Macroeconomic Effects of International Outsourcing

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Abstract

I present a two-country dynamic general equilibrium model of international outsourcing, consistent with the empirical observation that capital and unskilled labor are substitutes. The model predicts lower global savings and investment rates, lower real interest rates, and a change in the composition of U.S. foreign assets. The U.S. current account improves as a result of outsourcing. Nearly all the benefits associated with outsourcing are captured by unskilled-labor-abundant countries, such as China.

KEYWORDS: International outsourcing, capital-skill complementarity, skill premium, current account balance, foreign direct investment.

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1 Introduction

In the past two decades, trade liberalization and financial markets development, a fall in transportation costs, and improvements in telecommunication and information technologies have led to spectacular growth in international outsourcing. Although outsourcing is still small relative to world output, its effect on the world economy is rising. Numerous studies analyze the effect of international outsourcing on the wage skill premium and pinpoint differences in the skill distribution across countries as the driving force of outsourcing.\footnote{Feenstra and Hanson (1996, 1999, 2003), Feenstra, Hanson, and Swenson (2000), Feenstra (1998), and Hijzen, Gorg, and Hine (2002) find evidence in support of the hypothesis that trade in intermediate goods and, in particular, international outsourcing contribute to an increase in the wage skill premia in the U.S. and the U.K.}

In addition, the decision process of an outsourcing firm has been modeled extensively in the new trade theory literature.\footnote{See, for example, Antras (2003), Antras and Helpman (2004), Ethier and Markusen (1996), Grossman and Helpman (2002, 2005), and McLaren (2000).} In this paper I take a different approach and suggest a framework which allows study of the effects of international outsourcing from the perspective of open economy macroeconomics.

My two-country dynamic general equilibrium (DGE) model utilizes the empirical observation of capital-skill complementarity.\footnote{My model is related to the work of Stokey (1996) which investigates the implications of capital-skill complementarity for international trade. However, my experiments are different and I do not allow for human capital accumulation or perfect factor mobility.} According to the estimates of Krusell, Ohanian, Rios-Rull, and Violante (2000), and Hamermesh (1993), capital equipment in the U.S. is more substitutable for unskilled labor, than for skilled labor. In my model intermediate good manufacturing (using capital and unskilled labor) can be carried out domestically or outsourced to a foreign location. I adopt the definition of outsourcing, suggested by Amiti and Wei (2004) as the “procuring of service or material inputs by a firm from a source in a foreign country.”\footnote{To preserve tractability of the model, I do not distinguish between intra-firm and arm’s length international outsourcing: in the former case, the foreign provider of the input is owned by the domestic firm which receives the input, in the latter, the foreign provider is an independent entity. While outsourcing of goods production is far larger than the outsourcing of services, the model can also be interpreted as explaining the outsourcing of services from the U.S.}

The two countries start off with no or almost no outsourcing, then an exogenous shock makes outsourcing more attractive, and the economies gradually converge to a new steady state. I use a (standard) model with a constant rate of time preference, and, in addition, consider the stationary cardinal utility specification of Epstein (1983).

Most predictions of the model for the two utility specifications are similar. Outsourcing causes part of the U.S. capital stock to reallocate to the unskilled labor abundant country (e.g. China) in the form of foreign direct investment (FDI), however, most of the U.S. capital stock is substituted for by an increased
use of Chinese unskilled labor. The more efficient use of the world’s labor resources causes the world capital stock to fall. Global savings and investment rates decline as well. The transitional dynamics of the models resemble the behavior of a standard neoclassical growth model with an initial value of the capital stock above the steady state. Due to the initial capital disaccumulation, the world economy experiences a consumption boom in the short-run. The world real interest rate falls due to outsourcing and stays low throughout the transition period. As U.S. production is transferred to China, U.S. Gross Domestic Product (GDP) falls, and Chinese GDP rises. At the same time gross national products (GNP) of both the U.S. and China fall. U.S. and Chinese savings fall as a proportion of their GNPs.

In my model, an increase in outsourcing leads to an improvement in the U.S. current account and a worsening of the Chinese current account. Equivalently, the financial account of the U.S. decreases and the financial account of China rises. There are two assets in the model - risk-free bonds and the shares of the Chinese export sector firms. As outsourcing becomes more attractive FDI into China increases, and simultaneously, U.S. holdings of the risk-free bonds fall, but by a smaller amount than the increase in FDI. Therefore, outsourcing also leads to a change in the composition of the foreign asset portfolios of the two countries: the U.S. holds less debt and more equity.

In line with the standard predictions of international trade theory, the U.S. skill premium, the difference between the wage rates of skilled and unskilled workers, widens and the Chinese skill premium narrows as outsourcing increases. While economists consider technological change to be the main driver of wage premia, international trade and outsourcing have also been shown empirically to contribute to the observed increase in the skill premium. Although Acemoglu (2003) has suggested that the two might be directly linked, for simplicity I choose not to model endogenous technological progress. In my model the change in the skill premium is solely driven by outsourcing.

Somewhat surprisingly, China obtains most of the benefits associated with the increase in outsourcing whereas U.S. welfare does not change significantly. U.S. unskilled workers and domestic investors lose from outsourcing, whereas in China skilled workers and traditional sector investors suffer. If a lump-sum transfer were available, it would be possible to redistribute wealth in each country so that all groups would benefit from outsourcing. In reality, governments do not have access to these sorts of schemes and therefore has to resort to distortionary taxation. I study the effects of a U.S. import tariff on intermediate goods (i.e., a tariff

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on outsourcing). The model predicts that U.S. aggregate welfare would improve slightly and the welfare of China would fall as a result of a tariff introduction. American unskilled workers and domestic investors would benefit from such a tariff whereas skilled workers would suffer. The tariff proceeds alone are not high enough to compensate skilled workers for their lost wages, although if a lump-sum transfer from unskilled to skilled workers were possible all groups in the U.S. would benefit.

The paper is organized as follows. Section 2 describes the basic environment of the model, introduces outsourcing, and defines the competitive equilibrium with a constant rate of time preference. Section 3 contains numerical simulations and presents the results and their robustness. Section 4 studies the model with an endogenous rate of time preference. Section 5 studies the effect of imposing a tariff on U.S. intermediate good imports. Section 6 concludes.

2 Setup

I consider a two-country deterministic DGE model with production of intermediate and final goods. I denote the two countries $A$ and $B$. I interpret $A$ as the U.S. and $B$ as China. Section 2.1 presents a version of the model with no trade in intermediate goods and, hence, no outsourcing. Section 2.2 introduces outsourcing by allowing manufacturers in country $A$ to purchase intermediate goods from firms located in country $B$.

2.1 Model With No Outsourcing

The two countries only differ in their endowments of factors of production and their total factor productivities (TFPs). I index countries by $n$, with $n = A$ or $B$. There is no uncertainty in the model.

2.1.1 Technology

Each country produces two goods: a final good and an intermediate good. The final good can be either consumed or invested into domestic capital equipment. The intermediate good can only be utilized as an input into the production of the final good. The other factors of production are capital, skilled, and unskilled labor.

$Y^n$ units of the final good can be obtained by combining $S$ units of skilled labor with $M$ units of the
intermediate good according to the following technology:

(1) \[ Y^n = Z^n F(M, S). \]

The intermediate good, in turn, is produced by combining \( L \) units of unskilled labor and \( K \) units of capital:

(2) \[ M^n = H(K, L). \]

Both countries use the same technology to produce the intermediate good. The production functions of the final good are similar, albeit the levels of total factor productivity, \( Z^n \), can differ by country.

Both technologies exhibit constant returns to scale and the functions \( F(\cdot) \) and \( H(\cdot) \) are strictly increasing, twice continuously differentiable, and strictly concave. To perform the numerical exercises in Sections 3, 4, and 5 I assume that \( H(\cdot) \) is a CES production function and \( F(\cdot) \) is a Cobb-Douglas production function:

(3) \[ H(K, L) = \left[ \gamma (K)^\nu + (1 - \gamma) (L)^\nu \right]^{\frac{1}{\nu}}, \]

(4) \[ F(M, S) = (M)^{\alpha} (S)^{1-\alpha}. \]

Here \( \frac{1}{(1-\nu)} \) is the elasticity of substitution between capital and unskilled labor, \( \gamma \) is a parameter characterizing the relative importance of these two factors, \( (1 - \alpha) \) is the share of skilled labor in the production of the final good, and \( Z^n > 0 \) is the total factor productivity of country \( n \). I assume that country \( A \) has a higher TFP than country \( B \), that is, \( Z^A > Z^B \), whereas the other technological parameters are identical across the two countries.

2.1.2 Households

Country \( n \) is populated by a large number of identical, infinitely lived households. In every period \( t = 0, 1, ... \) each household is endowed with \( L^n > 0 \) hours of unskilled labor and \( S^n > 0 \) hours of skilled labor. A household’s instantaneous utility is described by the function \( U(\cdot) \), which is assumed to be strictly increasing, concave, twice continuously differentiable, and to satisfy the Inada conditions. The lifetime utility of a
representative household in country $n$ is given by:

$$
\sum_{t=0}^{\infty} \beta^t U(c^n_t),
$$

where $c^n_t$ is the household’s consumption in period $t$ and $0 < \beta < 1$ is the discount factor.

In every period a household supplies both types of labor services inelastically and makes investment and borrowing or lending decisions. A household of country $n$ chooses the domestic investment level, $i^n_t$. It can also purchase or sell international risk-free bonds, which have a price of one unit of the final good. These bonds mature in period $t+1$ and pay $(1 + r_{t+1})$ units of the final good, $r_{t+1}$ is determined in period $t$. Each household owns an identical share of both the intermediate-level and final-level firms and, therefore, is entitled to a share of their profits. To summarize, every household of country $n$ faces a sequence of budget constraints of the following form:

$$
c^n_t + i^n_t + a^{n+1}_t = (1 + r_t) a^n_t + w^n_t i^n_t + v^n_t s^n_t + R^n_t k^n_t + \pi^{F,n}_t + \pi^{I,n}_t, \forall t \geq 0,
$$

where $l^n_t$ and $s^n_t$ are the hours of unskilled and skilled labor supplied, $w^n_t$ and $v^n_t$ are the corresponding hourly wage rates, $R^n_t$ is the gross return on the domestic capital stock, $k^n_t$, $\pi^{F,n}_t$ and $\pi^{I,n}_t$ are the profits the household receives in period $t$ from the final and intermediate products sectors, respectively. Finally, $a^n_t$ is the net risk-free bond position of the household in period $t$. The price of the final good is normalized to one.

In addition to the sequence of budget constraints, each household faces a no-Ponzi game condition:

$$
\lim_{t \to \infty} \frac{a^{n+1}_t}{\prod_{k=0}^{n} (1 + r_k)} = 0.
$$

In the spirit of Abel and Blanchard (1983) capital replacement and the installation of new equipment is costly. In particular, capital accumulation is governed by the following process:

$$
k^{n+1}_t = (1 - \delta) k^n_t + \phi \left( \frac{i^n_t}{k^n_t} \right) k^n_t,
$$

where $\delta \in (0, 1)$ is the depreciation rate and $\phi(\cdot)$ is an adjustment cost function. The function $\phi(\cdot)$ is strictly

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6 As there is no uncertainty in the model, the financial markets are complete.

7 See also Lucas and Prescott (1971) and Hayashi (1982).
increasing, strictly concave, and satisfies the following properties:  

\[ \phi(\delta) = \delta, \]

\[ \phi'(\delta) = 1. \]

### 2.1.3 Intermediate Good Firms

There are a large number of identical firms producing intermediate goods in the economy of country \( n \). In every period firms hire unskilled labor, \( \tilde{u}_t^n \), and rent capital, \( \tilde{k}_t^n \), to produce the intermediate good, \( \tilde{m}_t^n \), using the technology \( H(\cdot) \) given in (2). A firm’s objective is to maximize its market value, which is equal to the present value of its lifetime profits. This is equivalent to the maximization of a firm’s instantaneous profit at every date \( t \):

\[
\pi^{I,n}_t = \max_{\{\tilde{m}_t^n, \tilde{r}_t^n, \tilde{k}_t^n\}} \left\{ p_t^n \tilde{m}_t^n - w_t^n \tilde{r}_t^n - R_t^n \tilde{k}_t^n \right\},
\]

where \( \tilde{m}_t^n = H\left(\tilde{r}_t^n, \tilde{k}_t^n\right) \).

### 2.1.4 Final Good Firms

In each country there are a large number of identical firms producing the final good. Firms purchase the intermediate good \( m_t^n \) from domestic intermediate good producers and hire skilled labor \( \tilde{s}_t^n \) at every date \( t \). They produce final goods using technology \( Z^n F(\cdot) \) in order to maximize their instantaneous profits:

\[
\pi^{F,n}_t = \max_{\{y_t^n, m_t^n, \tilde{s}_t^n\}} \left\{ y_t^n - p_t^n m_t^n - v_t^n \tilde{s}_t^n \right\},
\]

where \( y_t^n = Z^n F(m_t^n, \tilde{s}_t^n) \).

### 2.1.5 Competitive Equilibrium

Take the utility function \( U(\cdot) \), the production functions \( Z^n F(\cdot) \) and \( H(\cdot) \), the adjustment cost function \( \phi(\cdot) \), and parameters \( \beta, \delta, a_A^0, a_B^0, k_A^0, k_B^0, S_A, S_B, L_A, L_B, Z_A \) and \( Z_B \) as given.

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8 The conditions imply that adjustment costs are irrelevant for the determination of the steady state.
Definition. A competitive equilibrium is an allocation sequence \( \{c_{t}^{n}, y_{t}^{n}, l_{t}^{n}, s_{t}^{n}, m_{t}^{n}, i_{t}^{n}, k_{t+1}^{n}, a_{t+1}^{n}, \tilde{t}_{t}, \hat{t}_{t}, \hat{m}_{t}^{n}, \hat{s}_{t}^{n}; n = A, B\}_{t=0}^{\infty} \), profit sequence \( \{\pi_{t}^{I,n}, \pi_{t}^{F,n}; n = A, B\}_{t=0}^{\infty} \), and price sequence \( \{w_{t}^{n}, v_{t}^{n}, R_{t}^{n}, p_{t}^{n}, r_{t}; n = A, B\}_{t=0}^{\infty} \) such that:

1. Given the price sequence \( \{w_{t}^{n}, v_{t}^{n}, R_{t}^{n}, p_{t}^{n}, r_{t}; n = A, B\}_{t=0}^{\infty} \) and profit sequence \( \{\pi_{t}^{I,n}, \pi_{t}^{F,n}; n = A, B\}_{t=0}^{\infty} \), the representative household of country \( n \) chooses the sequence \( \{c_{t}^{n}, l_{t}^{n}, s_{t}^{n}, i_{t}^{n}, k_{t+1}^{n}, a_{t+1}^{n}\}_{t=0}^{\infty} \) to maximize its lifetime utility (5) subject to the sequence of budget constraints (6), capital evolution equation (8), no-Ponzi-game condition (7), and the following feasibility conditions:

\[
0 \leq l_{t}^{n} \leq L^{n}, \quad \forall t \geq 0, \\
0 \leq s_{t}^{n} \leq S^{n}, \quad \forall t \geq 0, \\
c_{t}^{n}, k_{t+1}^{n} \geq 0, \quad \forall t \geq 0;
\]

2. Given the price sequence \( \{w_{t}^{n}, R_{t}^{n}, p_{t}^{n}\}_{t=0}^{\infty} \), an intermediate good producer maximizes its profits by choosing \( \{\tilde{t}_{t}, \hat{k}_{t}, \hat{m}_{t}^{n}\}_{t=0}^{\infty} \) to solve (9); the resulting profit sequence is given by \( \{\pi_{t}^{I,n}\}_{t=0}^{\infty} ; \)

3. Given the price sequence \( \{v_{t}^{n}, p_{t}^{n}\}_{t=0}^{\infty} \), a final good firm maximizes its profits by choosing \( \{m_{t}^{n}, \hat{s}_{t}^{n}, y_{t}^{n}\}_{t=0}^{\infty} \) to solve (10); the resulting profit sequence is given by \( \{\pi_{t}^{F,n}\}_{t=0}^{\infty} ; \)

4. Markets for skilled and unskilled labor, capital goods, financial assets, intermediate goods, and final goods clear:

\[
c_{t}^{A} + c_{t}^{B} + i_{t}^{A} + i_{t}^{B} = y_{t}^{A} + y_{t}^{B}, \quad \forall t \geq 0, \\
a_{t+1}^{A} + a_{t+1}^{B} = 0, \quad \forall t \geq 0, \\
l_{t}^{A} = \tilde{t}_{t}^{A}, \quad l_{t}^{B} = \tilde{t}_{t}^{B}, \quad \forall t \geq 0, \\
s_{t}^{A} = \hat{s}_{t}^{A}, \quad s_{t}^{B} = \hat{s}_{t}^{B}, \quad \forall t \geq 0, \\
k_{t}^{A} = \hat{k}_{t}^{A}, \quad k_{t}^{B} = \hat{k}_{t}^{B}, \quad \forall t \geq 0, \\
m_{t}^{A} = \hat{m}_{t}^{A}, \quad m_{t}^{B} = \hat{m}_{t}^{B}, \quad \forall t \geq 0.
\]
2.2 Introducing Outsourcing

The model I describe in Section 2.1 has a symmetric structure. Any difference in the competitive equilibrium allocations and price sequences across the two countries is due to differences in the endowments of labor, capital, financial assets, and TFPs.

Let country A be relatively more skilled-labor-abundant than country B (country B is more unskilled-labor-abundant than country A):

\[
\frac{S_A}{L_A} > \frac{S_B}{L_B}.
\]

Since country A is relatively more skilled-labor abundant, the steady state wage of unskilled workers and the steady state price of the intermediate good are lower in country B than in country A.\(^9\)

The only good that could be traded in Section 2.1 was the final good. If trade in intermediate goods were possible, manufacturers in country A would be attracted by the lower costs of unskilled labor in country B and the availability of cheaper intermediate goods.

I introduce outsourcing by allowing households in country A to establish intermediate good firms in country B and ship their product back to country A. I assume those firms are owned by households in country A and that the intermediate good produced in country B is a perfect substitute for the intermediate good produced in country A. Therefore, there are now two types of intermediate good firms in country B: those owned by domestic households and producing for domestic use and those owned by households in country A and producing intermediate goods for export to country A. I will distinguish between the two by calling the former “traditional sector” firms and the latter “export sector” firms. Households of country A can only invest into the export sector firms of country B or firms in country A, whereas households in country B can only invest in the traditional sector of country B. One way to rationalize this assumption is as follows. Although the model assumes that the technologies available to U.S. and Chinese intermediate firms are similar, one can imagine that U.S. entrepreneurs possess certain know-how or managerial skills for exporting intermediate goods to the U.S. market, which are not possessed by Chinese entrepreneurs. Therefore, only U.S. entrepreneurs participate in the Chinese production of intermediate goods for export to the U.S.

Whereas the two sectors in country B rent capital equipment from different sources, they both hire

\(^9\)The proof is available upon request.
country B’s unskilled labor. In the model without outsourcing the only employer of the unskilled labor in country B was the traditional sector. Once outsourcing is possible, part of country B’s workforce might choose to move into the export sector.

The investment made by country A’s households in period $t$ in the capital of the export sector of country B is denoted as $i_{B1}^T$, the corresponding capital stock is denoted as $k_{B1}^T$, and the output of the export sector is $m_{B1}^T$. The domestic investment of country B is denoted as $i_{B2}^T$, the corresponding capital stock is $k_{B2}^T$, and the output of the traditional sector is $m_{B2}^T$. $\pi_{I,B1}^t$ and $\pi_{I,B2}^t$ refer to period-$t$ profits of the export and traditional sector, respectively.\(^{10}\) The rest of the notation remains unchanged.

Installation of new capital in the export sector, as well as equipment replacement due to depreciation, is assumed to be costly. In particular, the capital stock in the export sector evolves according to:

$$\displaystyle k_{B1}^{T,t+1} = (1 - \delta) k_{B1}^T + \phi \left( \frac{i_{B1}^t}{k_{B1}^T} \right) k_{B1}^T, \forall t \geq 0,$$

where $\phi(\cdot)$ is the adjustment cost function described in Section 2.1.2.

The technology used in the export sector is similar to that of the traditional sector and the domestic intermediate good sector in country A, but less productive than both. In particular, the underlying production function is $\xi H(\cdot)$, where $0 < \xi < 1$, so that a typical profit-maximizing firm in the export sector solves:

$$\displaystyle \pi_{I,B1}^t = \max \left\{ \bar{m}_{I,B1}^t - w_{I,B1}^t k_{B1}^T - R_{I,B1}^t, \tilde{m}_{I,B1}^t \right\},$$

where $\bar{m}_{I,B1}^t = \xi H \left( \hat{I}_{B1}^t, \hat{k}_{B1}^t \right)$.

Although export sector firms rent the capital equipment of country A, the firms hire the unskilled workers of country B, since the firm is physically located in country B.

The productivity of the export sector might be lower than the traditional sector due to transaction and transportation costs between the two countries and language barriers. I do not model the productivity differences explicitly.

The main features of the competitive equilibrium are presented below, full details are in the Appendix. The problem of a representative household in country A can be stated as follows. Given the sequence of

\(^{10}\)Here superscript $T$ stands for "intermediate production sector".
prices \{w_A^t, v_A^t, R_A^t, R_B^1, r_t\}_{t=0}^\infty and profits \{\pi^t_F A, \pi^t_B A, \pi^t A, \pi^t B\}_{t=0}^\infty, the household chooses the allocation sequence \{c_A^t, i_A^t, s_A^t, i_t, k_{t+1}^A, k_{t+1}^B, a_{t+1}^A\}_{t=0}^\infty to maximize its lifetime utility:

\[
\max \left\{ \sum_{t=0}^{\infty} \beta^t U(c_A^t) \right\}
\]

subject to the following budget and feasibility constraints:

\[
c_A^t + i_A^t + i_t^B + a_{t+1}^A = (1 + r_t) a_t^A + w_A^t i_A^t + v_A^t s_A^t + R_A^t k_A^t + R_B^1 k_{t+1}^B + \pi^t F_A + \pi^t I_A + \pi^t I_B
\]

(14)

\[
k_{t+1}^A = (1 - \delta) k_t^A + \phi \frac{i_t^A}{k_t^A}, \forall t \geq 0
\]

(15)

\[
k_{t+1}^B = (1 - \delta) k_t^B + \phi \frac{i_t^B}{k_t^B}, \forall t \geq 0
\]

(16)

\[
0 \leq l_A^t \leq L_A^t, \forall t \geq 0
\]

(17)

\[
0 \leq s_A^t \leq S_A^t, \forall t \geq 0
\]

(18)

\[
c_A^t, k_{t+1}^A, k_{t+1}^B \geq 0, \forall t \geq 0
\]

as well as the no-Ponzi game condition:

\[
\lim_{t \to \infty} \frac{a_{t+1}^A}{\prod_{k=0}^{t} (1 + r_k)} = 0.
\]

The representative household in country \(B\) faces a similar problem, but in addition, it can now supply unskilled labor to both traditional and export sectors. To summarize, given the sequence of prices
\{w_t^{B1}, w_t^{B2}, v_t^{B}, R_t^{B2}, r_t\}_{t=0}^\infty \text{ and profits } \{\pi_t^{I,B2}, \pi_t^{F,B}\}_{t=0}^\infty, \text{ a household in country } B \text{ chooses the allocation sequence } \{c_t^{B}, l_t^{B1}, l_t^{B2}, s_t^{B}, i_t^{B2}, k_{t+1}^{B2}, a_t^{B}\}_{t=0}^\infty \text{ to maximize its lifetime utility:}

\begin{equation}
\max_{\{c_t^{B}, l_t^{B1}, l_t^{B2}, s_t^{B}, i_t^{B2}, k_{t+1}^{B2}, a_t^{B}\}_{t=0}^\infty} \sum_{t=0}^\infty \beta^t U(c_t^{B})
\end{equation}

subject to the following set of budget and feasibility constraints:

\begin{equation}
c_t^{B} + i_t^{B2} + a_{t+1}^{B} = (1 + r_t) a_t^{B} + w_t^{B1} l_t^{B1} + w_t^{B2} l_t^{B2} + v_t^{B} s_t^{B} + R_t^{B2} k_t^{B2} + \pi_t^{F,B} + \pi_t^{I,B2}, \forall t \geq 0
\end{equation}

\begin{equation}
k_{t+1}^{B2} = (1 - \delta) k_t^{B2} + \phi \left( \frac{i_t^{B2}}{k_t^{B2}} \right) k_t^{B2}, \forall t \geq 0
\end{equation}

\begin{equation}
l_t^{B1} + l_t^{B2} = L^B, \forall t \geq 0
\end{equation}

\begin{equation}
0 \leq l_t^{B1}, l_t^{B2} \leq L^B, \forall t \geq 0
\end{equation}

\begin{equation}
0 \leq s_t^{B} \leq S^B, \forall t \geq 0
\end{equation}

\begin{equation}
c_t^{B} , k_{t+1}^{B2} \geq 0, \forall t \geq 0
\end{equation}

and the following no-Ponzi game condition:

\begin{equation}
\lim_{t \to \infty} \frac{a_{t+1}^{B}}{\prod_{k=0}^{t} (1 + r_k)} = 0.
\end{equation}

The introduction of outsourcing will have a non-trivial impact on the equilibrium path only if the productivity parameter, $\xi$, is sufficiently high. For values of $\xi$ close to zero intermediate goods production in the Chinese
export sector will be very low. The model has a discontinuity when export sector investment or capital are zero. For that reason, I will consider only sufficiently high values of $\xi$ so that export sector investment and capital values are positive along the equilibrium path.

3 Numerical Experiment

Initially the world economy is in a steady state with a low value of $\xi$ and therefore very little outsourcing. I refer to this steady state as “the initial steady state” from this point on. Then, at date $t = 0$, the economy experiences an unanticipated permanent increase in $\xi$, which results in an increase of outsourcing along the equilibrium path. This section studies the transition path of the world economy from the initial state to the steady state corresponding to the new value of $\xi$, as well as the welfare implications of the change in $\xi$. Although one can conjecture that the rise in $\xi$ is welfare improving for both countries, it is less obvious how those benefits will be distributed amongst the different groups of economic agents within each country and between the two countries.

3.1 Calibration

The benchmark calibration is based on data on economic performance and trade and investment flows between the U.S. and China during the last 25 years. From now on country $A$ is referred to as “the U.S.” and country $B$ as “China”.

Before the Equity Joint Venture Law of 1979, FDI into China was very small. After economic reforms began, FDI into China grew slowly although it was only in the early 1990s that FDI increased dramatically. Although FDI has declined after 1999, it remains higher than into any other developing country. China’s recent entry into the World Trade Organization in December 2001 is expected to further increase FDI.\textsuperscript{11}

Model FDI flows may not exactly map into observed FDI flows. One reason is that the model assumes a particular trade pattern that prohibits export sector firms from selling their product inside China. All the output of the export sector is assumed to be sent to the U.S. In addition, although the U.S. is one of the main investors in China, it is not the only one. Nevertheless, FDI flows to China provide a useful benchmark when analyzing the model’s predictions.

\textsuperscript{11}See OECD 2000 report on the economy of China.
Table 1: Benchmark Parameter Calibration

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$1 - \alpha$</td>
<td>0.25</td>
<td>skilled labor share of final output, U.S. and China</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$1/1.04$</td>
<td>discount factor</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.438</td>
<td>capital weight in the production function, U.S. and China</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.1</td>
<td>capital depreciation rate</td>
</tr>
<tr>
<td>$\frac{1}{1 - \nu}$</td>
<td>1.67</td>
<td>elasticity of substitution between capital and unskilled labor, in the U.S. and China</td>
</tr>
<tr>
<td>$Z^B/Z^A$</td>
<td>0.23</td>
<td>China/U.S. total factor productivity ratio</td>
</tr>
<tr>
<td>$c^B/c^A$</td>
<td>0.36</td>
<td>China/U.S. initial consumption ratio</td>
</tr>
<tr>
<td>$L^A$</td>
<td>1</td>
<td>endowment of unskilled labor in the U.S.</td>
</tr>
<tr>
<td>$L^B$</td>
<td>11.7</td>
<td>endowment of unskilled labor in China</td>
</tr>
<tr>
<td>$S^A$</td>
<td>0.5</td>
<td>endowment of skilled labor in the U.S.</td>
</tr>
<tr>
<td>$S^B$</td>
<td>0.5</td>
<td>endowment of skilled labor in China</td>
</tr>
<tr>
<td>$\phi''(\delta)$</td>
<td>-0.2</td>
<td>capital adjustment cost parameter</td>
</tr>
<tr>
<td>$\xi_0$</td>
<td>0.191</td>
<td>initial value of export sector productivity</td>
</tr>
<tr>
<td>$\xi^1$</td>
<td>0.203</td>
<td>final value of export sector productivity</td>
</tr>
</tbody>
</table>

The number of units of unskilled labor a household is endowed with in the U.S. is normalized to be unity. Data on the educational attainment of the U.S. and China labor force comes from the Bureau of Labor Statistics (2004) and from the China Statistical Yearbook (2003). I use these data to compute values of $L^B$, $S^A$, and $S^B$. A worker is defined to be skilled if he or she has at least a bachelor’s degree, otherwise the worker is considered unskilled. Further details on the calibration are provided in the Appendix.

Since every period is a year, I assume that the discount factor, $\beta$, is $1/1.04$, and the rate of capital depreciation is 10% of the capital stock.

The skilled labor share, $(1 - \alpha)$, in the Cobb-Douglas production function of the final good (4) is estimated to be 0.25, which comes from the BLS (Weekly earnings of full-time workers by educational attainment), and the Bureau of Economic Analysis (National Income and Product Accounts). Hall and Jones (1997) estimate the TFP ratio between China and the U.S. as 0.23.\textsuperscript{12}

For the elasticity of substitution between capital equipment and unskilled labor, $\frac{1}{1 - \nu}$, I use the estimate of Krusell et al. (2000) of 1.67. This estimate is consistent with the results of Hamermesh (1993) which implies that capital is highly substitutable for unskilled labor. This assumption has some important implications that are considered in Section 3.2.4.

\textsuperscript{12}The production function specification of Hall and Jones is slightly different from mine. I use the value of 0.23 as a benchmark.
As the model uses a Cobb-Douglas production function, the elasticity of substitution between capital and skilled labor, as well as between skilled labor and unskilled labor is equal to one. The parameter $\gamma$ is chosen so that the skill premium, the ratio of the wage rate of skilled workers to that of unskilled workers, for the U.S. at the initial steady state matches the value in the data.

I compute the China-U.S. initial consumption ratio using aggregate PPP-adjusted consumption data from the Penn World Tables for 2000. My model is a representative-consumer one, therefore, I use the aggregate consumption ratio, rather than that of per capita consumption levels. The households of both countries are assumed to have logarithmic instantaneous utility functions:

$$U(c) = \ln c.$$  

The values of the productivity parameter, $\xi$, are chosen as follows. The initial value $\xi^0$ is chosen to be low enough to make outsourcing unattractive for investors in the U.S. and, therefore, to make the initial export sector employment in China very close to zero. The after-shock value, $\xi^1$, is chosen in such a way that about 18% of the total labor force of China will be employed in the export sector in the new steady state. Other countries in the region actively participating in international outsourcing, such as Thailand and South Korea, have similar growth of export-sector employment. One main source of cheap, unskilled labor in China is migrants from rural areas, previously occupied in agriculture (Rawski (2003)). The average yearly rate at which the share of agriculture in total employment fell for each of those countries over the last twenty years appears in Table 2. The average annual change is about 0.9% to 1% per year. If the fall in agricultural employment can be attributed exclusively to outsourcing, then in 20 years the employment in the export sector would be around 17-18% of the total labor force.

Under the current calibration, to induce a reallocation of 18% of the total Chinese labor force from the traditional to the export sector $\xi$ has to go up by slightly over 6%. The fact that such a small change in productivity can have major consequences is, at least in part, due to the simplifying assumption of perfect substitutability between intermediate goods produced in China and the U.S.

The competitive equilibrium allocations and price sequences are calculated using standard linearization techniques. I linearize the first-order necessary conditions arising in the competitive equilibrium around the

---

13 For technical reasons, the export sector employment cannot be made exactly equal to zero.
### Table 2: Rate of Change in Agricultural Employment

<table>
<thead>
<tr>
<th>Employment in agriculture (% of total employment)</th>
<th>1980</th>
<th>2000</th>
<th>Average yearly change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>55.9%</td>
<td>45.3%</td>
<td>-0.53 %</td>
</tr>
<tr>
<td>Korea</td>
<td>34.0%</td>
<td>10.9%</td>
<td>-1.16 %</td>
</tr>
<tr>
<td>Malaysia</td>
<td>37.2%</td>
<td>18.4%</td>
<td>-0.94 %</td>
</tr>
<tr>
<td>Philippines</td>
<td>51.8%</td>
<td>37.4%</td>
<td>-0.79 %</td>
</tr>
<tr>
<td>Thailand</td>
<td>70.8%</td>
<td>48.8%</td>
<td>-1.10 %</td>
</tr>
<tr>
<td>China</td>
<td>68.7%</td>
<td>46.9%</td>
<td>-1.09 %</td>
</tr>
<tr>
<td><strong>Average change, including China</strong></td>
<td></td>
<td></td>
<td><strong>-0.92 %</strong></td>
</tr>
<tr>
<td><strong>Average change, excluding China</strong></td>
<td></td>
<td></td>
<td><strong>-0.89 %</strong></td>
</tr>
</tbody>
</table>

new steady state and solve the resulting system of linear difference equations. To solve the linearized model I do not need to choose a particular functional form for the adjustment costs, the only parameter which needs to be determined is the second derivative of the adjustment cost function, estimated at the steady state value of the argument. I use the value of $\phi''(\delta) = -0.2$, which means that the elasticity of $\phi'(\cdot)$ evaluated at the steady state is equal to 1/50. This value represents relatively low adjustment costs: the corresponding parameters in Baxter and Crucini (1993) and Correia, Neves, and Rebelo (1995) are 1/15 and 1/30, respectively.

#### 3.2 Results

The results of the benchmark calibration are presented in Figures 1 and 2.

Growth in the productivity parameter, $\xi$, can be interpreted as a fall in the transportation costs between the two countries (I will also refer to the reciprocal of $\xi$ as the “cost of outsourcing”). International trade theory suggests that such a change is welfare-improving for both participating countries, since now the comparative advantage of China, i.e. an abundance of unskilled labor, can be exploited more easily (since now both China and the U.S. have increased access to the resource that China has the comparative advantage in - unskilled labor). Households in both China and the U.S. benefit from an increase in $\xi$. I discuss three issues related to outsourcing: a) the significance of these benefits for each country in absolute terms; b) the distribution of the benefits between the two countries; and c) the distribution of the benefits amongst the economic agents within each country.

Findings based on the benchmark calibration are somewhat surprising: nearly all of the benefits associated
with the fall in the costs of outsourcing are enjoyed by China; U.S. households do not experience a significant welfare change. Further, the welfare effects of outsourcing on a Chinese household is equivalent to increasing the initial consumption level by approximately 0.6% and holding it constant forever. Although the change in \( \xi \) is significant enough to cause about 18% of the labor force in China to be reallocated into the export sector, this change only has a modest effect on the aggregate welfare of each country. However, the rise in \( \xi \) has more important effects on resource reallocation and wealth redistribution.

### 3.2.1 Resource Reallocation

It can be shown that for this model the First Fundamental Welfare Theorem holds, and the competitive equilibrium paths correspond to the solution of a certain social planner's problem. From the point of view of the social planner, there exists a trade-off in terms of the allocation of resources between the traditional and export sectors in the Chinese economy. On one hand, the TFP of the final good sector in China is quite low and, in addition, China has a relatively low endowment of skilled labor. Thus, if more of the intermediate good is produced within the export sector, then the comparative advantage of the U.S. in final goods production can be exploited to a greater extent. On the other hand, because of transportation costs, the productivity of the export sector is lower than the traditional sector in China, as well as the intermediate goods sector in the U.S. (\( \xi < 1 \)). Similar considerations apply to the allocation of capital between the U.S. intermediate good sector and the export sector in China. In equilibrium the marginal benefits of outsourcing exactly balance the opportunity costs of the resources diverted to it.

The main country-specific predictions of the model under the benchmark calibration can be summarized as follows. After the cost of outsourcing falls: (a) physical capital is reallocated from the U.S. intermediate good sector and Chinese traditional sector into the Chinese export sector; (b) Chinese unskilled labor partly shifts into the export sector; (c) U.S. final good production increases while that in China falls; (d) U.S. GDP falls and Chinese GDP increases; (e) U.S. households decrease their holdings of risk-free bonds and increase FDI into China, the U.S. current account improves; (f) the skill premium broadens in the U.S. and shrinks in China; (g) GNP of both countries falls. The dynamics of the model variables are discussed in detail below.

**Capital in the export sector:** As the total factor productivity, \( \xi \), of the Chinese export sector increases, the marginal product of capital employed in the export sector rises. It jumps upwards, immediately following the change in \( \xi \) and then converges to the steady state level from above. This makes FDI a more attractive
option for U.S. households. As a consequence, the export sector capital stock, $k_{tB1}$, rises along the equilibrium path. FDI to China rises immediately when outsourcing becomes less costly and then converges to a new higher level from above (see Figure 1).

**Labor in China:** The marginal product of unskilled labor in the Chinese export sector also increases after the shock. In addition, as the capital stock increases, the marginal product of labor in the export sector grows even further. As a result, each firm’s owners in the export sector are willing to pay more per unit of unskilled labor. This causes a reallocation of unskilled workers from the traditional sector to the export sector. This process puts upward pressure on the wage rate in both the export and traditional sectors. As a result, the wage rate in China increases.\(^\text{14}\)

**Skill premium:** As outsourcing becomes less costly, the wage of unskilled workers in the U.S., $w_{tA}$, falls. The reason is that U.S. unskilled workers now indirectly face competition from the unskilled workers in China. At the same time, as U.S. final good production increases and given the low degree of substitution between skilled and unskilled workers, the wage of the skilled workers, $v_{tA}$, increases. As a result, the skill premium in the U.S. broadens when outsourcing increases (see Figure 1).

**Capital in the traditional sector:** As the capital stock in the export sector, $k_{tB1}$, rises and a fraction of unskilled workers leaves the traditional sector in China, the marginal product of capital in the traditional sector falls, therefore the traditional sector becomes less attractive for domestic investment. The gross return on capital in the traditional sector, $R_{tB2}$, falls in response to the rise in $\xi$ and converges to its steady state level from below. Consequently, along the equilibrium path the capital stock, $k_{tB2}$, and investment in the traditional sector, $i_{tB2}$, fall (see Figure 2).

**Capital in the U.S.:** Outsourcing allows the two countries to reallocate some of the intermediate good production from the U.S. to China. As the capital stock in the U.S., $k_{tA}$, declines, U.S. intermediate good production, $m_{tA}$, falls along the equilibrium path converging from above to the new steady state. The investment, $i_{tA}$, initially drops then rises slowly to the new steady state level, but always stays below the initial steady state level (see Figure 1).

**Final good output, GDP:** As outsourcing becomes less costly for the U.S., exports of the intermediate good from China rise to nearly 8% of the total intermediate good use of the U.S. final good sector. Simultaneously, the final good production in the U.S. rises by about 3.8% in the new steady state. However,\(^\text{14}\) If the equilibrium is interior, in the sense that the employment of both traditional and export sector is positive, the wage rate is the same in both sectors.
the value added by domestically located factors in the U.S., i.e. GDP, falls by more than 2% (see Figure 1). This is due to the outsourcing of intermediate goods production from the U.S. to China. For similar reasons, the GDP of China increases by approximately 1.9% as a result of the export sector growth (see Figure 2). As the traditional sector contracts, final good production in China falls as well. GDP of the U.S. and China are defined as:

\[
GDP^A_t = y_t^A - p_t^{B1} m_t^{B1},
\]
\[
GDP^B_t = y_t^B + p_t^{B1} m_t^{B1}.
\]

**Current account:** The current account balance of a country in this model is equal to the negative of its financial account, which is in turn equal to the net change in foreign ownership of domestic assets. There are two assets in the model: risk-free bonds and shares of the Chinese export sector firms. Therefore, the U.S. current account is \(CA^A_t = a_{t+1}^A - a_t^A + i_t^{B1}\). Since the countries can only borrow from each other, the current account of China equals to the negative of the U.S. current account: \(CA^B_t = a_{t+1}^B - a_t^B - i_t^{B1} = - (a_{t+1}^A - a_t^A + i_t^{B1}) = -CA^A_t\).

As a result of outsourcing U.S. net foreign asset holdings, initially positive, increase monotonically in absolute terms as well as a proportion of U.S. GDP. Therefore, the U.S. runs a current account surplus in every period due to outsourcing (see Figure 1).\(^{15}\) U.S. net holdings of bonds decrease in absolute terms, whereas FDI into the Chinese export sector rises by a greater amount. This increases the proportion of equity relative to debt in the U.S. foreign assets portfolio. The increase in FDI is financed by a fall in U.S. domestic investment and bond holdings.

The result is based on the assumption that Chinese households are not allowed to invest into the export sector directly. However, if this assumption is relaxed the U.S. continues to run current account surplus at all times, as its households lend money to China to enable an increase in the export sector investment and Chinese consumption.

Under the benchmark calibration the U.S. current account surplus reaches a maximum of 2.07% of GDP in period 1 and slowly falls to a steady state value of 0.90%\.\(^{16}\)

\(^{15}\)The robustness of this result, as well as consumption dynamics, are discussed in Section 4.

\(^{16}\)In the steady state the U.S. current account surplus equals the export sector investment necessary to replace depreciating equipment. In other words, the value of U.S. owned factories in China is constant at the steady state.
**GNP:** Gross National Product (GNP) is given by the sum of a country’s GDP and the net income its residents receive from the rest of the world:

\[
\begin{align*}
GNP_t^A &= GDP_t^A + \frac{a_t^A}{t} + R_t^B k_t^B = y_t^A + \frac{a_t^A}{t} - w_{t^1}^B k_{t^1}^B, \\
GNP_t^B &= GDP_t^B + \frac{a_t^B}{t} - R_t^A k_t^A = y_t^B + \frac{a_t^B}{t} + w_{t^1}^A k_{t^1}^A.
\end{align*}
\]

GNP dynamics are determined by three components: domestic final good production, interest payments on debt, and wages paid in the export sector. Figures 1 and 2 show that the GNP of both the U.S. and China fall over time, albeit not necessarily monotonically. The reason for such dynamics in the U.S. is a fall in net bond holdings, a low interest rate, and a rising wage bill paid to the unskilled workers employed in the export sector in China. An increase in output of the final good is not enough to compensate for this decrease. At the same time, the decrease in U.S. GNP is less dramatic than that of China, therefore, U.S. GNP rises as a proportion of the world output. In the case of China, final good production falls significantly, interest payments on debt rise slightly and the export sector wage bill rises. The outcome is a decrease in Chinese GNP.

**Consumption:** By assuming complete asset markets the consumption ratio, \(\frac{c_t^A}{c_t^B}\), is constant along the equilibrium path. Consumption of the two countries (see Figures 1 and 2), \(c_t^A\) and \(c_t^B\), are proportional to global consumption. The dynamics of global consumption are discussed in Section 3.2.2. The consumption ratio, \(\frac{c_t^A}{c_t^B}\), is higher than it would be if there were no upward change in \(\xi\) and the world economy remained in the pre-outsourcing steady state. If one compares the steady state when \(\xi = \xi^0\) to the steady state when \(\xi = \xi^1\), two results follow. First, U.S. steady state consumption falls and that of China rises in response to an increase in \(\xi\), although by less than 0.5% in both cases. Second, U.S. consumption as a proportion of GNP increases from 70.4% in the initial state to 71.0% at \(t = 2\), and then converges to 70.8% in the new steady state. In other words, due to a rise in outsourcing activity, the U.S. savings rate falls from 29.6% to 29% at \(t = 2\) and then converges to the steady state value of 29.2%. U.S. consumption rises as a proportion of GDP as well. Chinese consumption also increases as a proportion of GNP from 86.6% in the initial state to 87.8% in the new steady state, which corresponds to a fall in the savings rate from 13.4% to 12.2%. As a proportion of GDP, Chinese consumption initially rises from 68.7% in the initial state to 70.0% at \(t = 0\), and then falls to 67.6% in the new steady state. The values of the savings rates the model delivers for China are
very low relative to what is observed in reality, and part of the reason for that is the assumption that export sector firms can only be owned by U.S. households and no foreign investment opportunities are available for Chinese households. Due to this assumption, the GNP of China is significantly lower than GDP, which leads to very high values of consumption-to-GNP ratios.

### 3.2.2 Global Variables

To gain further insight into model dynamics I compute the capital stock, investment level, output, and consumption for the two countries aggregated. I refer to these variables as “global” in the following discussion. Since the model has perfect capital mobility the international interest rate, $r_t$, is also a global variable.

The dynamics of the global variables resemble the dynamics of variables in a standard neoclassical model when the initial capital stock is above the steady state level. Under the benchmark calibration the aggregate capital stock and aggregate investment fall, while the international interest rate remains low (see Figures 1 and 2). This result depends crucially on the assumption of high substitutability between capital and unskilled labor. In particular, if the elasticity of substitution between capital and unskilled labor were changed to be close to one (a Cobb-Douglas production function), world capital would no longer fall.

Intuitively, if capital and unskilled labor are highly substitutable, then as soon as outsourcing of the intermediate good becomes cheaper, capital equipment located in the U.S. is substituted for, at least to some extent, by cheap Chinese unskilled labor. One of the implications is that the same permanent level of consumption can now be provided using a lower capital stock. In reality, consumption is not constant along the equilibrium path. When the shock to $\xi$ is realized, world investment adjusts downwards immediately and then converges from above to the new steady state level. The resources which free up due to the fall in investment are used to increase consumption. The world economy experiences a consumption boom for about a decade, but eventually world consumption converges to a new steady state which is slightly below the initial one (less than 0.3%) under the benchmark parameterization.

World investment and output both are lower in the new steady state than in the initial state. In the baseline example the new steady state world investment is 3.25% below the initial steady state level and the new steady state level of world output is approximately 1.0% below the initial level. The world savings rate as a percentage of world output falls slightly from 25.9% to 25.4%.
3.2.3 Welfare Analysis

The welfare implications of the model were obtained using a linearization technique. As Schmitt-Grohe and Uribe (2004) point out, “first-order approximation techniques are not well suited to handle questions such as welfare comparisons across alternative stochastic or policy environments.” While the model under the consideration is deterministic, the welfare estimates below represent a relatively rough approximation of the true figures.

Aggregate welfare of each country is measured as the equivalent variation in consumption that corresponds to the change in the lifetime utility of a representative household. The increase in aggregate welfare due to outsourcing is relatively modest: it is equivalent to increasing the initial steady state consumption level in China by approximately 0.6% and it is close to zero for the U.S. However, the redistributive effects of outsourcing are much more significant.

To evaluate the redistributive effects, I compute the present value (P.V.) (at $t = 0$) of the earnings of skilled and unskilled workers in the U.S. and China, net returns to U.S. and Chinese domestic investment, and net return to FDI into Chinese economy. For instance, the present value of the net return to U.S. domestic investment is:

$$PV^k_A(0) = R^A k^A_0 - i^A_0 + \sum_{t=1}^{\infty} \frac{R^A k^A_t - i^A_t}{(1 + r_t)^t},$$

where the sequence $\{k^A_t, R^A_t, i^A_t, r_t\}_{t=0}^{\infty}$ corresponds to the competitive equilibrium for $\xi = \xi^1$.\(^{17}\)

Further, I compare the computed present values to the corresponding present values if the world economy stayed forever in the initial steady state without outsourcing ($\xi = \xi^0$). The results of this comparison for the benchmark calibration are presented in Table 3. For example, the change in the present value of income for U.S. domestic investors due to outsourcing is computed as:

$$\frac{PV^k_A(0) - PV^k_A(\xi^1)}{PV^k_A(\xi^0)}.$$

\(^{17}\)I compute the present values of earnings rather than the equivalent variation in consumption for technical reasons. It would be fairly straightforward to rewrite the representative consumer model with standard preferences as a heterogeneous agents model and then compute the equivalent variations in consumption for each group of agents (skilled workers, unskilled workers, etc). It is intractable to perform this exercise for the model with the stationary cardinal utility specification. Computing the present values of earnings enables a meaningful comparison between the two models. The equivalent variations in consumption for the model with standard preferences are qualitatively and quantitatively similar to those reported in Table 3.
The two groups in the U.S. that lose from outsourcing are the unskilled workers (-1.71%) and domestic investors (-0.18%). As the export sector in China grows, production of the intermediate good becomes less dependent on U.S. unskilled workers. As U.S. unskilled workers face greater competition from unskilled workers in China, their wage and welfare fall. A similar argument applies to U.S. domestic investors: as outsourcing becomes cheaper, the U.S. final good sector relies less on the domestic supplier of the intermediate good and more on exports from China, therefore the return on U.S. capital and investment fall. The two groups in China who lose due to outsourcing are skilled workers and domestic investors. While the fall in the net return to domestic investment in both countries is moderate, the redistributive effect of outsourcing on wages is much more pronounced.

U.S. skilled labor becomes more valuable after $\xi$ increases. As more final good production becomes located in the U.S. (while intermediate good production is increasing in China), more intermediate goods need to be combined with U.S. skilled labor. Since the quantity of U.S. skilled labor is fixed, the marginal product, and hence the wage rate, of skilled workers rises. Similarly, the wage rate of unskilled laborers in China grows by more than 6% due to the increase in outsourcing of unskilled-labor-intensive production.

After the shock to $\xi$, returns to FDI into the Chinese export sector increase (not shown in Table 3), and U.S. households adjust their financial asset portfolios by decreasing their bond holdings and increasing their holdings of equity by a greater value.

### Robustness

I evaluate the robustness of the results along two dimensions. First, the sensitivity of the conclusions to parameter perturbations is examined and second, the sensitivity to underlying model assumptions is explored. Parameter perturbations are discussed below and model assumptions are varied in Section 4.
Clearly, some of the outcomes of the experiment depend on the parameterization to a greater extent than others. I perform several exercises with alternative calibrations, which are described below. The conclusion is that most of the results for the baseline calibration are robust to reasonable changes in parameters. In particular, the current account dynamics and the direction of the reallocation of capital and unskilled labor, as well as the direction of the welfare redistribution, remain the same for a wide range of parameters. The transition path dynamics are more sensitive to the choice of the adjustment cost parameter, as well as the process governing the shock to outsourcing costs. The result that the world interest rate is low in the short run and that world capital, investment, and output falls in the new steady state depends on the elasticity of substitution between capital and unskilled labor, $\frac{1}{1-\nu}$, although remaining highly robust.

To check the robustness of the predictions to the elasticity of substitution between capital and unskilled labor, $\frac{1}{1-\nu}$, I use the same parameterization as before, except that the value of $\nu$ is set to 0.01. Such parameterization of $\nu$ means that the production function is close to Cobb-Douglas and therefore labor and capital are not very substitutable. Most predictions remain qualitatively similar: a fraction of the unskilled workers switch from the traditional sector to the export sector in China; the skill premium broadens in the U.S. and narrows in China; the behavior of the returns on physical capital is similar; U.S. GDP falls and Chinese GDP rises; U.S. final good production rises and Chinese final output falls; the U.S. capital stock and domestic investment fall (although by less than with $\frac{1}{1-\nu} = 1.67$); as does capital and investment in the traditional sector in China. The U.S. runs a current account surplus at all times. Finally, FDI into the export sector in China increases relative to the initial steady state, and U.S. holdings of bonds decrease. The ratio of the Chinese capital stock employed in the traditional sector to the U.S. domestic capital stock is almost four times as high as it was in the baseline calibration. The reason is that, in the U.S., capital equipment cannot be as easily used to compensate for the lack of unskilled labor. At the same time, in China the ratio of the capital stock in the two sectors stays approximately the same as before.

The dynamics of the global variables for the case of $\nu = 0.01$ resemble the dynamics of variables in a standard neoclassical growth model when the initial capital stock is below the steady state level. World output increases in the new steady state relative to the initial one, as does the world capital stock and investment. This is to be expected given that capital cannot any longer be as readily substituted for by the abundant unskilled labor in China.

In particular, the calibration remains that 18% of the Chinese labor force will eventually move into the export sector.
The dynamics of consumption, the world interest rate, and U.S. GNP are completely different relative to the benchmark case. In particular, the international interest rate is higher in the short run. U.S. GNP grows over time not only relative to the world output level, but also in absolute terms. The reason for this is that the proportion of the export sector wage bill relative to the returns on physical capital is now lower, due to lower substitutability of the two production factors. Finally, world consumption, as well as the consumption of each country falls initially and then converges to a higher level. The short run dynamics are due to the fact that fewer resources are freed by disaccumulation of physical capital in the U.S. intermediate good sector and the Chinese traditional sector. Therefore, in order to increase the export sector investment after the shock to $\xi$, some current consumption must be sacrificed.

Lower substitutability of physical capital and unskilled labor also influences the distribution of the benefits from outsourcing between the two countries. With $\nu = 0.01$ U.S. households benefit more from outsourcing than with a higher $\nu$: their gain is equivalent to a permanent increase in the initial steady state consumption level of 0.1%. Not surprisingly, the benefit to China is lower, at 0.3%. With low $\nu$, physical capital is a better complement to unskilled labor than with a high $\nu$. The U.S. households exploit this fact by reallocating more capital into China and leaving less capital in the U.S. intermediate good sector (relative to the benchmark scenario). This causes a lower steady-state capital-labor ratio in the U.S. and higher capital-labor ratio in China in the scenario with outsourcing relative to the benchmark calibration.

I also consider a modification of the underlying shock. Instead of a discrete jump of the productivity parameter $\xi$, I consider an adjustment of the following form:

\[
\begin{align*}
\xi_{t+1} &= \kappa \xi_t + (1 - \kappa) \xi^1, \\
\xi_0 &= \xi^0,
\end{align*}
\]

where $\xi^0$ and $\xi^1$ stand for the initial and final values of export sector productivity, respectively, $\xi^1 > \xi^0 > 0$, $\kappa \in (0, 1)$.

By choosing $\kappa$, I can vary the speed of convergence of productivity to the new level $\xi^1$. I run several simulations of the model using the baseline calibration and different values of $\kappa$ in the range $(0, 1)$. The general pattern is that the initial and final values of the variables stay the same for a family of the simulations corresponding to different levels of $\kappa$. The main effect of $\kappa$ is on the speed of convergence to the new steady
state as is to be expected.

In addition, I study the extent to which the predictions of the model are sensitive to the assumption that the export sector firms in China are owned exclusively by U.S. households. Most implications, such as those dealing with the production side of the model, are completely insensitive to this assumption. In fact, the assumption about ownership structure can only affect the current account, GNP and consumption (which, in turn, affects welfare). For instance, under the assumption that the export sector firms can only be owned by the Chinese households, the U.S. still runs a current account surplus at all times (converging to zero in the steady state), the consumption paths of the U.S. and China are very similar to the baseline model, U.S. GNP falls by more than in the baseline model and the GNP of China increases in the new steady state, which is to be expected, since the only difference between GDP and GNP now is the interest payments on the debt. Finally, the predictions for the aggregate welfare are very similar to the baseline case, however China benefits slightly more from an increase in \( \xi \) and the U.S. slightly less. The case in which the export sector firms are owned exclusively by the Chinese households represents another extreme assumption, and it would be more realistic to assume that the export sector firms could be owned by both Chinese and U.S. households, in which case the model predictions would be very similar to those of the baseline model, with the possible exception of the behavior of countries' GNP's.

## 4 Alternative Model Specification: Stationary Cardinal Utility

### 4.1 Motivation

The implications of any theoretical model are driven by the assumptions made in its construction. How a particular assumption maps into a prediction that follows is often much less obvious. In this section I study the effects of the assumption about consumer preferences.

In a complete markets model with a constant rate of time preference, such as the baseline model described above, it follows immediately from the first order conditions that along the competitive equilibrium path the marginal rates of intertemporal substitution for the two representative consumers are equal and given by:

\[
\frac{U'(c^A_t)}{\beta U'(c^A_{t+1})} = \frac{U'(c^B_t)}{\beta U'(c^B_{t+1})} = 1 + r_{t+1}, \quad \forall t \geq 0.19
\]
This means that the ratio of marginal utilities, \( \frac{U'(c_A)}{U'(c_B)} \), stays constant over time and, for the class of CRRA utilities, the consumption ratio \( c_B^t/c_A^t \) remains constant.

One of the implications of this assumption is that consumption in the U.S. and China comove perfectly with each other. Therefore, as world consumption initially grows, due to the fall in investment, U.S. and Chinese consumption both increase. In order to simultaneously finance a short-run increase in both consumption and FDI it is not enough for U.S. households to cut down on domestic investment - they also have to sell some bonds to China as soon as the upward jump in \( \xi \) occurs. Chinese consumption increases due to the cut in domestic investment, an increase in the wage bill of the export sector, and a current account deterioration.

While the assumption of a constant rate of time preference is quite standard, it is often driven by “mathematical convenience, rather than innate plausibility” (Obstfeld (1990)). To study whether this assumption has an important effect on the predictions of the model, especially those regarding current account behavior and consumption dynamics, I consider an alternative stationary cardinal utility preference specification, first suggested by Epstein (1983).

### 4.2 Setup

I adapt the stationary cardinal utility formulation of Mendoza (1991). I assume that the lifetime utility of a household in country \( n \) is represented by the following expression:

\[
U^n(c^n) = \sum_{t=0}^{\infty} U(c^n_t) \exp \left( - \sum_{\tau=0}^{t-1} \log \left( Q^n + D^n c^n_t \right)^\beta \right),
\]

or, rewriting,

\[
U^n(c^n) = \sum_{t=0}^{\infty} \frac{U(c^n_t)}{\prod_{\tau=0}^{t-1} (Q^n + D^n c^n_t)^\beta}, \quad n = A, B,
\]

where I assume that \( D^A, D^B, Q^A, Q^B, \beta > 0 \).

This setup allows for an endogenously determined rate of time preference. Epstein (1983) defines a measure of impatience, \( \rho(c) \), so that for a constant consumption stream \( \{c^n_t\}_{t=0}^{\infty} \), such that \( c^n_t = c, \rho^n(c) + 1 \)
is the marginal rate of substitution between consumption in period 0 and 1:

\[ \rho^n (c) = \frac{\partial U^n (c^n)}{\partial c^n_0} / \frac{\partial U^n (c^n)}{\partial c^n_1} - 1 = (Q^n + D^n c)^\beta - 1. \]

All else equal, a higher stream of constant consumption makes a person more impatient. The consumption choice in period \( t \) influences the marginal rate of substitution between period \( t \) and period \( t+s \), \( s = 1, 2, \ldots \) in two ways: first, through a change in marginal utility \( U' (\cdot) \) in period \( t \) and second, through a change in the weights assigned to the marginal utilities on successive dates. Under the specification in (28) the consumption on different dates are Edgeworth substitutes. This relation becomes weaker the further apart the two dates are.

The model is unaltered except for the change in the representative household’s utility function, therefore, the only change in the definition of the competitive equilibrium is that expressions (12) and (20) are substituted by (29) and (30), respectively:

\[
\max_{\{c^A_t, l^A_t, s^A_t, a^A_{t+1}, k^A_{t+1}, k^{B1}_{t+1}\}_{t=0}^\infty} \sum_{t=0}^{t-1} U(c^A_t) \prod_{t=0}^{t-1} (Q^A + D^A c^A_t)^\beta.
\]

\[
\max_{\{c^B_t, l^B_t, l^{B2}_t, s^B_t, a^B_{t+1}, s^{B2}_{t+1}, k^{B2}_{t+1}\}_{t=0}^\infty} \sum_{t=0}^{t-1} U(c^B_t) \prod_{t=0}^{t-1} (Q^B + D^B c^B_t)^\beta.
\]

Combining the first order conditions for the representative household’s problem, it can be shown that:

\[ 1 + r_{t+1} = \frac{\eta^n_A}{\eta^n_{t+1}} (Q^A + D^A c^A_t)^\beta = \frac{\eta^n_B}{\eta^n_{t+1}} (Q^B + D^B c^B_t)^\beta, \forall t \geq 0, \]

where \( \eta^n_t \) is a Lagrange multiplier for the household’s period \( t \) budget constraint in country \( n \) corresponding to the shadow price of consuming \( c^n_t \) units of period \( t \) output. In the steady state:

\[
1 + r = (Q^A + D^A c^A)^\beta = (Q^B + D^B c^B)^\beta.
\]

The effect is that the consumption ratio in the two countries is no longer required to be constant along the
Table 4: Recursive Utility Model Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.11</td>
</tr>
<tr>
<td>$D^A$</td>
<td>1</td>
</tr>
<tr>
<td>$D^B$</td>
<td>1</td>
</tr>
<tr>
<td>$Q^A$</td>
<td>0.232</td>
</tr>
<tr>
<td>$Q^B$</td>
<td>1</td>
</tr>
</tbody>
</table>

equilibrium path.

4.3 Calibration

I use the modified setup with a time-varying discount factor to perform the experiment described in Section 3. The economy starts in the initial steady state, corresponding to a low value of $\xi$, then $\xi$ rises and stays at a higher level forever, leading to a permanent increase in outsourcing. To solve for the transition path I linearize the first order conditions describing the competitive equilibrium and solve the resulting system of difference equations. Parameter values for the calibration are found in Table 4.

In the calibration the values for $D^A, D^B, Q^A,$ and $Q^B$ are chosen in such a way that the consumption ratio $c^B/c^A$ in the initial steady state is the same as in the baseline calibration, i.e., 0.36. The value of $\beta$, 0.11, is chosen as in Mendoza (1991). The rest of the parameter values stay the same as in the baseline calibration (Table 1). Under this calibration the implied initial world interest rate is approximately 4%, that is, the same as in the baseline calibration.

4.4 Results

I refer to the model with a constant rate of time preference as Model A and the stationary cardinal utility specification described above as Model B. I compare the results of simulations performed for the baseline calibration of the two models.

Selected results of the numerical simulation for Model B are presented in Figure 3. The current account behavior is not significantly affected by the change in consumer preferences. The dynamics of the variables characterizing the production side of the world economy in Model B are very similar to those in model A with one exception. Since the rate of impatience is endogenous in Model B, the new steady state value of the world interest rate no longer has to be the same as its initial state. As outsourcing becomes cheaper, the
world interest rate converges to a steady state which is below its starting level. The same happens to the gross returns on physical investment, because outsourcing makes physical capital a less important factor of world production.

The two models differ in their predictions of consumption and GNP dynamics.

In Model A consumption in the U.S. comoves perfectly with consumption in China and global consumption at all times. As outsourcing becomes cheaper, the world needs less capital for production, since it can be substituted for by unskilled labor in China. Global investment starts falling right away and the freed resources are consumed immediately. Due to adjustment costs, it takes time for the capital stock to fall and global output does not start falling until period 2. Since the final product can be used only for consumption and investment, global consumption grows for the first two periods and only then starts converging from above to the steady state. The same happens to U.S. and Chinese consumption.

In Model B consumption streams in the two countries do not necessarily have to be proportional to each other along the equilibrium path. Indeed, global consumption dynamics are similar to that in Model A, however neither U.S. nor Chinese consumption is proportional to aggregate consumption. In particular, the ratio of consumption in China to consumption in the U.S. rises initially for three periods than starts falling, staying higher than the initial steady state level for more than 50 years. In other words, Chinese consumption grows faster than that of the U.S. in the beginning. The reason for that is that in Model B an increase in the current consumption influences the household’s utility in two ways: directly, through an increase in its instantaneous utility (similar to Model A) and indirectly, affecting its rate of time preference, i.e., making the future consumption stream less valuable. In this situation Chinese households prefer to increase their consumption in early periods, immediately following an increase in $\xi$, in exchange for the lower steady state level than that in Model A. As a result, the initial increase in consumption of China is greater in Model B than in Model A. The opposite is true for U.S. households. They sacrifice a part of the initial consumption boom observed in Model A in exchange for the slightly higher steady state level than that in Model A. The different savings behavior of households affects the GNPs. The new steady state level of U.S. GNP in Model B is higher than in model A and that of China is lower than in Model A.

To summarize, the model predictions regarding the production side and current accounts of the U.S. and Chinese economies stay essentially the same for a wide range of parameters, as well as for the alternative specifications of consumer preferences. At the same time, consumption and GNP dynamics depend on the
Table 5: Income Comparisons, by Group of Economic Agents, Model B

<table>
<thead>
<tr>
<th>Income categories</th>
<th>Percentage change in the P.V, relative to the initial steady state</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. unskilled workers</td>
<td>-1.49 %</td>
</tr>
<tr>
<td>U.S. skilled workers</td>
<td>4.96 %</td>
</tr>
<tr>
<td>Returns to U.S. domestic investment</td>
<td>-0.19 %</td>
</tr>
<tr>
<td>Chinese unskilled workers</td>
<td>6.71 %</td>
</tr>
<tr>
<td>Chinese skilled workers</td>
<td>-10.93 %</td>
</tr>
<tr>
<td>Returns to Chinese domestic investment</td>
<td>-0.75 %</td>
</tr>
</tbody>
</table>

utility specification.

**Welfare implications:** Model B predicts that, as a result of outsourcing, the representative Chinese household’s welfare improvement is equivalent to an increase of their initial consumption level forever by 0.7%. The U.S. representative household gains are close to zero. Therefore, the results are similar to those obtained before for Model A, but the effect on China is more pronounced.

Similar to the exercise performed for Model A, I compute the present values of income of different groups in the U.S. and China and compare them to a constant stream of the initial steady state’s income forever, under the assumption that $\xi$ never changed. Table 5 summarizes these results.

Table 5 shows that U.S. unskilled workers, Chinese skilled workers, and domestic investors in both countries lose as a result of outsourcing. This conclusion is similar to the welfare implications of Model A.

5 The Effects of Tariffs

This section is motivated by a growing discussion of the necessity for protectionist measures in the U.S., an issue that was debated in the 2004 U.S. presidential election. I study the effects of imposing a tariff on intermediate good imports by the U.S. This action will lower the competition that U.S. unskilled workers face from abroad, thus improving their welfare. I examine the consequences of the tariff for the welfare of the U.S. and China, as well as for the long-run behavior of the economy.

I assume that an unanticipated per-unit import tariff, $\tau$, is imposed permanently on the intermediate good exported from China starting in period $t = 5$ and the proceeds are given to U.S. households as a lump-sum. I use the baseline calibration and a value of 3% for $\tau$. As before, the outsourcing parameter $\xi$ is at the low level $\xi^0$ initially, then increases to $\xi^1$ in the beginning of period zero, and stays at that level
forever.

I compare the welfare of a representative household in each country for two scenarios: first, the tariff is imposed from period \( t = 5 \) onwards, and second, no tariff is imposed. I start by analyzing these scenarios using Model A. First, I compute the lifetime utilities along the equilibrium path for both scenarios starting at time \( t = 5 \). For instance, the lifetime utility of a representative household in the U.S. if the tariff is imposed is:

\[
U^A_{5, T} = \sum_{t=5}^{\infty} \beta^{t-5} U \left( c^A_{t, T} \right),
\]

where \( \left\{ c^A_{t, T} \right\}_{t=0}^{\infty} \) is the equilibrium consumption sequence. I denote the U.S. equilibrium consumption sequence in the no-tariff scenario by \( \left\{ c^A_{t, NT} \right\}_{t=0}^{\infty} \), and the two corresponding sequences in China by \( \left\{ c^B_{t, T} \right\}_{t=0}^{\infty} \) and \( \left\{ c^B_{t, NT} \right\}_{t=0}^{\infty} \). For each scenario I compute the amount of a constant consumption stream that would deliver exactly the same lifetime utility. For example, the U.S. constant consumption equivalent under the no-tariff scenario, \( c^A_{NT} \), satisfies:

\[
U^A_{5, NT} = \sum_{t=5}^{\infty} \beta^{t-5} U \left( c^A_{t, NT} \right) = \sum_{t=5}^{\infty} \beta^{t-5} U \left( c^A_{t, NT} \right) = \frac{U \left( c^A_{NT} \right)}{1 - \beta}.
\]

Finally, I compare the constant consumption equivalents between the two scenarios. For Model A the permanent tariff of 3% imposed in period 5 improves the welfare of a representative U.S. household by 0.1%, that is, \( \frac{U^A_{5, T}}{U^A_{5, NT}} \approx 1.001 \). A representative household in China loses 0.5% of its welfare in terms of the equivalent constant consumption.

In Model B, there is no underlying fixed discount rate, therefore, the procedure has to be modified. In particular, (32) above should be rewritten for Model B as:

\[
U^A_{5, NT} = \sum_{t=5}^{\infty} \beta^{t-5} U \left( c^A_{t, NT} \right) = \sum_{t=5}^{\infty} \beta^{t-5} U \left( c^A_{t, NT} \right) = \frac{U \left( c^A_{NT} \right)}{1 - \beta}
\]

Nevertheless, the results are the same as in Model A: the tariff introduction causes welfare gain of 0.1% for the U.S. and a welfare loss of 0.5% for China.
Further, I compute the P.V. of earnings (at $t = 5$) of skilled and unskilled workers in the U.S. and China, net returns to U.S. and Chinese domestic investment, and the net return to FDI into the Chinese economy under the two scenarios and compare them. Table 6 contains the results of the comparison for Model A and Model B.

The redistributive effect of the tariff is similar to that of a reduction in the parameter $\xi$. The two U.S. groups that benefit from the introduction of the tariff are exactly those that lose from outsourcing: unskilled workers and domestic investors. The group losing in China due to the tariff introduction is the unskilled workers, the only Chinese group that benefits from outsourcing.

The dynamics of the model are illustrated in Figure 4. The tariff appears to achieve the desired objective of improving some U.S. economic indicators. In particular, as soon as the tariff is introduced, U.S. domestic investment and the capital stock start to rise, and the wage of unskilled workers recovers. U.S. GDP stops falling and converges to a higher steady state level than it would have without the tariff. The negative effects of the tariff in the U.S. are worsening of the current account (due to a drop in FDI), a fall in the wage of skilled workers, plus a drop in export sector performance and final good output. The tariff collected by the U.S. government is returned back to U.S. households in the form of a lump-sum subsidy. The government can attempt to use the subsidy to compensate for the losses associated with the tariff introduction. In the case of U.S. investors into China, the tariff proceeds would be big enough to completely offset the negative effect of the tariff. At the same time, they would be too small to offset the welfare loss of U.S. skilled workers.

---

Table 6: Income Comparisons, with and without an Import Tariff

<table>
<thead>
<tr>
<th>Income categories</th>
<th>Percentage change in the P.V. due to the tariff introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model A</td>
</tr>
<tr>
<td>U.S. unskilled workers</td>
<td>0.87 %</td>
</tr>
<tr>
<td>U.S. skilled workers</td>
<td>-2.06 %</td>
</tr>
<tr>
<td>Returns to U.S. domestic investment</td>
<td>0.08 %</td>
</tr>
<tr>
<td>Returns to FDI into China</td>
<td>-4.59 %</td>
</tr>
<tr>
<td>Chinese unskilled workers</td>
<td>-2.97 %</td>
</tr>
<tr>
<td>Chinese skilled workers</td>
<td>6.05 %</td>
</tr>
<tr>
<td>Returns to Chinese domestic investment</td>
<td>0.32 %</td>
</tr>
<tr>
<td>U.S. skilled workers if given all the tariff proceeds</td>
<td>-1.69 %</td>
</tr>
<tr>
<td>Returns to FDI into China plus all the tariff proceeds</td>
<td>31.95 %</td>
</tr>
</tbody>
</table>

---

20 Since the tariff proceeds are redistributed back to the U.S. households, the two effects are not identical.
If the U.S. government could also make lump-sum transfers, for instance, from unskilled workers to skilled workers, then the introduction of the import tariff described above would be desirable. Otherwise, skilled workers are made worse off by the tariff introduction.

6 Conclusion

Krusell et al. (2000) and Hamermesh (1993) estimate that physical capital and unskilled labor are substitutes. This paper analyzes the implications of this substitutability for the dynamics of a two-country DGE model where the possibility of outsourcing is introduced. Among many predictions of the model is the result that an increase in outsourcing leads to an improvement in the U.S. current account, a worsening of the Chinese current account, and a change in the composition of the foreign asset portfolios of the two countries in such a way that the U.S. holds less debt and more equity. The results above are obtained in a deterministic setup with complete financial markets. Mendoza, Quadrini and Rios-Rull (2007) show that financial integration when countries differ in financial markets deepness has similar effect on the U.S. foreign asset portfolio composition. Their result though emerges under the assumption of incomplete financial markets and in the presence of uncertainty. They also demonstrate that in such an environment financial integration can lead to U.S. current account deterioration, welfare gains for the U.S. and welfare losses for less financially-developed countries.

Given that financial integration and globalization go hand in hand with the growth of outsourcing activity, to understand the implications these processes would have on the world economy, we have to take both into account. Therefore, one could get a better idea of what to expect from the world economy in general and the U.S. economy in particular by combining the predictions of my model with those emerging from the study of Mendoza et al. In this way, integration of financial markets, accompanied by a rise in outsourcing would lead to a change in the composition of the U.S. portfolio holdings to include more equity and an improvement in U.S. aggregate welfare (though not necessarily large). It would have mixed effects on the U.S. current account balance and the welfare of less financially developed countries, such as China, which often provide outsourcing services.

Further, Samuelson (2004) emphasizes that the welfare implications of international trade in general, and outsourcing in particular, become less obvious once one takes technological change into account. U.S. welfare
gains from outsourcing might decrease if China learns to imitate U.S. technology. An extension of my model would be to incorporate the possibility of technology adoption and to study its implications. Some other channels that can have a negative effect on the U.S. welfare, such as capital market frictions or imperfect insurance of labor income risk, are also not considered in the current version of the model.

Finally, while the recent worsening of the U.S. current account cannot be attributed to outsourcing in my model, there are other mechanisms, not captured by the present version of the model, which can be responsible for that, such as financial markets imperfections (for instance, as in Mendoza et al.), government policies, and changes in demographics or household behavior.
Note: Most variables are depicted in percentage deviations from their initial steady state values. For the other variables, the dotted lines refer to their initial steady state values.

Figure 1: Model A, Benchmark Calibration - Panel 1
Figure 2: Model A, Benchmark Calibration - Panel 2
Figure 3: Model B

Note: Most variables are depicted in percentage deviations from their initial steady state values. For the other variables, the dotted lines refer to their initial steady state values.
Note: Most variables are depicted in percentage deviations from their initial steady state values. For the other variables, the dotted lines refer to their initial steady state values.

Figure 4: Model A, Benchmark Calibration, Tariff
7 Appendix

7.1 Definition of Competitive Equilibrium (Model With Outsourcing)

Consider the utility function \( U(\cdot) \), the production functions \( Z^nF(\cdot) \), \( n = A, B \) and \( H(\cdot) \), the adjustment cost function \( \phi(\cdot) \) and parameters \( \beta, \delta, a_0^A, a_0^B, k_0^A, k_0^B, k_1^B, k_{01}^B, l^A, S^A, S^B, L^A, L^B, Z^A, Z^B \), and \( \xi \) as given.

Definition. A competitive equilibrium is an allocation sequence \( \{c_i^A, g_i^A, y_i^A, y_i^B, l_i^A, s_i^A, s_i^B, m_i^n, i_i^n, k_i^n, a_i^A, a_i^B, \tilde{l}_i^n, \tilde{k}_i^n, \tilde{m}_i^n, \tilde{s}_i^n, \tilde{y}_i^n, n = A, B1, B2 \}_{t=0}^\infty \), profit sequence \( \{\pi^f_{i,n}, \pi^{fA}_{i}, \pi^{fB}_{i}; n = A, B1, B2 \}_{t=0}^\infty \) and price sequence \( \{w_i^n, v_i^A, v_i^B, R_i^n, p_i^n, r_t; n = A, B1, B2 \}_{t=0}^\infty \) such that:

1. Given the price sequence \( \{w_i^A, v_i^A, R_i^A, R_i^{B1}, r_t \}_{t=0}^\infty \) and profit sequence \( \{\pi^f_{i,n}, \pi^{fA}_{i}, \pi^{fB}_{i} \}_{t=0}^\infty \), the representative household of country \( A \) chooses the sequence \( \{c_i^A, g_i^A, y_i^A, y_i^B, l_i^A, s_i^A, s_i^B, m_i^n, i_i^n, k_i^n, a_i^A, a_i^B, \tilde{l}_i^n, \tilde{k}_i^n, \tilde{m}_i^n, \tilde{s}_i^n, \tilde{y}_i^n; n = A, B1, B2 \}_{t=0}^\infty \) to maximize its lifetime utility (12) subject to the sequence of budget constraints, capital evolution equations, feasibility constraints, and no-Ponzi game condition (13-19);

2. Given the price sequence \( \{w_i^{B1}, w_i^{B2}, v_i^B, R_i^{B2}, r_t \}_{t=0}^\infty \) and profit sequence \( \{\pi^{fA}_{i}, \pi^{fB}_{i} \}_{t=0}^\infty \), the representative household of country \( B \) chooses the sequence \( \{c_i^B, g_i^B, y_i^B, y_i^B, l_i^B, s_i^B, s_i^B, m_i^n, i_i^n, k_i^n, a_i^B, a_i^B, \tilde{l}_i^n, \tilde{k}_i^n, \tilde{m}_i^n, \tilde{s}_i^n, \tilde{y}_i^n; n = A, B1, B2 \}_{t=0}^\infty \) to maximize its lifetime utility (20) subject to the sequence of budget constraints, capital evolution equation, feasibility constraints and no-Ponzi game condition (21-27);

3. Given the price sequence \( \{w_i^n, R_i^n, p_i^n \}_{t=0}^\infty \), an intermediate good producer in sector \( n = A, B1, B2 \) maximizes its profit by choosing \( \{\tilde{l}_i^n, \tilde{k}_i^n, \tilde{m}_i^n \}_{t=0}^\infty \) to solve (9) for \( n = A, B2 \) or (11) for \( n = B1 \); the resulting profit sequence is given by \( \{\pi^{fA}_{i,n} \}_{t=0}^\infty \);

4. Given the price sequence \( \{v_i^n, p_i^n \}_{t=0}^\infty \), a final good firm in country \( n = A, B \) maximizes its profit by choosing \( \{m_i^n, \tilde{s}_i^n, \tilde{y}_i^n \}_{t=0}^\infty \) to solve (10); the resulting profit sequence is given by \( \{\pi^{fA}_{i,n} \}_{t=0}^\infty \);

5. Markets for skilled and unskilled labor, capital goods, bonds, intermediate goods, and final goods clear, in particular, the sequence of the following resource constraints holds:

\[
\begin{align*}
\delta c_i^A + d_i^B + l_i^A + l_i^{B1} + l_i^{B2} &= y_i^A + y_i^B, \forall t \geq 0, \\
\delta a_i^A + d_i^B &= 0, \forall t \geq 0,
\end{align*}
\]
\[ l_t^A = \hat{l}_t^A, l_t^{B1} = \hat{l}_t^{B1}, l_t^{B2} = \hat{l}_t^{B2} \forall t \geq 0, \]
\[ s_t^A = \hat{s}_t^A, s_t^B = \hat{s}_t^B, \forall t \geq 0, \]
\[ k_t^A = \hat{k}_t^A, k_t^{B1} = \hat{k}_t^{B1}, k_t^{B2} = \hat{k}_t^{B2}, \forall t \geq 0, \]
\[ m_t^A = \hat{m}_t^A, m_t^{B1} = \hat{m}_t^{B1}, m_t^{B2} = \hat{m}_t^{B2}, \forall t \geq 0. \]

### 7.2 Note on Calibration


Quartiles and selected deciles of usual weekly earnings of full-time wage and salary workers by selected characteristics, second quarter 2004 averages, not seasonally adjusted:

<table>
<thead>
<tr>
<th>Educational Attainment</th>
<th>Number of workers, '000</th>
<th>Median, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total, 25 years and over</td>
<td>90,337</td>
<td>684</td>
</tr>
<tr>
<td>Less than a high school diploma</td>
<td>8,661</td>
<td>404</td>
</tr>
<tr>
<td>High school graduates, no college (1)</td>
<td>27,383</td>
<td>576</td>
</tr>
<tr>
<td>Some college or associate degree</td>
<td>24,450</td>
<td>664</td>
</tr>
<tr>
<td>Bachelor’s degree and higher (2)</td>
<td>29,844</td>
<td>973</td>
</tr>
<tr>
<td>Bachelor’s degree only</td>
<td>19,386</td>
<td>902</td>
</tr>
<tr>
<td>Advanced degree</td>
<td>10,457</td>
<td>1,142</td>
</tr>
</tbody>
</table>

I call a worker skilled if he or she obtained at least a bachelor’s degree and unskilled otherwise.

Therefore, out of 90.3 million employed people of 25 years and above 29.8 million are skilled and 60.5 million are unskilled.

The only data available for China are the educational attainment of the population. I present the data for 2002 below:

<table>
<thead>
<tr>
<th>Employment, millions</th>
<th>737.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population with Junior College and above, millions</td>
<td>56.2</td>
</tr>
</tbody>
</table>

I estimate the number of people in China with a bachelor’s degree and higher as follows. I assume that
the ratio of the population in China with a bachelor’s degree to the number of people with at least junior college is the same as the ratio of number of employed people with bachelor’s degree to the number of employed people with at least some college in the U.S. Therefore, the number of people in China with at least a bachelor’s degree is estimated to be:

\[
56.2 \times \frac{29.8}{24.4 + 29.8} \approx 30.9 \text{ million people.}
\]

I make the simplifying assumption that all the people with a bachelor’s degree in China are employed. Therefore, the number of employed people with a bachelor’s degree in China is 30.9 million and the number of employed people without a bachelor’s degree in China is 706.5 million people.

I normalize \( L^A \) to be unity and I choose the other labor endowments as follows:

\[
\begin{align*}
L^B &= \frac{706.5}{60.5} \approx 11.7, \\
S^A &= \frac{29.8}{60.5} \approx 0.5, \\
S^B &= \frac{30.9}{60.5} \approx 0.5.
\end{align*}
\]

Further, using the BLS table above, I estimate parameter \( \alpha \) as follows. The total weekly wage of workers with bachelor’s degree can be approximated as a product of the number of workers and the median weekly earnings: \( 29.8 \times 973 = \$29,038.2 \) million. Similarly, the total weekly wage of unskilled workers can be approximated by \( 8.7 \times 404 + 27.4 \times 576 + 24.5 \times 664 = \$35,506.4 \) million.

There are 13 weeks in a quarter. So, the quarterly wage payments of all skilled workers is approximately \$377 billion.

This is not a very good approximation though, since the income distribution is not symmetric within each group and mean earnings tend to be higher than the median. In particular, from the Bureau of Economic Analysis (BEA) tables on national accounts, the share of the compensation of the employees in the national income is \$6,568 billion on an annualized basis. At the same time, if we compute the total yearly wage bill using the table above, we obtain \$3,356 billion. One way to deal with this discrepancy is to assume that the real share of the skilled workers’ compensation in GDP is \$377 billion \( \times \$6,568.0 \) billion/\$3,356.3 billion = \$738.73 billion.
In this case, the skilled labor income share in U.S. GDP (data for the second quarter, 2004) would be equal to

\[
\frac{738.73}{11657.5} \times 4 \approx 25.35\%.
\]

Finally, notice that the ratio of per-worker weekly wage rates between the groups of skilled and unskilled workers is approximately 1.658. I use this number to choose the value of \( \gamma \).
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