrast, in a version of the model where workers are immobile across the two sectors, more of the adjustment is pushed into relative prices, which considerably dampens the contraction in the import-competing sector. Importantly, this version of the model generates relative movements in sector output and revenue that are very close to the data. Additionally, we provide new direct evidence that the mobility of workers across sectors is indeed very limited. Therefore, we consider the model with immobile workers as the most useful benchmark. Nevertheless, we also discuss versions of the model where workers can move either freely across sectors or are subject to a sector migration cost.

The mobility of workers and the structure of trade also have implications for the comovement of GDP across countries. In our benchmark with immobile workers, the response of GDP to domestic shocks is dampened while its response to foreign shocks is enhanced, relative to both a traditional model with only one sector (and thus only intra-industry trade) and a model with two sectors and mobile workers. Concerning the volatility of GDP, both effects work in the opposite direction so that it is very similar across models. However, concerning the correlation of GDP across countries both effects reinforce each other so that it is clearly higher in our benchmark model. Thus, our analysis of inter-industry trade introduces inter-sector shifts in production as a novel channel to generate business cycle comovement across countries.

Finally, our model also has implications for wage inequality. The shift in relative demand toward the exporting sector that follows a decline in domestic productivity implies an increase in the relative demand for skilled workers, which are used more intensively in the exporting sector. Consequently, the wage income of skilled workers goes up relative to that of unskilled workers and overall wage inequality increases.

Our paper lies in the tradition of open economy business cycle models, a literature that goes back to Backus et al. (1992), and more specifically to recent attempts to include endogenous firm entry as in Ghironi and Melitz (2005), Cacciatore et al. (2016), or Cacciatore and Ghironi (2021). Another recent paper related to ours is Caselli et al. (2020) who address the question whether trade liberalization increases or decreases the volatility of GDP, using a variant of the model in Eaton and Kortum (2002). Their focus is on sector-specific vs. country-specific shocks, and they show that the effect of specialization on GDP volatility depends on the volatility of sector-specific shocks, on the covariance among sector-specific shocks, and on the covariance between sector-specific shocks and country-specific shocks. In contrast, we use a smaller model in the tradition of international macro models and focus on the endogenous shifts in specialization that follow shocks to aggregate productivity.

Like in our paper, movements in relative sector prices are an important mechanism to propagate business cycle comovement across countries in Jin and Li (2018). However, in their paper the

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distinguishing feature of sectors is the intensity with which they use capital vs. labor. They assume symmetric countries which do not differ in their factor-endowments. Their paper is thus more focused on industrialized countries, whereas we focus on the trade between developed and developing countries. More importantly, in their paper the larger volatility of labor-intensive sectors is generated by assuming that the productivity of these sectors responds more strongly to domestic productivity shocks than the productivity of capital-intensive sectors, whereas in our model the larger volatility of unskilled-intensive sectors is endogenously generated by the interaction of factor-endowments, sector-specialization, and international trade.

To the best of our knowledge, the only two other papers that consider Heckscher–Ohlin type trade in RBC models are Cunat and Maffezzoli (2004) and Kraay and Ventura (2007). However, our focus is very different from theirs. Cunat and Maffezzoli (2004) are not interested in the trade between industrialized and developing countries and therefore calibrate their model to OECD countries. Furthermore, they do not analyze sector shifts in output and the role of factor-mobility in shaping these shifts. Kraay and Ventura (2007) are interested in the relative volatility of sectors but in their framework differences are based on the type of technology that is used and the demand elasticity this implies: Sectors that use new technologies have more market power and thus face lower demand elasticity. In our framework, import-competing sectors are more volatile, even though they face the same demand elasticity, because they depend more on domestic demand. Furthermore, both papers do not analyze the effects of business cycles on wage inequality.

The paper proceeds as follows. In the next section, we develop our stylized fact that output and revenue of import-competing sectors respond much more strongly to shocks in domestic aggregate productivity than output and revenue of exporting sectors. In Section 3, we develop a model that can explain this stylized fact. Section 4 discusses our calibration approach. Section 5 describes theoretical responses to both domestic and foreign shocks to aggregate productivity and the resulting business cycle statistics. Section 6 analyzes the robustness of our results to costly worker mobility. Section 7 concludes.

2. Aggregate productivity and sector responses in the data

The introduction motivated the analysis of inter-industry trade with the observation of the rising importance of China and other developing countries for the world economy and international trade. A central aspect of inter-industry trade is the distinction between comparative advantage sectors and comparative disadvantage sectors. It is to be expected that both types of sectors are affected differently by business cycle shocks, but in the end this is an empirical question. Thus, in this section we use US data to assess the responsiveness of both types of sectors to changes in total factor productivity (TFP) growth. We find that comparative disadvantage sectors are considerably more responsive to domestic productivity shocks.[4]

To measure TFP growth, we use an annual series constructed by the San Francisco Federal Reserve, which calculates business sector TFP growth as output growth less the contribution of capital and labor.[5] We then estimate the effect of aggregate TFP growth on the growth rate of sector-level revenue and output, where $\Delta y_{it} = log(y_{it}) - log(y_{it-1})$ is the growth rate of output in sector i at period t and $\Delta r_{it} = log(r_{it}) - log(r_{it-1})$ is the growth rate of revenue. We obtain data on sector output from the NBER-CES Manufacturing Industry Database. Output is measured as the value of shipments divided by a sector price deflator. Revenue is measured in real terms by dividing the value of shipments by the personal consumption expenditure price index obtained from the Saint Louis Federal Reserve website. The data are annual and run from 1980 to 2006, and include 86 four-digit level manufacturing sectors based on the North American Industry Classification System (NAICS).[6]

We distinguish between comparative advantage and comparative disadvantage sectors based on a measure of revealed comparative advantage (RCA_i) which takes account of exports and

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imports at the sector level. RCA_i is defined as the ratio of the export share of the sector in total manufacturing exports over the import share of the sector in total manufacturing imports ($RCA_i = \frac{(Ex_i/Ex_{manuf})}{Im_i/Im_{manuf})}$), with $RCA_i \geq 1$ referring to comparative advantage sectors and $RCA_i < 1$ referring to comparative disadvantage sectors.[7] We construct a dummy which takes the value of 0 if the sector has $RCA_i \geq 1$ and the value of 1 if $RCA_i < 1$. Note that due to the limited time range of our export/import data, the RCA dummy is defined based on a period average and only varies across sectors but not across time. Then we estimate a regression equation with the following specification:

$$\Delta x_{it} = \alpha_i + \beta_0 + \beta_1 \Delta tfp_t + \beta_2(\Delta tfp_t)(dummy_i) + u_{it}, \tag{1}$$

where Δx_{it} corresponds to either Δy_{it} or Δr_{it}, α_i is a sector fixed effect, and u_{it} is a random error. This is a fixed effects panel data regression. The coefficient of interest is $\hat{\beta}_2$ which if positive and significant would indicate that the changes in aggregate productivity have a larger impact on the growth rate of comparative disadvantage sectors than on the growth rate of comparative advantage sectors. We run two regressions: one with output growth as the dependent variable and one with revenue growth as the dependent variable. The difference between both measures is that revenue evaluates output at market prices.

Equations 2 and 3 show the estimated parameters with standard errors in parenthesis.

$$\begin{array}{llll} \Delta y_{it} = & -0.0001 & + \quad 1.160\Delta tfp_t & + \quad 0.638(\Delta tfp_t)(dummy_{it}) \\ & (0.001) & \quad (0.189)^{***} & \quad (0.289)^{**} \end{array} \tag{2}$$

$$\begin{array}{llll} \Delta r_{it} = & -0.012 & + \quad 1.307\Delta tfp_t & + \quad 0.579(\Delta tfp_t)(dummy_{it}) \\ & (0.001)^{***} & \quad (0.183)^{***} & \quad (0.306)^{*} \end{array} \tag{3}$$

Notes: # of observations = 2268; sample = 1980-2006; sectors = 84; sector fixed effects are included. Robust standard errors are reported to control for heteroscedasticity in the residuals. Dummies take the value of one if the $RCA_i < 1$ and zero, otherwise.

"*" significance at the 10% level, "**" at the 5% level, and "***" at the 1% level.

The estimated equations show that the aggregate productivity shock is an important driver of both sector-level output and sector-level revenue. The coefficient $\hat{\beta}_1$ is large (1.16 for output and 1.307 for revenue) and statistically significant in both cases. The results also reveal that comparative disadvantage sectors are more responsive to productivity shocks than comparative advantage sectors both in terms of output and revenue: the coefficient $\hat{\beta}_2$ is large and statistically significant in both cases. Our results suggest that in response to a 1% increase in aggregate productivity the output of comparative advantage sectors increases by 1.16% on average, while the output of comparative disadvantage sectors increases by 1.80%. In response to the same increase in aggregate productivity, revenue of comparative advantage sectors increases by 1.31% while revenue of comparative disadvantage sectors increases by 1.89%.

The results from the two regressions imply a roughly equal relative response across sectors both in terms of revenue and output. In both specifications, comparative disadvantage sectors are roughly 1.5 times more responsive to aggregate productivity changes than comparative advantage sectors. One implication of this result is that a decline in aggregate productivity leads to temporarily enhanced specialization of production in comparative advantage sectors. In the appendix, we show that our results are robust to alternative specifications and assumptions regarding the definition of comparative advantage, the presence of time fixed effects, alternative identifications of aggregate productivity, and alternative levels of disaggregation for industries. Since we analyze how the business cycle of developed countries is affected by inter-industry trade, we would have liked to use quarterly data for our specification. However, due to data limitations, we use annual

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data instead. Nevertheless, in the appendix, we run a similar specification on quarterly sector data for industrial production and find that our results hold with quarterly data as well.

Our empirical exercise demonstrates that there is a considerable difference in the extent to which comparative advantage sectors and comparative disadvantage sectors are affected by domestic shocks to aggregate productivity. In the following, we develop a model that is able to explain this stylized fact and use the model to analyze its consequences for business cycle fluctuations.

3. Theoretical model

We build a DSGE model of two countries, Home (H) and Foreign (F). Each country produces two goods, good 1 and good 2, which are aggregated into a final consumption good using a Cobb-Douglas technology. The production of each good requires two inputs, skilled and unskilled labor. The sector that produces good 1 is skill-intensive, that is, the production of good 1 requires relatively more skilled labor than the production of good 2.

H has a comparative advantage in producing good 1 because it has a higher relative endowment with skilled workers. Similarly, F has a comparative advantage in sector 2 because it has a higher relative endowment with unskilled workers. We assume that unskilled workers are more abundant than skilled workers in both countries in order to generate a positive skill premium.[8] In the long run, workers are assumed to be perfectly mobile between sectors but not across countries. Concerning the short run, we consider various assumptions about worker mobility to understand its relevance. As it turns out, the model with immobile workers is most successful in replicating the stylized facts. As is common in the business cycle literature, we also assume an intensive margin of labor supply in order to allow for endogenous changes in the labor input in response to business cycle shocks.

At the sector level, the model features a continuum of firms, each selling a different variety under monopolistic competition. As in Ghironi and Melitz (2005), we assume that new firms have to pay a sunk entry cost to enter the market, thus endogenizing the number of firms and varieties. Again in line with Ghironi and Melitz (2005), we assume that firms are heterogeneous in their productivity and have to pay a fixed export cost in order to sell to the foreign market, which endogenizes the number of exporting firms and the number of exported varieties. In the appendix, we will demonstrate that both features, endogenous firm entry and firm heterogeneity, are important in replicating the stylized facts. The bundle of varieties produced by firms is aggregated into a sector good using a CES technology.

The economy is subject to country-specific shocks to aggregate productivity. In the following section, we describe all the decision problems in H; equivalent equations hold for F.

3.1. Households

In our model, there are two types of households, ones that comprise skilled workers and ones that comprise unskilled workers.[9] In the following, we describe the problem of a skilled worker's household, with analogous equations holding for unskilled workers' households. The utility of a skilled worker's household is given by:

$$E_t \left\{ \sum_{k=0}^{\infty} \gamma^k \left[log\left(C_{t+k}^S\right) S - \sum_{i=1,2} \frac{\left(H_{it+k}^S\right)^{1+\upsilon}}{1+\upsilon} S_{it+k} \right] \right\}, \tag{4}$$

where C_{t+k}^S is the consumption of each worker, H_{it+k}^S is the hours supplied by each worker that is employed in sector i, S_{it+k} is the number of workers in sector i, $S = S_{1t} + S_{2t}$ is the total number of workers in the household, γ is the subjective discount factor, and υ is the inverse of the Frisch

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elasticity of labor supply. So every household member receives the same consumption, but labor supply might differ across sectors.

Every period the household faces the following budget constraint written in terms of final consumption:

$$SC_t^S + A_t^S + Q_t Af_t^S + \frac{\eta}{2}(A_t^S)^2 + Q_t \frac{\eta}{2}(Af_t^S)^2 \\ = \sum_{i=1,2} w_{it}^S H_{it}^S S_{it} + A_{t-1}^S(1+r_{t-1}) + Q_t Af_{t-1}^S(1+r_{t-1}^*) + S\Pi_t + TA_t^S \quad (5)$$

The left-hand side includes household expenditure on consumption SC_t^S, H bonds A_t^S, and F bonds Af_t^S. F bonds are in terms of the foreign consumption good and thus adjusted by the real exchange rate $Q_t \equiv e_t P_t^*/P_t$, defined as the relative price of F goods versus H goods. The nominal exchange rate e_t is normalized to 1, since our model does not include any nominal rigidities. Note that households have to pay a quadratic adjustment cost for H bonds $\frac{\eta}{2}(A_t^S)^2$ and F bonds $Q_t\frac{\eta}{2}(Af_t^S)^2$. These costs are paid to financial intermediaries whose only function is to collect these transaction fees and rebate them to the households in a lump-sum fashion. The purpose of these adjustment costs is to assure stationarity of the steady state (see GM for more details).

The right hand side of equation 5 includes the sources of income such as the wage income from both sectors $\sum_{i=1,2} w_{it}^S H_{it}^S S_{it}$, interest income on H bond holdings $A_{t-1}^S(1+r_{t-1})$ and F bond holdings in last period $Q_t Af_{t-1}^S(1+r_{t-1}^*)$, profit transfers from a mutual fund that owns all firms Π_t (to be defined in more detail below), and the bond adjustment cost rebate TA_t^S. r_{t-1} and r_{t-1}^* are the real interest rates on H and F bond holdings.

The household chooses how much to consume, how many hours to work in both sectors, and how much H and F bonds to buy by optimizing its utility subject to the budget constraint. The optimization problem implies the following optimality conditions:

$$\frac{\left(H_{it}^S\right)^{\upsilon}}{\left(C_t^S\right)^{-1}} = w_{it}^S \text{ for } i = 1, 2, \quad (6)$$

$$(1+\eta A_t^S) = \gamma E_t\left[\left(\frac{C_{t+1}^S}{C_t^S}\right)^{-1}(1+r_t)\right], \quad (7)$$

$$(1+\eta Af_t^S) = \gamma E_t\left[\left(\frac{C_{t+1}^S}{C_t^S}\right)^{-1}(1+r_t^*)\frac{Q_{t+1}}{Q_t}\right]. \quad (8)$$

The first condition determines optimal labor supply by equating the marginal rate of substitution between leisure and consumption to the real wage. The other two conditions are the Euler equations that determine the optimal demand for H and F bonds, respectively.

As mentioned above, we distinguish two specifications concerning the mobility of workers across sectors. In our baseline case, workers are fully mobile in the long run but fully immobile in the short run. In the other case, workers are fully mobile across sectors both in the short run and in the long run, without any restrictions.[10] In the case of short-run mobility, the number of workers in each sector is pinned down by a further optimality condition which assures that the value generated by a worker is the same in each sector (following from maximizing utility with respect to S_{1t+k}):

$$w_{1t}^S H_{1t}^S\left(C_t^S\right)^{-1} - \frac{\left(H_{1t}^S\right)^{1+\upsilon}}{1+\upsilon} = w_{2t}^S H_{2t}^S\left(C_t^S\right)^{-1} - \frac{\left(H_{2t}^S\right)^{1+\upsilon}}{1+\upsilon}. \quad (9)$$

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Under short-run mobility, equation 9 holds at any time. Under short-run immobility, it still pins down the steady-state distribution of workers across sectors, but no longer holds in the short run.

The composition of the aggregate consumption bundle is the same for all workers, only the quantity of consumed goods differs across skilled and unskilled workers. Therefore, in the following, we will omit the indices for the worker's skill class to avoid cumbersome notation. The aggregate consumption bundle C_t is a Cobb–Douglas composite of the goods produced in the two sectors:

$$C_t = C_{1t}^{\alpha} C_{2t}^{1-\alpha}, \tag{10}$$

where α is the share of good 1 in the consumption bundle for both H and F. We obtain relative demand functions for each good from the expenditure minimization problem of the household. The implied demand functions are

$$C_{1t} = \alpha \frac{P_t}{P_{1t}} C_t \quad \textit{and} \quad C_{2t} = (1-\alpha) \frac{P_t}{P_{2t}} C_t, \tag{11}$$

where $P_t = \left(\frac{P_{1t}}{\alpha}\right)^{\alpha} \left(\frac{P_{2t}}{1-\alpha}\right)^{1-\alpha}$ is the price index that buys one unit of the aggregate consumption bundle C_t.

Each sector good is a consumption bundle defined over a continuum of varieties Ω_i, both domestic and imported,

$$C_{it} = \left[\int_{\omega \varepsilon \Omega_i} c_{it}(\omega)^{\frac{\theta-1}{\theta}} d\omega \right]^{\frac{\theta}{\theta-1}}, \tag{12}$$

where $\theta > 1$ is the elasticity of substitution between goods. At any given time, only a subset of varieties $\Omega_{it} \in \Omega_i$ is available in each sector. The consumption-based price index for each sector is $P_{it} = \left[\int_{\omega \varepsilon \Omega_i} p_{it}(\omega)^{1-\theta} d\omega \right]^{\frac{1}{1-\theta}}$ and the household demand for each variety is

$$c_{it}(\omega) = \left(\frac{p_{it}(\omega)}{P_{it}} \right)^{-\theta} C_{it}. \tag{13}$$

It is useful to redefine the demand functions in terms of aggregate consumption units. To this end, let us define $\rho_{it}(\omega) \equiv \frac{p_{it}(\omega)}{P_t}$ and $\psi_{it} \equiv \frac{P_{it}}{P_t}$ as the relative prices for individual varieties and for the sector bundles, respectively. Then, we can rewrite the demand functions for goods and sector bundles as $c_{it}(\omega) = \rho_{it}(\omega)^{-\theta} C_{it}$ and $C_{it} = \alpha_i \psi_{it}^{-1} C_t$, respectively, with $\alpha_1 = \alpha$ and $\alpha_2 = 1 - \alpha$.

3.2. Firms

3.2.1. Production

Within each sector, there is a continuum of firms, each producing a different variety. The number of firms and varieties is endogenous and determined by the entry of firms. Newly entering firms face a sunk entry cost f_e in effective labor units. The production technology is assumed to be Cobb–Douglas in the two inputs of production:

$$y_{it} = Z_t z \left(S_{it} H_{it}^S \right)^{\beta_i} \left(L_{it} H_{it}^L \right)^{(1-\beta_i)} \tag{14}$$

where Z_t is the aggregate productivity, which is the same in both sectors, z is the firm-specific productivity, and S_{it} and L_{it} are the numbers of skilled and unskilled workers used in a firm, whereas H_{it}^S and H_{it}^L are the hours worked per worker. Since firm-specific variables are now indexed by the firm-specific productivity z, we can omit the variety-index ω from now on.

As explained above, we use the extensive margin of labor supply to model comparative advantage and the intensive margin of labor supply to model adjustments in labor supply in response

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to business cycle shocks. Aggregate productivity follows an AR(1) process with autocorrelation ρ_z and is subject to i.i.d. shocks ε_z, following a normal distribution with mean 0 and standard deviation σ_z. β_i is the share of skilled labor required by a firm to produce one unit of output y_{it} in sector i. Sector 1 is assumed to be skill-intensive and sector 2 unskilled-intensive which implies that $1 > \beta_1 > \beta_2 > 0$. The labor market is assumed to be perfectly competitive implying that the hourly real wage of both skilled and unskilled workers equals their marginal products. Furthermore, workers are perfectly mobile across firms implying that all firms pay the same wage. Consequently, relative labor demand can be described by the following condition:

$$\frac{w_{it}^S}{w_{it}^L} = \frac{\beta_i}{(1-\beta_i)} \frac{L_{it} H_{it}^L}{S_{it} H_{it}^S}, \tag{15}$$

which says that the ratio of the skilled hourly real wage w_{it}^s to the unskilled hourly real wage w_{it}^L for sector i is equal to the ratio of the marginal contribution of each factor into producing one additional unit of output. Note that this condition implies that relative demand for labor is the same across firms and is independent of firm-specific productivity.

3.2.2. Firm heterogeneity

Firms are heterogeneous in terms of their productivity z_i. The productivity differences across firms translate into differences in the marginal cost of production. Measured in the units of the aggregate consumption bundle, the marginal cost of production is $\frac{(w_{it}^S)^{\beta_i}(w_{it}^L)^{1-\beta_i}}{z_i Z_t}$.

Prior to entry, firms are identical and face a sunk entry cost f_e. Upon entry firms draw their productivity level z_i from a common distribution $G(z_i)$ with support on $[z_{min}, \infty)$. This firm productivity remains fixed thereafter. As in GM, there are no fixed costs of production, so that all firms produce each period until they are hit by an exit shock. This exit shock is independent of the firm's productivity level, so $G(z_i)$ also represents the productivity distribution of all producing firms.

Exporting goods to F is costly and involves both an iceberg trade cost $\tau \geq 1$ and a fixed cost f_x, again measured in units of effective labor. In real terms, these costs are $\frac{f_x (w_{it}^S)^{\beta_i}(w_{it}^L)^{1-\beta_i}}{Z_t}$. The fixed cost of exporting implies that not all firms find it profitable to export.

All firms are monopolistic competitors and face the residual demand curve, equation 13. They set prices as a proportional markup $\frac{\theta}{\theta-1}$ over marginal cost. Let $p_{d,it}(z_i)$ and $p_{x,it}(z_i)$ denote the nominal domestic and export prices of an H firm in sector i. We assume that the export prices are denominated in the currency of the export market. Prices in real terms are then given by:

$$\rho_{d,it}(z_i) = \frac{p_{d,it}(z_i)}{P_t} = \frac{\theta}{\theta-1} \frac{\left(w_{it}^S\right)^{\beta_i} \left(w_{it}^L\right)^{1-\beta_i}}{Z_t z_i}, \rho_{x,it}(z_i) = \frac{p_{x,it}(z_i)}{P_t^*} = \frac{1}{Q_t} \tau \rho_{d,it}(z_i). \tag{16}$$

Profits, expressed in units of the aggregate consumption bundle of the firm's location, are the sum of domestic $d_{d,it}(z_i)$ and export profits $d_{x,it}(z_i)$, such that $d_{it}(z) = d_{d,it}(z_i) + d_{x,it}(z_i)$, and,

$$d_{d,it}(z_i) = \frac{1}{\theta} \left(\frac{\rho_{d,it}(z_i)}{\psi_{it}} \right)^{1-\theta} \alpha_i C_t \tag{17}$$

$$d_{x,it}(z_i) = \begin{cases} \frac{Q_t}{\theta} \left(\frac{\rho_{x,it}(z_i)}{\psi_{it}^*} \right)^{1-\theta} \alpha_i C_t^* - \frac{f_x (w_{it}^S)^{\beta_i} (w_{it}^L)^{1-\beta_i}}{Z_t}, & \text{if firm} z_i \text{exports} \\ 0 & \text{otherwise.} \end{cases} \tag{18}$$

A firm will export if and only if it earns non-negative profits from doing so. For H firms, this will be the case if their productivity draw z_i is above some cutoff level $z_{x,it} = \inf\{z : d_{x,it} > 0\}$.

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We assume that the lower bound productivity z_{min} is identical for both sectors and low enough relative to the fixed costs of exporting so that $z_{x,it}$ is above z_{min}. Firms with productivity between z_{min} and $z_{x,it}$ serve only their domestic market.

3.2.3. Firm averages

In every period, a mass $N_{d,it}$ of firms produces in sector i of country H. The number of exporters is $N_{x,it} = \left[1 - G(z_{x,it})\right] N_{d,it}$. It is useful to define two average productivity levels, an average $\tilde{z}_{d,it}$ for all producing firms in sector i of country H and an average $\tilde{z}_{x,it}$ for all exporters in sector i of country H:

$$\tilde{z}_{d,it} = \left[\int_{z_{min}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{(\theta-1)}}, \quad \tilde{z}_{x,it} = \left[\int_{z_{x,it}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{(\theta-1)}}.$$

As in Melitz (2003), these average productivity levels summarize all the necessary information about the productivity distributions of firms.

We can redefine all the prices and profits in terms of these average productivity levels. The average nominal price of H firms in the domestic market is $\tilde{p}_{d,it} = p_{d,it}(\tilde{z}_{d,it})$ and in the foreign market is $\tilde{p}_{x,it} = p_{x,it}(\tilde{z}_{x,it})$. The price index for sector i in H reflects prices for the $N_{d,it}$ home firms and F's exporters to H. Then, the price index for sector i in H can be written as $P_{it}^{1-\theta} = [N_{d,it} \left(\tilde{p}_{d,it}\right)^{1-\theta} + N_{x,it}^{*} \left(\tilde{p}_{x,it}^{*}\right)^{1-\theta}]$. Written in real terms of aggregate consumption units, this becomes $\psi_{it}^{1-\theta} = [N_{d,it} \left(\tilde{\rho}_{d,it}\right)^{1-\theta} + N_{x,it}^{*} \left(\tilde{\rho}_{x,it}^{*}\right)^{1-\theta}]$, where $\tilde{\rho}_{d,it} = \rho_{d,it}(\tilde{z}_{d,it})$ and $\tilde{\rho}_{x,it}^{*} = \rho_{x,it}^{*}(\tilde{z}_{x,it}^{*})$ are the average relative prices of H's producers and F's exporters.

Similarly, we can define $\tilde{d}_{d,it} = d_{d,it}(\tilde{z}_{d,it})$ and $\tilde{d}_{x,it} = d_{x,it}(\tilde{z}_{x,it})$ such that $\tilde{d}_{it} = \tilde{d}_{d,it} + \left[1 - G(z_{x,it})\right] \tilde{d}_{x,it}$ are average total profits of H firms in sector i.

3.2.4. Productivity distribution of firms

Productivity z follows a Pareto distribution with lower bound z_{min} and shape parameter $k > \theta - 1$: $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^{k}$. Let $\nu = \left\{\frac{k}{[k-(\theta-1)]}\right\}^{\frac{1}{\theta-1}}$, then average productivities are

$$\tilde{z}_{d,it} = \nu z_{min} \text{ and } \tilde{z}_{x,it} = \nu z_{x,it}. \tag{19}$$

The share of exporting firms in sector i in H is

$$\frac{N_{x,it}}{N_{d,it}} = 1 - G(z_{x,it}) = 1 - \left(\frac{\nu z_{min}}{\tilde{z}_{x,it}}\right)^{k}. \tag{20}$$

Together with the zero export profit condition for the cutoff firm, $d_{x,it}(z_{x,it}) = 0$, this implies that average export profits must satisfy

$$\tilde{d}_{x,it} = (\theta - 1) \left(\frac{\nu^{\theta-1}}{k}\right) \frac{f_x \left(w_{it}^{S}\right)^{\beta_i} \left(w_{it}^{L}\right)^{1-\beta_i}}{Z_t}. \tag{21}$$

3.2.5. Firm entry

We assume that all firms in a given country are owned by a mutual fund who invests in new firms on behalf of the entire population, collects all the profits, and distributes the surplus of profits over firm investment in a lump-sum fashion.[11] To set up a new firm, the sunk entry cost $\frac{f_e (w_{it}^{S})^{\beta_i} (w_{it}^{L})^{1-\beta_i}}{Z_t}$ has to be paid. Note that entry costs can differ between sectors due to different factor intensities and due to inter-sectoral wage differentials.

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All firms are subject to exit shocks, which occur with probability $\delta \in (0, 1)$ at the end of each period. We assume that entrants at time t only start producing at time $t+1$, which introduces a one-period time-to-build lag in the model. Thus, a proportion δ of new entrants will never produce. The number of existing firms is denoted by $N_{d,it}$ and the number of newly entering firms by $N_{e,it}$. Then the law of motion for the stock of producing firms can be written as:

$$N_{d,it} = (1-\delta)(N_{d,it-1} + N_{e,it-1}). \tag{22}$$

The present discounted value of expected profits is

$$\widetilde{v}_{it} = E_t \sum_{s=t+1}^{\infty} \left[\gamma^{s-t} (1-\delta)^{s-t} \left(\frac{C_s}{C_t} \right)^{-1} \widetilde{d}_{is} \right]. \tag{23}$$

Firm profits are discounted using the aggregate stochastic discount factor adjusted for the probability of firm survival $(1-\delta)$. Note that equation 23 can be written in recursive form as:

$$\widetilde{v}_{it} = \gamma(1-\delta) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-1} \left(\widetilde{v}_{it+1} + \widetilde{d}_{it+1} \right) \right]. \tag{24}$$

Entry occurs until firm value is equal to the entry cost:

$$\widetilde{v}_{it} = \frac{f_e \left(w_{it}^S\right)^{\beta_i} \left(w_{it}^L\right)^{1-\beta_i}}{Z_t}. \tag{25}$$

Finally, the surplus of the mutual fund is given by:

$$\Pi_t = \widetilde{d}_{1t} N_{d,1t} + \widetilde{d}_{2t} N_{d,2t} - \widetilde{v}_{1t} N_{e,1t} - \widetilde{v}_{2t} N_{e,2t} \tag{26}$$

3.3. *Market clearing conditions, aggregate accounting, and trade*

Market clearing requires that total production in each sector must equal total income so that:

$$N_{d,it} \left(\frac{\widetilde{\rho}_{d,it}}{\psi_{it}} \right)^{1-\theta} \alpha_i C_t + Q_t N_{x,it} \left(\frac{\widetilde{\rho}_{x,it}}{\psi_{it}^*} \right)^{1-\theta} \alpha_i C_t^* + \widetilde{v}_{it} N_{e,it} = w_{it}^S S_{it} H_{it}^S + w_{it}^L L_{it} H_{it}^L + \widetilde{d}_{it} N_{d,it}. \tag{27}$$

Total production of the sector includes the production of the aggregate consumption bundle and the production of new firms. Total income generated by the sector includes wage earnings and profits.

The trade balance is defined as total exports minus total imports:

$$tb_t = \sum_{i=1}^{2} \left[Q_t N_{x,it} \left(\frac{\widetilde{\rho}_{x,it}}{\psi_{it}^*} \right)^{1-\theta} \alpha_i C_t^* - N_{x,it}^* \left(\frac{\widetilde{\rho}_{x,it}^*}{\psi_{it}} \right)^{1-\theta} \alpha_i C_t. \right] \tag{28}$$

Let us define aggregate bond holdings in H as $A_t \equiv \sum_{i=1}^{2} (A_{it}^S + A_{it}^L)$ and $Af_t \equiv \sum_{i=1}^{2} (Af_{it}^S + Af_{it}^L)$ for H and F bonds, respectively. Similarly, aggregate bond holdings in F are $A_t^* \equiv \sum_{i=1}^{2} (A_{it}^{*S} + A_{it}^{*L})$ and $Af_t^* \equiv \sum_{i=1}^{2} (Af_{it}^{*S} + Af_{it}^{*L})$. In equilibrium, the international net supply of bonds is zero for H bonds such that $A_t + A_t^* = 0$ and for F bonds such that $Af_t + Af_t^* = 0$. Then net foreign assets evolve according to the following law of motion:

$$A_t + Q_t Af_t = (1 + r_{t-1}) A_{t-1} + \left(1 + r_{t-1}^*\right) Af_{t-1} Q_t + tb_t. \tag{29}$$

Finally, if workers are mobile between sectors, then, at each point of time the sum of workers employed in both sectors equals the exogenous worker endowment for skilled and unskilled workers, respectively, such that $S = \sum_{i=1}^{2} S_{it}$ and $L = \sum_{i=1}^{2} L_{it}$. Equivalent equations hold for F.

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4. Calibration

This section describes the calibration of the model that we use for the numerical simulations. In many aspects, we follow GM. We interpret each period as a quarter and set the household discount factor γ to 0.99, the standard choice for quarterly business cycle models. We set the inverse of the Frisch elasticity of labor supply υ equal to 1, again a standard choice for business cycle models. We set the elasticity of substitution between varieties to $\theta = 3.8$, based on the estimates from plant-level US manufacturing data in Bernard et al. (2003). We set the parameters of the Pareto distribution to $z_{\min} = 1$ and $k = 3.4$, respectively. This choice satisfies the condition for finite variance of log productivity: $k > \theta - 1$. We also set the parameter for adjustment costs of international bond portfolios to $\eta = 0.01$.

Changing the sunk cost of firm entry f_e only re-scales the mass of firms in an industry. Thus, without loss of generality we can normalize it so that $f_e = 1$. We set the fixed cost of exporting f_x to 23.5% of the per-period, amortized flow value of the sunk entry costs, $[1 - \gamma(1 - \delta)]/\,[\gamma(1 - \delta)]f_e$. This leads to a steady-state share of exporting firms of 24% in the exporting sector, 12% in the import-competing sector, and an average share of 22.5%. We set the size of the exogenous firm exit probability to $\delta = 0.025$, to match the level of 10% job destruction per year in the USA. These choices of parameter values are based on GM.

To focus on the role of comparative advantage, we assume that all industry parameters are the same across industries and countries except for factor intensity (β_i). To calibrate factor intensities, we use the NBER-CES Manufacturing Industry Database,[12] which provides annual industry-level data from 1958–2009 on output, employment, payroll and other input costs, investment, capital stocks, TFP, and various industry-specific price indexes. We aggregate the data set to feature 19 3-digit NAICS industries and then classify these industries based on their revealed comparative advantage as in section 2, implying that there are 9 comparative advantage sectors that are net exporters and 10 comparative disadvantage sectors that are net importers.[13] In order to calibrate factor intensities of each sector, we calculate the wage share of production workers in the total payroll for comparative advantage sectors and comparative disadvantage sectors. Production workers refer to blue-collar, unskilled workers. We take the period average from 1980 to 2009 and find that the implied wage share for skilled workers in comparative advantage sectors is $\beta_1 = 0.45$ and in comparative disadvantage sectors is $\beta_2 = 0.32$. Thus, our model assumption is confirmed by the data as net exporting sectors tend to be more skill-intensive than net importing sectors. Similarly, we calculate the average share of comparative advantage sectors in total sector revenue to be 0.627 for 1980–2009. We use it to calibrate $\alpha = 0.6$.

In our calibration approach, we assume that the Home and the Foreign economy are symmetric except for their relative endowments of skilled workers. We take this approach in order to isolate the role of comparative advantage trade for the business cycles of developed countries. Given the definition of skilled workers and unskilled workers in the NBER-CES data, we calibrate the endowments based on the ratio of production workers to managers in figure 3 in Ebenstein et al. (2011). For the USA, this ratio is 4 to 1 in 1990 and 3 to 1 in 2005. For China, the ratio is 8 to 1 in 1990 and 11 to 1 in 2005. Taking the average over the two available years and for a population of 2000 workers, these ratios imply that $S = 444$ and $L = 1356$ for the Home country and $S^* = 191$ and $L^* = 1809$ for the Foreign country. These endowments imply that the USA has a higher relative endowment of skilled workers than China, and thus a comparative advantage in producing skill-intensive goods.

In line with the fact that there is no physical capital in our framework, we follow Den Haan et al. (2000) and Cacciatore (2014) and calibrate the properties of the productivity shocks to match the properties of real GDP relative to employment. We estimate the following VAR system:

$$\begin{bmatrix} log(Z_t) \\ log(Z_t^*) \end{bmatrix} = \begin{bmatrix} 0.73(0.09) & -0.07(0.04) \\ -0.10(0.14) & 0.70(0.07) \end{bmatrix} \begin{bmatrix} log(Z_{t-1}) \\ log(Z_{t-1}^*) \end{bmatrix} + \begin{bmatrix} e_{zt} \\ e_{zt^*} \end{bmatrix},$$

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where Z_t is the output per employed worker in the USA and Z_t^* is the output per employed worker in China, and e_{zt} and e_{zt^*} are productivity disturbances in the USA and China, respectively. Standard errors are in parenthesis. The series $log(Z_t)$ and $log(Z_t^*)$ are normalized so that they have a mean of zero. Note that the estimated persistence of the US shock is $\rho_Z = 0.73$ and of the Chinese shock $\rho_{Z^*} = 0.70$, and both are significantly different from zero at the 5% level. The off diagonal terms are not significant implying no built-in dependence on the lags of the other country's shock. The standard deviation of the US residuals (e_{zt}) is 0.0047. The standard deviation of the Chinese residuals (e_{zt^*}) is 0.0078. The correlation between the residuals is 0.0227. Thus, we set $\sigma_z = 0.0047$, $\sigma_{z*} = 0.0078$, and $corr(e_z, e_{z^*}) = 0.0227$. We conclude from this analysis that the processes of aggregate productivity in the USA and China are largely independent of each other. This is in contrast to the results in, e.g., Backus et al. (1992) and Cunat and Maffezzoli (2004), who find a much larger correlation of productivity shocks among industrialized countries.

Finally, we calibrate the iceberg trade costs for both countries to deliver a share of total trade in Home GDP of 0.62. This corresponds to the average share of total manufacturing trade in manufacturing value added for the USA over the period 1980–2009. This share implies trade costs of $\tau = \tau^* = 1.1837$.

5. Aggregate productivity shocks

In this section, we discuss the reaction of our model economy in response to two standard business cycle shocks, a temporary productivity shock at Home and a temporary productivity shock at Foreign. In each case, aggregate productivity is assumed to decrease on impact by one standard deviation and then to slowly converge back to its steady-state level with an autocorrelation of 0.73 for H and 0.70 for F, in line with our estimates in section 4. We assume that the productivity shock affects both sectors equally, i.e., it is not sector-specific. Analysis of the role of sector-specific shocks can be found in the appendix.

Before starting the discussion of these shocks, let us briefly discuss the steady state of this economy. As pointed out in section 4, we calibrate the model such that Home is relatively more abundant in skilled workers than Foreign, which means that the share of skilled workers to unskilled workers is higher at Home than at Foreign. This implies that at the steady state international trade leads to specialization of production. Home concentrates on the production of the skill-intensive good while Foreign concentrates on the production of the unskilled-intensive good.

At the aggregate level, trade is balanced in steady state, but at the sector level it is not. In the following discussion of the results, we call the sector, in which a country specializes, its exporting sector because in that sector it produces more than it consumes and exports the difference. We call the other sector the import-competing sector because in it the country consumes more than it produces and imports the difference. Each country finances the trade deficit in its import-competing sector with the trade surplus in the exporting sector. This specialization pattern is important for our analysis, because it responds to business cycle shocks (in line with the empirical results in section 2).

5.1. Aggregate productivity shock at Home

We start our discussion with our baseline case where workers are assumed to be immobile across sectors. This assumption is in line with recent empirical evidence suggesting that workers are immobile both geographically and across sectors. Furthermore, in section 6 we provide new empirical evidence that sectoral employment reacts only weakly to productivity shocks. Nevertheless, we will discuss the role of worker mobility in more detail further below (section 5.5) and present a version of the model with costly worker mobility in section 6.

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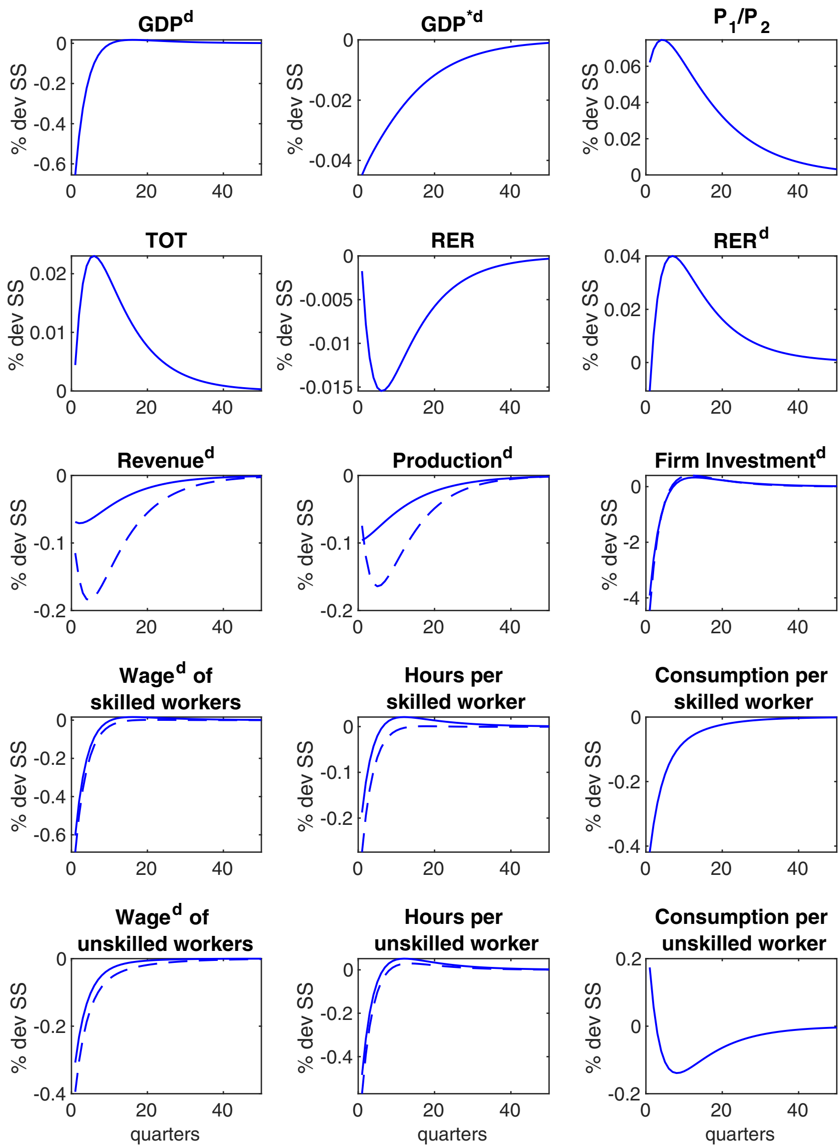

Figure 3. Domestic productivity shock. Impulse responses to a decline in domestic aggregate productivity. Variables are measured in %-deviations from steady state. Solid lines either refer to aggregate variables (first and second rows) or sector 1, the exporting sector(all other rows) while dashed lines refer to sector 2, the import-competing sector.

Figure 3 shows the development of selected variables at Home in response to a drop in domestic aggregate productivity. The figure reports data-consistent measures of GDP, sector output, sector revenue, sector firm investment, and sector wages, correcting for the change in the number of varieties.[14]

A negative productivity shock leads to a contraction in output because production becomes less efficient and real marginal costs $((w^S_{it})^{\beta_i}(w^L_{it})^{1-\beta_i}/\,(z_i Z_t))$ rise. Output contracts in both sectors but the contraction is much larger in the import-competing sector than in the exporting sector, so that output and revenue become relatively more concentrated in the exporting sector. Thus, the temporary fall in Home productivity leads to a temporary increase in specialization. Note that

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this is very much in line with the stylized facts developed in section 2, where we show empirically that in the USA comparative disadvantage sectors are significantly more responsive to changes in aggregate productivity than comparative advantage sectors. According to the empirical analysis, the reaction of import-competing sectors to shocks in aggregate productivity is 1.5 times stronger than the reaction of exporting sectors in the year that the shock hits. Our simulation matches this result very well.

The shift in specialization is driven by movements in relative demand and relative prices. As Figure 3 shows, the fall in productivity leads to an appreciation in the welfare-consistent RER, meaning that foreign products get cheaper relative to domestic products. This is the case because the fall in productivity makes Home production less efficient. Marginal costs increase and thus the price level at Home increases relative to the price level at Foreign. Figure 3 also reports the data-consistent RER which moves in the opposite direction of the welfare-consistent RER, illustrating that the appreciation of the welfare-consistent RER is driven by the reduction in the number of Home's varieties. Note that the development of both measures of the RER is the same as in GM (see figure III on page 892).

The appreciation of the welfare-consistent RER is associated with an increase in Home's terms of trade. As in the standard Heckscher–Ohlin model, an increase in the terms of trade translates into an increase in specialization. Our model is more complicated since it incorporates both inter- and intra-industry trade, but the basic mechanism remains intact. In the standard Heckscher–Ohlin model, the exporting sector only exports and does not import, while the import-competing sector only imports and does not export. This is different in our model due to the co-existence of comparative advantage and love of variety, but it is still the case that exports are more concentrated in the exporting sector.[15] Since exports are concentrated in the exporting sector, this sector depends relatively more on foreign demand and relatively less on domestic demand. To the contrary, the import-competing sector depends relatively more on domestic demand.[16] Thus, in response to a negative shock to aggregate domestic productivity the import-competing sector faces a relatively larger decline in demand. Relative demand and the relative price of the two sectors move in favor of the exporting sector. Note, however, that the movement in relative prices is relatively mild, implying that concentration in terms of revenue increases only little more than concentration in terms of output. This is again in line with our empirical analysis in section 2.

Naturally, the shift in the relative demand for the products of both sectors has implications for the relative demand for production factors. While the negative productivity shock lowers the demand for labor and firms in general, the shift in relative product-demand lowers factor-demand more in the import-competing sector. If workers and firms were mobile, they would migrate from the import-competing sector to the exporting sector. In the absence of this possibility to migrate, it is only hours worked and firm investment that can react. Consequently, firm investment goes down in both sectors, but it goes down more in the import-competing sector. Analogously, hours worked, along with wages, go down in both sectors but more in the import-competing sector. Note, however, that the sectoral shifts in firm investment and hours worked are very small relative to the general decline of both variables.

Figure 3 also shows that the hours worked go down more for unskilled workers than for skilled workers, which is in line with the data.[17] This is explained by the distribution of profits from the mutual fund. In response to the negative productivity shock, the mutual fund reduces investment in new firms, and therefore can redistribute more profits to the households, even though firm profits actually go down. Thus, the transfers of the mutual fund are countercyclical and stabilize consumption. This mechanism is analogous to a decision to dissave during times of crises to smooth consumption. The cyclicality of consumption is important for the cyclicality of the labor supply because labor supply is determined by both the real wage and the marginal utility from consumption (see equation 6). Due to the stabilizing effects of the mutual fund, consumption

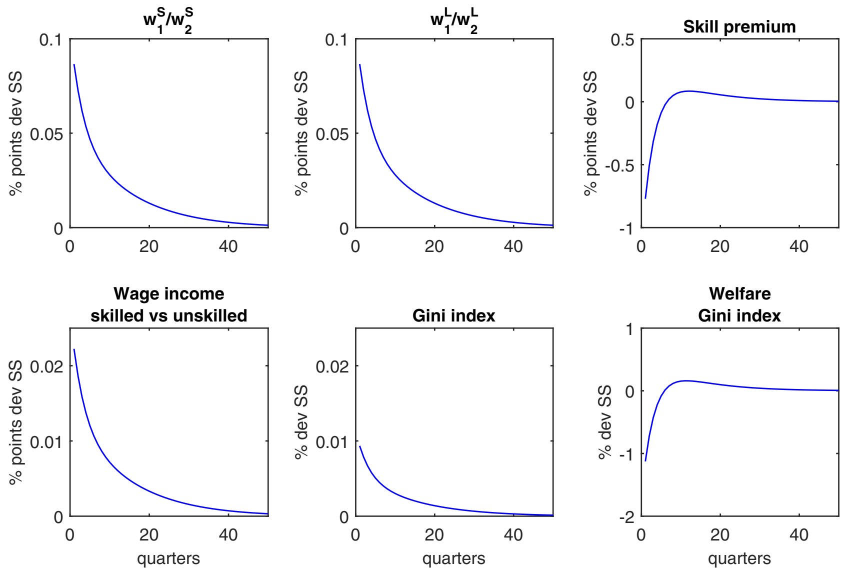

Figure 4. Inequality. Impulse responses to a decline in domestic aggregate productivity.

goes down by less, the marginal utility from consumption goes up by less, and thus labor supply goes down by more.

For unskilled workers, the stabilizing effect of the mutual fund is more important, because unskilled workers have a lower wage income and thus the transfers of the mutual fund make up a bigger portion of their income. The marginal utility from consumption increases by less for unskilled than for skilled workers, and therefore they reduce their labor supply more in response to the drop in the real wage.[18] Arguably, the large volatility of hours worked for unskilled workers in the data is not all due to voluntary labor supply decisions but to a certain extent also due to insufficient labor demand. This aspect could be captured by including labor market frictions which is left for future research.

The diverging development of the labor supply of unskilled and skilled workers in turn contributes to the sectoral shift in production. Since unskilled workers are relatively more important in the import-competing (unskilled-intensive) sector, this shift in the relative labor supply decreases output in the import-competing sector relative to output in the exporting sector.

5.2. Inequality

Our model, in deviating from the standard representative household framework, allows us to discuss inequality across various margins. Figure 4 shows the development of wage and income differences across sectors, across skill classes, and in the whole economy (for a precise definition of these inequality measures, see the appendix).

As discussed above, the shift in relative demand for both sectors that follows a decrease in aggregate productivity raises the relative demand for labor in the exporting sector. Because workers are immobile across sectors, this is reflected in a temporary increase in the wage of the exporting sector relative to the import-competing sector.[19]

The aggregate productivity shock also has consequences for the wage inequality between skilled workers and unskilled workers. As explained above, the drop in aggregate productivity leads to a shift in relative demand from the import-competing sector to the exporting sector. Since the exporting sector is skill-intensive, this also implies relatively more demand for skilled workers

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than for unskilled workers. As a consequence, the share of total wage income (the wage times hours worked) that goes to skilled workers increases temporarily.

Figure 4 also reports that the skill premium goes down which seems to contradict the argument above. Note, however, that this can be explained by the stronger reduction in hours worked of unskilled workers. This has the effect of making unskilled workers relatively scarcer and that pushes down the skill premium. So the shift in relative demand raises the relative wage income of skilled workers. Nevertheless, the decrease in the supply of unskilled labor lowers the skill premium.

These developments are reflected in overall wage inequality measured by the Gini coefficient, which is based on the deviation of income from a totally equal distribution. Since the Gini coefficient measures income inequality and not just wage inequality, it depends more on the relative wage income of skilled and unskilled workers, and not so much on the skill premium, and thus goes up. Note, however, that the Gini coefficient quantitatively changes only little.

Let us stress again that this increase in wage inequality is driven to a large extent by the different responses of skilled and unskilled workers to the technology shock: Unskilled workers reduce their labor supply by more than skilled workers. This reduces their income by more and wage inequality goes up. Since unskilled workers can enjoy more leisure, wage inequality is only an imperfect measure of welfare inequality in this setting. To this end, Figure 4 also shows a Gini of "utility inequality" that is constructed in the exact same way as the income Gini, but based on the total period utility of a worker rather than just his income. This makes a big difference, the inequality of utility actually goes down in response to the aggregate productivity shock reflecting the larger increase in leisure for unskilled workers.

5.3. Productivity shocks at Foreign

Figure 5 shows the effects of a temporary productivity shock at Foreign for the economy at Home. As expected, the development of prices is the exact opposite as for the domestic productivity shock. Home's welfare-consistent RER depreciates because Foreign produces less efficiently and thus its marginal costs increase.[20] Consequently, Home's import-competing sector faces lower competition from abroad and can expand its revenue and output, while its exporting sector faces decreased foreign demand and thus contracts. Correspondingly, the relative price of both sectors moves in favor of the import-competing sector.

Although the expansion in the import-competing sector is relatively larger than the contraction in the exporting sector, the larger size of the latter implies that domestic GDP goes down. That domestic GDP is negatively affected by the foreign shock already suggests that the correlation of GDP in both countries is positive, something that is in line with empirical data but often a challenge for RBC models to replicate.

Figure 6 also reports some measures of inequality. These develop in the opposite direction compared to the domestic shock. The shift in relative demand toward the import-competing sector implies that wages in the import-competing sector go up relative to those in the exporting sector, and that the demand for unskilled workers rises. This implies that the skill premium and the relative wage income that goes to skilled workers decrease. Overall wage inequality is largely driven by the inequality between skilled and unskilled workers and therefore decreases, even though intersector inequality increases. Again our welfare-Gini goes in the opposite direction, driven by the development of leisure.

5.4. Business cycle statistics

This section presents (partially) new evidence on business cycle statistics for the US-economy vis-a-vis its Chinese counterpart and compares them to the same statistics generated by our model for the productivity shock processes specified in section 4. In doing so, we focus specifically on

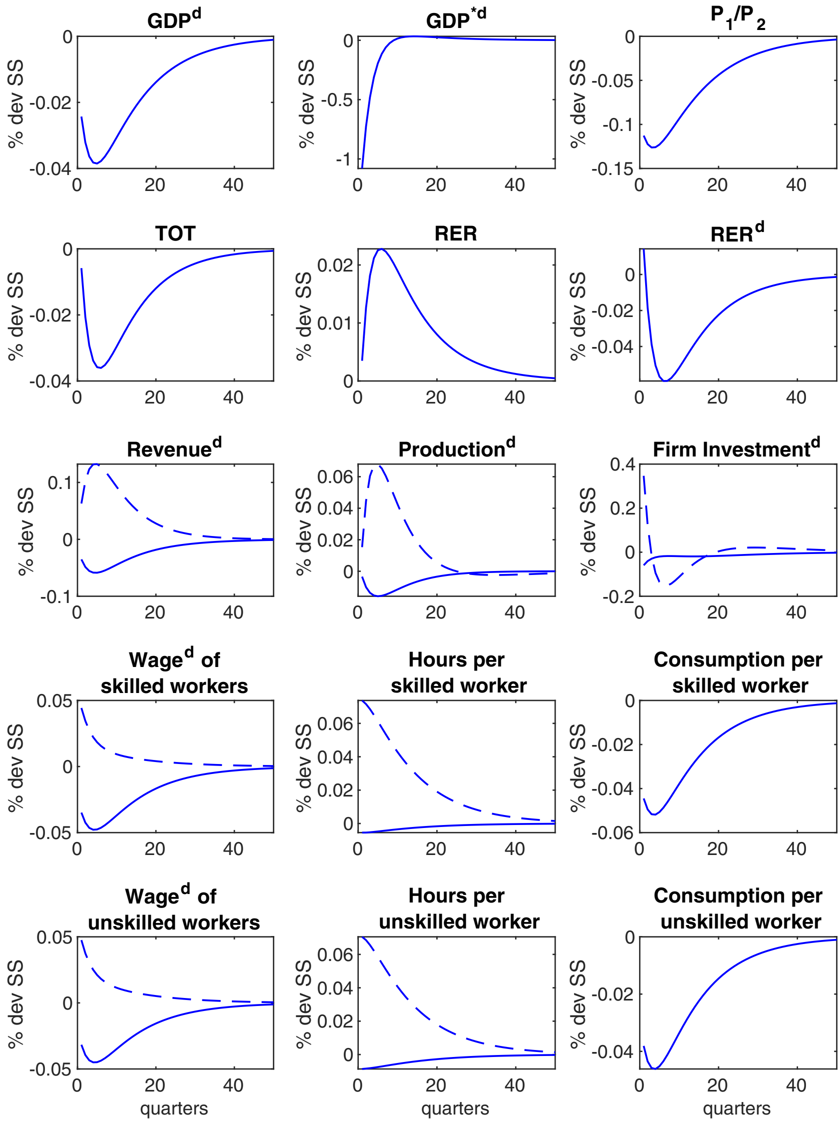

Figure 5. Foreign productivity shock. Impulse responses to a decline in foreign aggregate productivity. Variables are measured in %-deviations from steady state. Solid lines either refer to aggregate variables (first and second row) or sector 1, the exporting sector, (all other rows) while dashed lines refer to sector 2, the import-competing sector.

the novel aspect of our analysis, the distinction between comparative advantage and comparative disadvantage sectors.

We report statistics for data on the USA and China for relevant aggregate variables as well as some sector-specific variables for the USA. All data series are log-transformed, quarterly, seasonably adjusted, hp-filtered (with smoothing parameter 1600), and span the period from 1992q1 to 2007q3. The period of analysis is restricted by the availability of data for China and exclusion of the Great Recession period. We report (real) GDP, which is nominal GDP deflated by the CPI, investment I, which is nominal gross fixed capital formation deflated by the CPI, and consumption C, which is nominal consumption expenditure deflated by the CPI.[21] We also report the bilateral real

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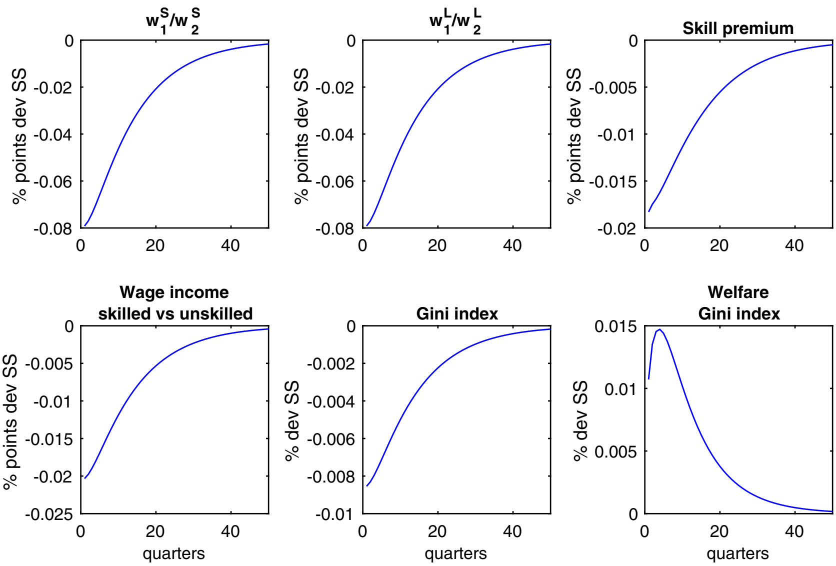

Figure 6. Inequality. Impulse responses to a decline in foreign aggregate productivity.

exchange rate of the USA vis a vis China defined as $RER_{US,CHN} = \frac{eCPI^{CHN}}{CPI^{US}}$, where e is the nominal exchange rate in dollars per yuan and an increase in $RER_{US,CHN}$ corresponds to a real depreciation of the dollar.[22]

We also report measures on the trade balance as a percent of GDP, where tb/GDP is the net exports between China and the USA divided by nominal US GDP.[23] Y_{CD} and Y_{CA} are averages of industrial production over comparative disadvantage and comparative advantage sectors, respectively, where comparative advantage refers to net exporting sectors and comparative disadvantage refers to net importing sectors as outlined in our calibration approach in section 4.[24] The measure of the relative sector price, P_{CD}/P_{CA}, is the log of the comparative disadvantage sector price minus the log of the comparative advantage sector price; due to data limitations this is an annual series, hp-filtered with smoothing parameter 100 and compared to annual real GDP in the tables.[25] Finally, we also report the US skill premium, defined as the ratio of the hourly wage of skilled to unskilled workers and $Hours^S/Hours^L$, defined as the relative hours worked of skilled to unskilled workers.[26] We report these two measures because they are important indicators in our model and data on them are available.

The second and fourth columns in Table 1 report the relevant moments based on the data described above. In section 2, we have shown that in the USA import-competing sectors are more volatile conditional on shocks to aggregate productivity. Table 1 confirms that the same is true for unconditional volatilities. The standard deviation of output in comparative disadvantage sectors is about 70% larger than the standard deviation of output in comparative advantage sectors. Sector output is positively correlated with GDP but far from perfectly. Sector output is more volatile than GDP. This is to be expected given that variations at the sector level might offset each other to a certain extent. The price of comparative disadvantage sectors relative to the price of comparative advantage sectors is also volatile and procyclical, i.e., during a recession the price of comparative advantage sectors goes up relative to the price of comparative disadvantage sectors.

The results for the aggregate variables are standard. Investment is more volatile than GDP, while consumption is less volatile. Both variables are almost perfectly correlated with GDP. The US–China RER is more volatile than GDP and recessions in the USA tend to be associated with RER depreciations, in the sense than US goods become cheaper relative to Chinese goods. GDP

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Table 1. Baseline model versus data

	Standard deviation in % in first row and relative to GDP thereafter		Correlation with GDP	
	Model	Data	Model	Data
GDP	0.92%	1.14%	1	1
GDP^{*}_{CHN}	1.58	1.23	0.12	0.3
I	5.8	3.10	0.97	0.93
C	0.32	0.76	0.62	0.91
$Skill\ Premium$	0.68	0.69	0.95	0.09
$Hours^{S}/Hours^{L}$	0.45	0.61	−0.96	−0.33
tb/GDP	0.0002	0.01	0.0001	−0.35
Y_{CD}	0.61	1.87	0.4	0.65
Y_{CA}	0.3	1.08	0.69	0.56
P_{CD}/P_{CA}	0.42	2.32	0.15	0.43
$RER_{US,CHN}$	0.26	4.39	0.01	−0.20

Notes: The first row reports the relative standard deviation of real GDP for the model and the standard deviation of real GDP for the data in percent. The rest of the rows report the standard deviations of relevant variables relative to the volatility of real GDP. Model-based moments are based on raw data while data moments are based on hp-filtered logged data.

in China is more volatile than GDP in the USA and the correlation between both is 0.3. This is in line with Fidrmuc and Korhonen (2015) who summarize previous research on China's business cycle correlation with other countries and report a mean correlation coefficient of 0.245 based on 24 surveyed papers. So the business cycle comovement between the USA and China is significant, albeit lower than the one among developed countries (see, e.g., Backus et al. (1992) or Cunat and Maffezzoli (2004)). The trade balance between the two countries is surprisingly stable. Our analysis also shows that the skill premium is less volatile than GDP and weakly procyclical, which is in line with the evidence in Keane and Prasad (1993), Lindquist (2004), and Castro and Coen-Pirani (2008), and that the ratio of hours worked of skilled workers to hours worked of unskilled workers is less volatile than GDP, less than 1 and countercyclical, confirming that hours worked of unskilled workers are more volatile than hours worked of skilled workers.

The first and third columns of Table 1 provide the analogous moments for our benchmark model economy, subject to domestic and foreign productivity shocks as specified in section 4. It can be seen that the model does a reasonably good job in replicating many important stylized facts of the business cycle.

Importantly, all variables, except the trade balance and the RER[27], exhibit the right cyclicality, i.e., the right sign of correlation with GDP. Given that the trade balance is extremely stable over time both in the data and in the model, its wrong cyclicality is not really meaningful. In the model, the correlation between RER and GDP is close to zero while it is slightly negative in the data. Note, however, that the zero-correlation in the model is the effect of two counter-acting effects. In response to domestic shocks, the RER is countercyclical and −0.18, very close to the −0.2 found in the data. However, in response to foreign shocks the response is procyclical and the correlation very strong (0.95). Thus, the model probably over-predicts the importance of RER-responses to foreign shocks. Further below, we will demonstrate that labor mobility also matters for the cyclicality of the RER.

The volatility of GDP is reasonably close to the data, although the model under-predicts US GDP volatility and over-predicts Chinese GDP volatility, so that in the model China's GDP

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appears much more volatile than the USA's, whereas this is not the case in the data. The correlation of US and Chinese GDP in the model is smaller than in the data (0.12 vs. 0.3), but larger than in typical RBC models (without correlated shocks).[28] As in GM, the model generates consumption volatility that is too low. Investment, as in GM measured as firm investment, is more volatile than GDP both in the data and in the model, but the model clearly over-predicts the volatility of investment. Note, however, that investment in model and data is defined differently. The volatility of the RER in the model is too low relative to the data. This is analogous to GM, who argue that this reflects fluctuations in the nominal exchange rate that have no impact on real variables in models with flexible prices.

Let us now turn to some of the variables that are specific to our model, the variables that pertain to the sectors. The GDP-correlation of both sectoral output measures is close to their empirical counterparts. However, the model does predict that the comparative advantage sector is more procyclical than the comparative disadvantage one, contrary to the data. Note, however, that the difference between the correlation coefficients in the data is small (0.09) and not statistically significant. In addition, the volatility of both sectoral output measures is substantially lower than in the data. In a way this is to be expected, given that we only consider aggregate productivity shocks that affect both sectors equally.[29] Importantly, however, the model does a very good job in replicating the relative volatility of import-competing and exporting sectors, which is 1.73 in the data and 2 in the model. Thus, import-competing sectors are substantially more volatile than exporting sectors both in the model and in the data. This is reassuring since this is a central aspect of our analysis.

The model also does a fairly good job in replicating the cyclicality of the relative price of both sectors, even if the ratio is less volatile relative to the data. Concerning the skill premium and the relative hours worked of skilled and unskilled workers, the model succeeds in replicating their volatility relative to the volatility of GDP. However, both variables exhibit a GDP-correlation that is too high. In our model, the business cycle is the only factor driving both variables, while in the data obviously other factors also play an important role.

5.5. The role of worker mobility and international trade

Having established the reasonable performance of our preferred model with respect to business cycle statistics, we now compare the model with other versions of the model to highlight the role of international trade, of workers' mobility, and of the structure of international trade. To this end, we simulate an autarky version of the model, a version in which workers are freely mobile across sectors and a one-sector version of the model (basically the model in GM).[30]

Tables 2 and 3 compare the relative standard deviations of selected variables and their correlations with GDP for the empirical data and the four versions of the model. On a general note, the results for GDP, investment, and consumption are very similar across the different versions of the model, but important differences arise with respect to the volatility of sectoral output, relative prices, and international business cycle comovement. We now discuss each version of the model in more detail.

5.5.1. International trade

Comparing our benchmark model with the model under autarky (column 2), we see that the larger volatility of the comparative disadvantage sector is indeed due to shifts in international specialization and thus inter-industry trade, since under autarky both sectors exhibit roughly equal volatility, and the relative price of both sectors barely fluctuates. As a result of this, the ratio of hours worked and the skill premium are also less volatile under autarky. Table 2 also demonstrates that international trade in our model reduces GDP volatility, albeit only very little. Although the

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Table 2. Models versus data volatility

Standard deviation in % in first row and relative to GDP thereafter					
	Baseline model	Autarky model	Full mobility of workers model	1 sector model	Data
GDP	0.92%	0.95%	0.96%	0.95%	1.14%
GDP^{*}_{CHN}	1.58	1.58	1.54	1.61	1.23
I	5.8	5.34	5.63	5.67	3.11
C	0.32	0.31	0.34	0.33	0.76
$Skill\ Premium$	0.68	0.63	0.55	–	0.69
$Hours^{S}/Hours^{L}$	0.45	0.36	0.43	–	0.61
tb/GDP	0.0002	–	0.0003	0.0001	0.01
Y_{CD}	0.61	0.32	3.24	–	1.87
Y_{CA}	0.3	0.31	0.32	–	1.08
P_{CD}/P_{CA}	0.42	0.01	0.21	–	2.32
$RER_{US,CHN}$	0.26	–	0.30	0.33	4.39

Notes: The first row reports standard deviations of real GDP in percent. The rest of the rows report the standard deviations of relevant variables relative to the volatility of real GDP.

Table 3. Models versus data correlation with GDP

Correlation with GDP					
	Baseline model	Autarky model	Full mobility of workers model	1 sector model	Data
GDP^{*}_{CHN}	0.12	0.02	0.07	0.05	0.3
I	0.97	0.97	0.97	0.97	0.93
C	0.62	0.68	0.65	0.65	0.91
$Skill\ Premium$	0.95	0.96	0.51	–	0.09
$Hours^{S}/Hours^{L}$	−0.96	−0.96	−0.95	–	−0.33
tb/GDP	0.0001	–	−0.15	−0.13	−0.35
Y_{CD}	0.4	0.69	0.34	–	0.65
Y_{CA}	0.69	0.68	0.38	–	0.56
P_{CD}/P_{CA}	0.15	−0.84	−0.04	–	0.43
$RER_{US,CHN}$	0.01	–	−0.12	−0.09	−0.20

economy is now subject to foreign shocks, the reduced reaction to domestic shocks more than compensates for this.

5.5.2. Worker mobility

As already suggested above, the mobility of workers is very important in the two-sector model. Whereas under worker immobility the sectoral shifts in demand are partly translated into persistent shifts in the relative price of both sectors, under worker mobility workers migrate from the import-competing sector to the exporting sector. On the one hand, this leads to stronger shifts in sectoral production. On the other hand, the relative price of both sectors fluctuates much less.

As column 3 in Tables 2 and 3 demonstrates the model with worker immobility fairs much better along these dimensions. In the model with worker mobility, the standard deviation of the import-competing sector is more than 10 times that of the exporting sector, while this ratio is only 1.73 in the data (and 2 in the model with immobile workers). Thus, the model with mobile workers grossly overstates sectoral shifts in production. At the same time, the volatility of the ratio of sector prices is much too stable and acyclical, while it is procyclical in the data (and in the model with immobile workers). This confirms that the model with immobile workers is the better benchmark.

Another aspect along which the model with worker immobility fares better is to match the positive comovement of output across sectors. According to Katayama and Kim (2018), sector comovement of output and hours worked is a prominent feature of business cycle data but most two-sector neoclassical models fail to generate it. Indeed, the correlation between Y_{CD} and Y_{CA} in the data is 0.56. Our benchmark model with immobile workers generates sector comovement of 0.84 for output and of 0.78 for skilled and 0.94 for unskilled hours. So, it successfully generates positive comovement although it does overpredict the comovement of output. Katayama and Kim (2018) show that labor immobility is the key ingredient that allows their model to generate positive sector comovement. Our results are somewhat similar as the output comovement in the model with full worker mobility is -0.4601 but sectoral hours comove perfectly. The model of costly worker mobility that we develop in section 6 also highlights the key role of labor mobility as it also generates positive sectoral comovement of output of 0.42 which is lower than our benchmark and lower than the data. Note, however, that hours in the limited mobility model still comove almost perfectly. Thus, labor immobility is needed to generate positive sector comovement of output but not of hours. The key assumption that allows us to generate sectoral comovement of hours is that firm ownership is spread equally across all workers. In the appendix, we discuss a case where only skilled workers own the firms. When that is the case, the sector comovement for skilled hours is positive but it is negative for the unskilled hours.

It is important to note that the model with worker mobility exhibits the right sign of correlation between RER and GDP. On the one hand, the RER reacts more strongly to domestic shocks. On the other hand, GDP reacts less strongly to foreign shocks, which decreases the relevance of foreign shocks (which induce the "wrong" correlation of the RER with GDP). This implies that allowing for some degree of worker mobility will allow us to fit the data better. Indeed in section 6, we extend the model to include limited worker mobility and in this version the correlation between RER and GDP is -0.07. Note, however, that the volatility of the RER under worker mobility is still much lower than the one in the data.

Another striking feature is that the model with worker mobility generates less business cycle comovement in GDP across the two countries. The more stable and acyclical ratio of sector prices reduces the spillovers of productivity shocks and thereby the correlation of the GDP in both countries. Finally, GDP is more volatile when workers are mobile, albeit again the difference is very small.

5.5.3. Inter-industry trade

Finally, column 4 in Tables 2 and 3 compares our benchmark model with a one-sector version of the model that represents the standard approach in the open economy macroeconomic literature. Most notably, the one-sector model is much less successful in generating positive comovement between the two countries than the two-sector model with immobile workers. The reason for this is that the possibility to readjust sectoral output and sectoral prices in the two-sector model on the one hand dampens the effects of domestic shocks, but on the other hand implies larger spillovers to the foreign country, which is also forced to re-balance its sectoral production structure. Thus, the introduction of inter-industry trade into a business cycle model clearly helps to generate positive business cycle comovement.[31]

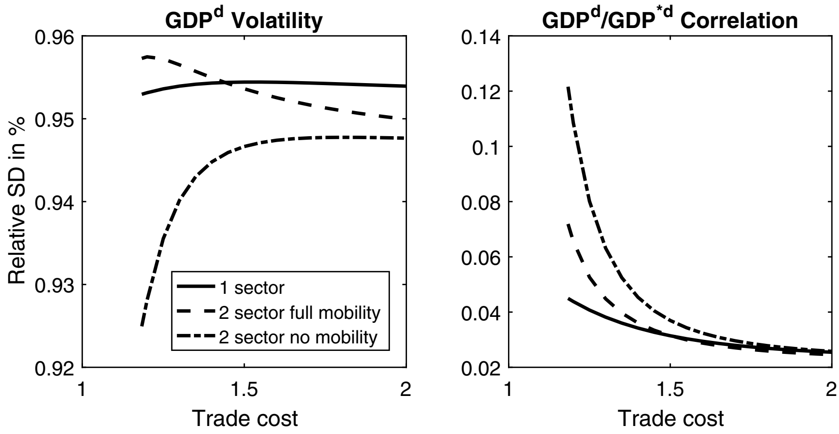

Figure 7. Effect of trade costs on volatility and correlation: models comparison.

5.5.4. Trade openness

Naturally, the openness to trade plays a crucial role in determining business cycle comovement. To further highlight this, Figure 7 shows the volatility of GDP at Home and the correlation between the GDP of both countries for different levels of iceberg trade costs, which are the most prominent measure of openness to trade in theoretical trade models. The figure compares our benchmark model with worker immobility, the two-sector model with worker mobility, and the one-sector model.

The right panel of Figure 7 reveals that for all models, higher openness to trade leads to larger business cycle comovement across the two countries. Note, however, that this effect is much stronger for our benchmark model. For high trade costs, all three versions of the model yield very similar and very low cross-country correlations of GDP. As trade costs become smaller, correlations increase substantially for the benchmark model but only little for the other two models. Thus, Figure 7 confirms that it is primarily the immobility of workers across sectors that enhances business cycle comovement.

Regarding the volatility of GDP, we observe a surprising pattern (in the left panel of Figure 7). Whereas in the one-sector model, openness to trade hardly affects the volatility of GDP, it increases GDP volatility in the two-sector model with mobile workers (unless trade costs become very small) and decreases GDP volatility in the two-sector model with immobile workers. The immobility of workers pushes more of the adjustment in response to business cycle shocks toward relative prices, which dampens the volatility of the import-competing sector, stabilizing GDP to a certain extent. The freer the international trade is, the more important this channel becomes. To the contrary, when workers are mobile they move quickly to the expanding sector which enhances especially the volatility of the import-competing sector.

6. A model with costly worker mobility

So far we have discussed two polar cases concerning the mobility of workers across sectors, they were either freely mobile across sectors or completely immobile. In this section, we present a simple extension of the model that allows for the modeling of the intermediate case of costly worker mobility. We calibrate the movement cost based on empirical estimates using the same data as in section 2.

As in Dix-Carneiro (2014), we model the movement cost in terms of utility which has the advantage that it is not traded in the market. In the following, we describe the problem for the

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skilled household. An identical problem holds for the unskilled household. The utility function for skilled workers changes to:

$$E_t \left\{ \sum_{k=0}^{\infty} \gamma^k \left[log \left(C_{t+k}^S \right) S - \sum_{i=1,2} \frac{\left(H_{it+k}^S \right)^{1+\upsilon}}{1+\upsilon} S_{it+k} - \frac{\nu}{2} \left(M_{t+k}^S \right)^2 \right] \right\},$$

with the two additional laws of motion:

$$S_{1t} = S_{1t-1} + M_t^S$$
$$S_{2t} = S_{2t-1} - M_t^S, \tag{30}$$

where ν is a parameter determining the size of the movement cost and M_t^S is the number of workers moving from sector 2 to sector 1 (a negative value for M_t^S implies workers moving from sector 1 to sector 2). In steady state, M_t^S is zero and no movement cost has to be paid. Out of steady state, the convexity of the movement cost implies that the adjustment of workers across sectors is smoothed out over time. The first-order condition associated with the choice of M_t^S is

$$\nu M_t^S = \mu_{1t}^S - \mu_{2t}^S,$$

where μ_{it}^s is the shadow value of a skilled worker in sector i.

To calibrate the parameter ν, we first estimate how strongly the employment in import-competing sectors and exporting sectors responds to shocks in domestic aggregate productivity. We use the same data and a similar approach as in section 2 (for more details see the appendix). In line with previous results, we find that the share of workers employed in exporting sectors increases in response to negative shocks to domestic aggregate productivity, while the share of workers employed in import-competing sectors decreases. Thus, workers move from import-competing sectors to exporting sectors. Note, however, that the movement is relatively mild, the share of workers in the exporting sectors only increases by 0.4%.

We choose the parameter ν to match this pattern. Choosing $\nu = 0.003425$ implies that the share of workers in the import-competing sector decreases by 0.4% during the first year after the shock hits. Results are illustrated in the second column of Table 4. As expected, allowing for a certain extent of worker mobility reduces the variability of the relative sector price, because more of the necessary adjustments can be accomplished via moving input factors. This also implies that the output of the comparative disadvantage sector becomes more volatile, since it contracts more strongly in response to negative productivity shocks. Although the extent of worker mobility is rather limited, the implied relative volatility of both sector's output is much too high, with output in the comparative disadvantage sector being about 5 times as volatile as output in the comparative advantage sector, while this number is below 2 in the data. This is considerably better than the factor 10 generated by the model with full mobility, but worse than the factor 2 generated by our baseline model. Looking at the aggregate variables, the model with costly worker mobility and the benchmark model are fairly close to each other. A notable exception is the RER which now has the right sign of cyclicality with GDP, although its volatility is still too low.

7. Conclusion

Motivated by the sharply rising trade between developed and developing countries over the last two decades, we analyze how the structure of trade, inter-industry vs. intra-industry trade, affects business cycle fluctuations and how differently import-competing and exporting sectors are affected by business cycle shocks. We provide new empirical evidence showing that net importing sectors react 1.5 times more strongly to domestic shocks than net exporting sectors, that they tend to be less skill intensive than net exporting sectors, and that the unconditional volatility of their output is about 1.7 times higher than the volatility of exporting sectors. We proceed by

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Table 4. Models versus data

	St. dev. relative to St. dev. of GDP			Correlation with GDP		
	Model without mobility	Model with limited mobility	Data	Model without mobility	Model with limited mobility	Data
GDP	0.92%	0.93%	1.14%	1	1	1
GDP^*_{CHN}	1.58	1.58	1.23	0.12	0.10	0.3
I	5.8	5.75	3.11	0.97	0.97	0.93
C	0.32	0.33	0.76	0.62	0.62	0.91
$Skill\ Premium$	0.68	0.66	0.69	0.95	0.91	0.09
$Hours^S/Hours^L$	0.45	0.44	0.61	−0.96	−0.95	−0.33
tb/GDP	0.0002	0.0002	0.01	0.0001	−0.04	−0.35
Y_{CD}	0.61	1.35	1.87	0.4	0.31	0.65
Y_{CA}	0.3	0.27	1.08	0.69	0.73	0.56
P_{CD}/P_{CA}	0.42	0.22	2.32	0.15	0.20	0.43
$RER_{US,CHN}$	0.26	0.3	4.39	0.01	−0.07	−0.20

Notes: The first row reports relative standard deviations of real GDP in percent. The rest of the rows report the standard deviations of relevant variables relative to the volatility of real GDP.

building a DSGE model which features inter-industry as well as intra-industry trade. It is a model with two countries, two sectors, and two factors of production, skilled and unskilled workers. The industrialized country has a relatively larger endowment of skilled workers and thus a comparative advantage in the skill-intensive sector. The model also features an intensive margin of labor supply (hours per worker) that can be adjusted at business cycle frequency as in most models of international macroeconomics.

We find that the mobility of factors across sectors in general, and the mobility of workers in particular, matters a lot for the effects that the change in the structure of trade might have on the business cycles of developed countries and their comovement with the business cycles of developing countries. We have shown that in response to negative domestic productivity shocks relative demand shifts from the import-competing sectors to the exporting sectors. The economy can react to this shift in two different ways. If production factors are mobile, they will move temporarily to the exporting sector, thus enhancing the specialization pattern. If production factors are immobile, the relative price of both sectors will shift very persistently in favor of the exporting sector, dampening but not shutting off the increase in specialization. The model with immobile workers does a very good job in replicating the relative volatility of both sectors while the model with mobile workers generates a much too volatile import-competing sector. Interestingly, the model with immobile workers is able to generate much higher positive business cycle comovement across countries than the model with mobile workers. Thus, the model with immobile workers is clearly superior.

Since labor mobility and adjustments in the labor input are central aspects in our analysis, the introduction of labor market frictions would be a next natural step. Among other things, this would allow for the analysis of the role of labor market institutions in shaping the business cycle effects of trade with China.

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Notes

1 The Grubel Lloyd index is equal to the sum of the intra-industry trade for the industries as a percentage of the total export plus import trade of the n industries, defined as $GL_t = \sum_i^n [(Ex_{it} + Im_{it}) - |Ex_{it} - Im_{it}|] / \sum_i^n (Ex_{it} + Im_{it})$, where i is an industry at the 6-digit NAICS level for US manufacturing and n refers to the total of industries included in US manufacturing. The index lies between zero and one. It is the most popular measure of the importance of intra-industry trade and measures the share of intra-industry trade in total trade.

2 The economic importance of China for the USA is also illustrated by the relatively high correlation of both countries' GDP, which lies at 0.3 despite their aggregate productivity being uncorrelated. For further details see sections 4 and 5.4.

3 We do not claim that our model is the only possible explanation but it is certainly a plausible one.

4 In the appendix, we provide a more detailed description of the empirical strategy and the data used, as well as some robustness checks.

5 The data and details on how it was constructed can be found at the San Francisco Fed website: http://www.frbsf.org/economic-research/indicators-data/total-factor-productivity-tfp/.

6 Details on aggregation from six- to four-digit level sectors can be found in the appendix.

7 To construct the sector-level RCA index, we used sector-level data on exports and imports at the six-digit NAICS level, retrieved from Peter Schott's website. The data only run from 1989 to 2005. Both imports and exports were aggregated to 84 four-digit level sectors by summing up across all industries within each sector. Then, the RCA measure is calculated at the sector level and averaged over the period 1989–2005. Based on this average RCA, we construct the indicator dummy. A short coming of our preferred measure of comparative advantage is that it goes to infinity if the import share of the sector is zero. To account for this, we conduct our analysis at the 4-digit level of aggregation where no manufacturing industry has a zero import share. Moreover, in the appendix, we show that our results are robust to alternative definitions of comparative advantage and the level of aggregation.

8 What matters for comparative advantage are relative endowments, so skilled labor can be scarce in both countries.

9 We assume two households and not one household, because this gives a more meaningful interpretation to wage inequality. We do not assume separate households for workers in different sectors, because then worker mobility across sectors would imply workers switching between households. In the robustness section, we will discuss the case of separate households for both sectors for the case of worker immobility.

10 In section 6, we also consider the case of worker reallocation subject to movements costs.

11 In the appendix, we will also consider the cases where only skilled workers own the mutual fund, and where skilled workers own a larger share of the mutual fund.

12 The data can be accessed at http://www.nber.org/nberces/.

13 This aggregation was motivated by the availability of quarterly data on industrial production for these 19 NAICS sectors. Specifically, the 9 comparative advantage sectors include aerospace and miscellaneous transportation eq. (NAICS = 3364-9); chemical (NAICS = 325); computer and electronic product (NAICS = 334); food, beverage, and tobacco (NAICS = 311,2); fabricated metal product (NAICS = 332); machinery (NAICS = 333); paper (NAICS = 322); printing and related support activities (NAICS = 323); plastics and rubber products (NAICS = 326); and the 10 comparative disadvantage sectors include apparel and leather goods (NAICS = 315,6); furniture and related product (NAICS = 337); nonmetallic mineral product (NAICS = 327); petroleum and coal products (NAICS = 324); primary metal (NAICS = 331); textiles and products (NAICS = 313,4); wood product (NAICS = 321); electrical equipment, appliance, and component (NAICS = 335); miscellaneous (NAICS = 339); and motor vehicles and parts (NAICS = 3361-3).

14 Each variable X^d refers to the data-consistent measure of X, correcting for the number of varieties, where $X^d = X\left[\left(N_{d,1t} + N^*_{x,1t}\right)^{\alpha}\left(N_{d,2t} + N^*_{x,2t}\right)^{1-\alpha}\right]^{\frac{1}{1-\theta}}$, except for sector production, which is $Y^d_{it} = Y_{it}\left(N_{d,it} + N^*_{xit}\right)^{\frac{1}{1-\theta}}$. See GM for more details.

15 In steady state, the exports of exporting sector make up 95% of total exports while the imports of the exporting sector make up only 13% of total imports.

16 To be precise, in steady state the share of domestic demand in total revenue is 32% higher in the import-competing sector than in the exporting sector.

17 We calculated measures of hours worked by high-skilled and low-skilled workers based on data provided by the "WORLD KLEMS consortium" for the period 1960-2010. The standard deviation of the HP-filtered series for hours worked is 0.009 for low-skilled workers and 0.006 for high-skilled workers (HP filtering parameter $\lambda = 100$). Both series appear to be procyclical. More details are available upon request.

18 In the appendix, we discuss the case when the mutual fund distributes its profits only to the skilled households, based on the argument that it is primarily richer households that participate in capital markets. In that case, the labor supply of unskilled workers is acyclical because their consumption is very responsive to productivity shocks, which is in contrast to what is found in the data. Aggregate dynamics remain unaltered.

19 If workers are freely mobile across sectors, worker movement will arbitrage away all cross-sectoral wage differences.

20 As before, the data-consistent RER moves in the opposite direction of the welfare-consistent RER.

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21 Sources for GDP, I, and C are the Federal Reserve Economic Data at St. Louis Fed for the USA and Chang et al. (2016) for China.
22 Source: International Financial Statistics of the IMF.
23 The trade balance is not log-transformed. Source: FRED at St. Louis.
24 Measures of sectoral industrial production are based on weighted averages for nine comparative advantage and ten comparative disadvantage sectors. The classification of sectors used is the same as in section 2. Specifically, each sector i's industrial production index (IPI_i) is weighted according to the following formula: $IPI_i = \frac{(weight_i IPI_i)}{\sum_{i=1}^{I}(weight_i)}$, where $weight_i$ is the relative importance weight of sector i in total manufacturing, and I is the total number of sectors combined (I is 9 for CA sectors and 10 for CD sectors). Finally, we take the average of the weighted IPI_s over the nine CA sectors and the ten CD sectors. Source for data on sector industrial production as well as importance weights is the Federal Reserve Board.
25 Source: NBER-CES Manufacturing Industry Database.
26 The measures of the skill premium and the relative hours of skilled to unskilled workers are based on data from Balleer and Van Rens (2013).
27 As in GM, the data-consistent real exchange rate in the model is defined as $RER = Q_t(\frac{N_t}{N_{t*}})^{\frac{1}{1-\theta}}$.
28 Backus et al., (1992) point out the inability of standard RBC models to generate positive cross-country correlation of GDP. GM show that a one-sector model with intra-industry trade resolves this puzzle and implies positive comovement across countries. Our results indicate that the two-sector model with inter-industry trade is able to generate a cross-country correlation even larger than the one-sector model (see Table 3 to be discussed later).
29 In the appendix, we analyze the role of sector-specific shocks in H.
30 The size of the one-sector model is calibrated in such a way that its steady-state GDP is the same as Homes's steady-state GDP in the two-sector model under trade. The autarky version of the two-sector model uses the same calibration as the trade version, with the only difference of prohibitively high trade costs, which implies a lower steady-state GDP.
31 Note that this version of the model yields similar statistics for the RER as the two-sector model with worker mobility: the cyclicality is right, but the volatility is much too low.

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