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Structural Change in an Open Economy

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Abstract

We develop a tractable, three-sector model to study structural change in an open economy. The model features an endogenous pattern of trade dictated by comparative advantage. We derive an intuitive expression linking sectoral employment shares to sectoral expenditure shares and to sectoral net export shares of total GDP. Changes in productivity and in trade barriers affect expenditure and net export shares, and thus, employment shares, across sectors. We show how these driving forces can generate the "hump" pattern that characterizes the manufacturing employment share as a country develops, even when manufacturing is the sector with the highest productivity growth.

JEL: F20, F40, O13, O41

Keyword: structural transformation, international trade, sectoral labor reallocation

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1 Introduction

While the reach of globalization was limited primarily to the advanced economies in the first few decades after World War II, in recent decades, it has extended to include numerous emerging market economies, including the giants China and India. Most of these emerging market economies are simultaneously undergoing structural change: changes in sectoral employment and output shares over time. A key feature of the structural change has been the pattern in manufacturing. Since the 1960s, manufacturing employment has been mainly declining in developed economies and rising (but not permanently) in emerging market economies. This pattern has for some time generated consternation in many advanced economies; indeed, the decline in the rich nations' manufacturing sectors is commonly attributed to increased manufacturing imports from emerging market countries.

There is a large and rich body of empirical and theoretical research that has studied global integration, on the one hand, and structural change, on the other hand. Surprisingly, with very few exceptions, these bodies of research have not overlapped and, hence, have left many interesting questions unexplored. What is the effect of international trade on the process of structural change? What is the role of productivity growth and declining trade barriers on structural change in an open economy? How does a surge in manufacturing in one country lead to a hastened decline in manufacturing in another country? The goal of our paper is to develop a simple, tractable framework to address these questions.

Our framework has two countries and three sectors. Two sectors, agriculture and manufacturing, consist of a continuum of tradable goods. The motive for trade is Ricardian; productivity differences across sectors and countries determine comparative advantage. The third sector, services, consists of a non-traded good.[1] There is one factor of production, labor, which is mobile across sectors, but immobile across countries. There are also barriers that make the cost of international trade non-zero. Preferences are homothetic across sectors and goods. The key parameters determining sectoral labor allocations are those governing productivity, trade costs, and the elasticity of substitution between sectors.[2]

In our framework, under autarky, each sector's labor share equals the share of expen-

[1]We recognize that many multi-sector, multi-country models have been developed. Nevertheless, to our knowledge, with the exceptions of the few papers we cite later, virtually none has been employed to studying structural change in an open economy setting.

[2]A two-country framework is considerably less tractable than a small open economy framework. Nevertheless, it is important to use a multi-country framework for two reasons. First, in a small open economy setting, the economy would specialize in only one good at a time. This would hamper the analysis on several dimensions. Second, and more importantly, our goal is to investigate the effect of international trade on structural change in both emerging market countries and advanced countries; this requires a multi-country framework.

ditures on that sector's goods. By contrast, in an open economy, each sector's labor share equals its expenditure share plus its net export share of total GDP. The tight link between sectoral expenditure and sectoral production in a closed economy is broken owing to the specialization according to comparative advantage in the presence of international trade. Each country runs a net export surplus in its sector of comparative advantage. All else equal, the labor share will be higher in the comparative advantage sector (and lower in the other tradable sector) in an open economy compared to autarky. This specialization channel is not the only channel, however, as there is a second channel, an expenditure channel, that operates through relative prices. Comparing the open economy to autarky, the price level for each sector will differ depending on whether the sector is tradable, and whether it is the sector of comparative advantage. For example, in the non-comparative advantage sector, access to international trade creates opportunities to import inexpensive goods, and the price level for this sector will be lower than under autarky.[3] Then, if the elasticity of substitution between sectors is less than one, the sector experiencing a lower price will experience a lower expenditure share, thus leading to, all else equal, a lower sectoral labor share. The expenditure channel also affects the non-traded sector; the price level for services is higher in an open economy than under autarky, thus contributing to a higher sectoral labor share when the elasticity of substitution is less than one.

The dynamics of our model are driven by changing sectoral productivities and trade costs over time. These changes alter relative prices and specialization patterns. Thus, both the expenditure and specialization channels contribute to the dynamics. In particular, even if a sectoral expenditure share is declining, its employment share could still be rising if its net export share is rising sufficiently rapidly. This implication is key to generating the "hump" in the manufacturing employment share that is arguably the most striking fact about structural change to emerge in recent decades.

We highlight the roles of changing sectoral productivity and changing trade costs in structural change with two plausible development scenarios. In the first scenario, the elasticity of substitution is less than one, and the home country is sufficiently small and has a comparative advantage in manufacturing. Moreover, the home country's relative productivity advantage in manufacturing increases over time. The relative price of manufactured goods falls over time, which leads to declining manufacturing expenditure shares in both countries. This contributes to declining manufacturing labor shares. However, owing to its comparative advantage in manufacturing, the home country has a net export surplus in the sector. If its manufacturing productivity growth is high enough, the home country will

[3]The difference between the open economy and autarky price levels for the comparative advantage sector cannot be signed.

export an increasing fraction of manufacturing output for some time, which contributes to increasing manufacturing labor shares. If the trade effect dominates the expenditure effect, the home country's manufacturing labor share will rise.

The rise, however, cannot continue forever. As the country approaches complete specialization in manufacturing, the increase in employment arising from the trade effect will diminish over time. Hence, the expenditure effect will become dominant, and the manufacturing labor share will necessarily decline. Hence, our model can deliver a hump in the manufacturing labor share, even if manufacturing has the highest productivity growth.

What happens to manufacturing in the larger country? Relative to the closed economy case, it will experience a faster decline of its employment share for two reasons. The first is that over time an increasing share of its demand for manufactured goods is being supplied from abroad. Second, as mentioned above, the relative price of manufactured goods in this country is falling over time, which reduces the share of total expenditure devoted to manufactured goods. In other words, there is less expenditure on manufactured goods over time, and an increasing fraction of that expenditure is on imported goods.

A closed economy version of this scenario can capture the declining manufacturing employment shares present in most advanced nations. But, it cannot explain the increasing manufacturing employment shares, let alone a hump pattern in such shares, in the emerging market nations that experience high productivity growth in manufacturing. By contrast, an open economy setting can rationalize both sets of patterns. The presence of international trade transforms the process of structural change.

In the second scenario, manufacturing trade costs decline over time. As they decline, each country's comparative advantage is increasingly revealed, and there is increased specialization. This leads to a rising manufacturing employment share in the country with the comparative advantage in that sector. If this country is small enough initially, its relative wage will increase over time, because the gains from specialization and trade are larger for smaller countries. However, the increase in relative wages reduces the relative purchasing power of the foreign country, which reduces the amount of domestic labor needed to satisfy foreign demand for manufactured goods. Eventually, this effect dominates, and the manufacturing employment share falls.

In both scenarios, country size matters. If the two countries had similar sizes, then the effect of trade on manufacturing in one country will be mirrored by the effect on agriculture in the other country. On the other hand, if a country is large enough, only the pace of its structural change dynamics is altered in an open economy; the qualitative features are not.

Most existing theoretical work on structural change can be put into one of two groups, those with roots in Engel's law and those with roots in Baumol (1967). The first group of models is based on an income elasticity of demand that is different across sectors. A notable recent contribution is Kongsamut, Rebelo, and Xie (2001). The second group of models is based on sector-biased productivity growth, and typically, an elasticity of substitution between sectors that is less than one. A notable recent contribution of the second group is Ngai and Pissarides (2007). Both groups of models are set in a closed economy.

Until very recently, the main contribution in open economy models of structural change were by Matsuyama (1992, 2009). The latter paper and Coleman (2007) are the most closely related to ours.[4] Matsuyama (2009) employs a simple Ricardian model to demonstrate that high manufacturing productivity growth need not lead to a decline in manufacturing employment in an open economy. Coleman (2007) uses a multi-country Heckscher-Ohlin-Ricardo framework to study the effect of a large emerging market country on other countries' GDPs and welfare. Neither paper fully addresses the differences between autarky and the open economy, and the conditions under which productivity growth and declining trade barriers can generate the hump path of manufacturing employment.

The rest of the paper is organized as follows. In the next section, we present some motivating evidence. The benchmark model is presented in section 3. Section 4 briefly analyzes the autarky version of the model, and the next section presents the main derivations and discussion. We demonstrate in section 6 that the our main findings hold in the presence of non-homothetic preferences or intermediate goods. The final section concludes.

2 Motivating Evidence

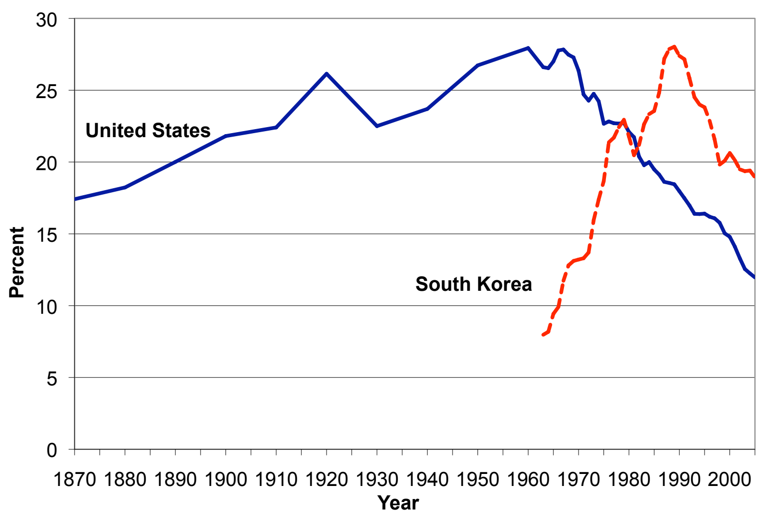
The reallocation of labor and output across broad economic sectors is one of the most prominent features of development. The early empirical research by Clark (1957), Kuznets (1957, 1966), and Chenery and Syrquin (1975), among others, documented that the agriculture shares of output and employment decline, while the industry and services shares of output and employment rise, as a country develops. In light of this pattern, most models of structural change developed at that time were two sector models.[5] In more recent years,

[4] Other recent open economy models of structural change include Galor and Mountford (2008), Stefanski (2009), Teignier-Bacque (2009), and Ungor (2009). In Stefanski (2009) and Ungor (2009), trade is motivated exogenously via Armington aggregators. Ungor studies the effect of China on structural change in the G7 countries. Teignier-Bacque (2009) studies the role of international trade in a two-sector framework with Engel's law preferences. Galor and Mountford (2008) study the effect of trade on fertility and population growth, and on human capital acquisition.

[5] The sectoral divisions were often agriculture and non-agriculture, agriculture and industry (manufacturing), or capital-intensive and labor-intensive. For recent examples of these divisions, see Caselli and Coleman (2001), Laitner (2000), and Acemoglu and Guerrieri (2008). Caselli and Coleman (2001) is effectively an open economy model with labor mobility and human capital, but its focus is on agriculture vs. non-agriculture, and hence, it does not highlight manufacturing. Also, Desmet and Rossi-Hansberg (2009)

Maddison (1991), Buera and Kaboski (2008), and others have shown clearly that there are three distinct sectoral allocation patterns: agriculture declines, services rises, and manufacturing follows a hump pattern, first rising, then falling, as Figure 1 shows for the United States and South Korea.[6] The hump shape in manufacturing may be one of the most important new facts about structural change in the past three decades. As a consequence, three-sector models have become more prevalent in recent years, including Kongsamut, Rebelo, and Xie (2001) and Ngai and Pissarides (2007).[7] These models are all set in a closed economy.

Figure 1: Hump in Manufacturing Labor Share



We motivate studying structural change in an open economy by providing two empirical relationships. The first is the relation between the change over time in a country's manufacturing net exports as a share of total GDP and the change in its manufacturing employment share. Our sample of countries includes the 19 countries in the Groningen Growth and Development Centre (hereafter, GGDC) 10-sector database, as well as 19 OECD countries covered by the OECD's Annual Labor Force Statistics (hereafter, ALFS), rev. 2, database. The GGDC 10-sector database includes Japan and emerging market countries in from South and Central America and East and South Asia for which a fairly

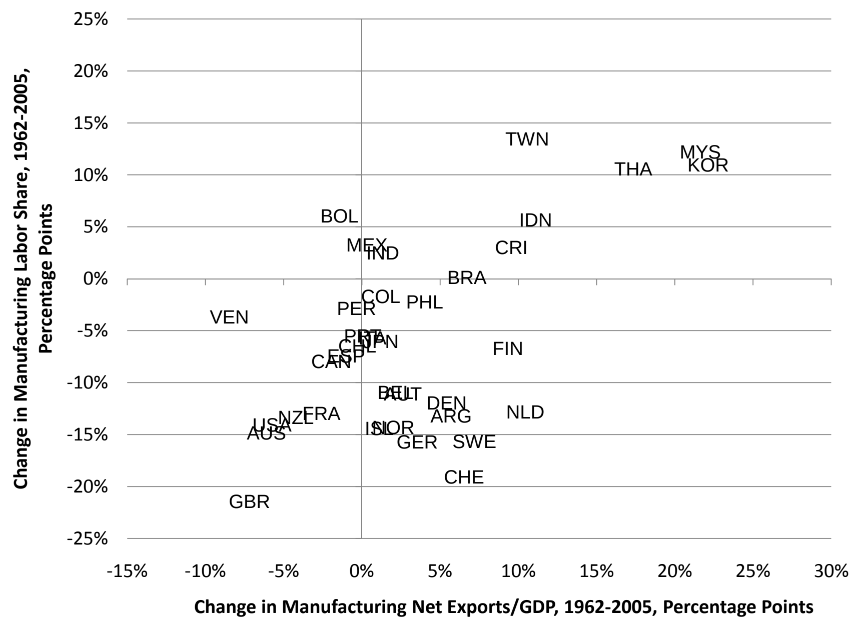
develop and calibrate a spatial model of structural change in which geography influences the shift between services and manufacturing.

[6]Data sources are *International Historical Statistics* (United States, 1870–1960), *OECD Statistics* (United States, 1963–2005) and *GGDC cross-country database* (South Korea, 1963–2005).

[7]Also, see Buera and Kaboski (2008, 2009), Duarte and Restuccia (2009), Foellmi and Zweimuller (2008), Rogerson (2008), Herrendorf, Rogerson and Valentinyi (2009), Restuccia, Yang, and Zhu (2008), and Verma (2008). Also, see Ju, Lin and Wang (2009) for an n-sector model of structural change.

long time series of sectoral data exists. Details on the construction of the variables and on the data sources are given in Appendix A1. Figure 2 shows that countries with larger increases in their manufacturing net export share of GDP tended to have larger increases in their manufacturing employment share.[8] The correlation coefficient is 0.57.[9].

Figure 2: Manufacturing Net Exports and Manufacturing Employment



The second empirical relationship looks at the services sector. We run a regression of the services employment share on per capita GDP and on openness, as measured by the trade share of total GDP. Specifically, we examine 37 of the 38 countries from above[10]. The time period covers 1960 to 2005. To reduce the effects of business cycles, we construct four-year non-overlapping averages for each of the three main variables. Details about construction of the variables and the data sources are given in Appendix A2. We run the following regression:

$$l_{ist} = \beta_0 + \beta_1 trade_{it} + \beta_2 gdppc_{it} + \gamma_i + \epsilon_{it} \tag{1}$$

[8]We exclude Hong Kong and Singapore from the figure as they are essentially city-states and are outliers. Nevertheless, these two cities, taken together, are consistent with the above pattern. Singapore's manufactured net export share of GDP rose 81 percentage points, while its manufacturing employment share was essentially unchanged. In Hong Kong, the manufacturing net export share of GDP share rose 16 percentage points, and its manufacturing employment share fell 37 percentage points.

[9]All countries but Japan, South Korea and Taiwan are, for most of the years of the sample, either on one side of the hump or are not experiencing a sharply defined hump. We re-did the plot including only those years for which Japan, South Korea and Taiwan were on the increasing part of the hump. In that case, the correlation coefficient is 0.63

[10]Taiwan is excluded.

where l_{ist} is the employment share in the services sector for country i in time period t, $trade_{it}$ is exports+imports as a share of GDP, and $gdppc_{it}$ is PPP GDP per capita in constant 2005 international dollars. Per capita income is included to allow for an income elasticity of demand for services that exceeds one. To control for country-specific factors, such as the effects of geography and institutions on the services employment share, we also include country fixed effects in the regression. The estimation results are given in Table 1.

Table 1: Trade and Services Labor Share

	Trade	Income per capita	Constant	R^2	Observations
Fixed Effect[a]	0.0801	1.23e-5	0.369	0.67	379
	(0.0289)	(1.12e-6)	(0.0251)		

[a]: The fixed effect is at the country level. The standard errors reported in parentheses are robust to heteroskedasticity.

The estimated coefficients β_1 and β_2 are statistically significant at the 1 percent level. The coefficient on trade indicates that a 10 percentage point increase in the export (as well as import) share of GDP is associated with a 1.6 percentage point increase in the services employment share. This suggests the possibility of spillover from international trade to structural change even in the (relatively) non-traded sector. Both empirical relationships suggest the importance of the open economy for structural change, and are consistent, as we will show, with the implications of our model.

3 Model

Our model builds on Ngai and Pissarides (2007, hereafter, NP) and Eaton and Kortum (2002). As discussed in the introduction, the driving force in NP is sector-biased productivity growth. A natural extension of NP to an open economy setting is one emphasizing productivity differences as the motive for international trade, the Ricardian trade model. We adopt the Eaton and Kortum (2002) Ricardian setting.[11] To highlight the role of trade in structural change as clearly as possible, our model has one factor of production, two countries, and three sectors: agriculture, manufacturing and services. The agriculture and manufacturing goods are tradable and the services good is non-tradable. Preferences are homothetic. (We relax the homotheticity assumption and also allow production to occur with intermediate goods in section 6.) Productivity and trade costs change at different rates across sectors and countries; these forces drives the dynamics of structural change.

[11]Also, see Alvarez and Lucas (2007).

3.1 Technologies

There is a single *non-tradable* good in the services sector (s). The agriculture (a) and manufacturing (m) sectors each consist of a continuum of *tradable* goods along the $[0,1]$ interval. Each country possesses technologies for producing all the goods in all sectors. The production function for the services sector good of country i in period t is

$$Y_{ist} = A_{ist} L_{ist}, \tag{2}$$

where Y_{ist} and L_{ist} denote output and labor devoted to services, and A_{ist} denotes exogenous productivity of producing the services good.

The production function for tradable good $z \in [0,1]$ in sector $q \in \{a, m\}$ of country i in period t is

$$y_{iqt}(z) = A_{iqt}(z) l_{iqt}(z), \tag{3}$$

where $y_{iqt}(z)$ and $l_{iqt}(z)$ denote output and labor devoted to this tradable good, and $A_{iqt}(z)$ denotes exogenous productivity of producing this tradable good.

Productivity $A_{iqt}(z)$ is the realization of a random variable Z_{iqt} drawn from the cumulative distribution function $F_{iqt}(A) = Pr[Z_{iqt} \leq A]$. Following Eaton and Kortum (2002), we assume that $F_{iqt}(A)$ is a Fréchet distribution: $F_{iqt}(A) = e^{-T_{iqt}A^{-\theta}}$, where $T_{iqt} > 0$, $\theta > 1$, and $q \in \{a, m\}$. The parameter T_{iqt} governs the mean of the distribution; a larger T_{iqt} implies that a high efficiency draw for any good z is more likely. The larger is θ, the lower the heterogeneity or variance of Z_{iqt}.[12] We assume that the productivity is drawn each period.[13]

When agriculture or manufacturing goods are shipped abroad, they incur trade costs, which include tariff rates, transportation costs, and other barriers to trade. We model all of these costs as iceberg costs. Specifically, if one unit of manufacturing good z is shipped from country j in period t, then $\frac{1}{\tau_{ijmt}}$ units arrive in country i. Similarly, τ_{ijat} is the gross trade cost incurred from shipping one unit of the agriculture good from country j to country i in period t. We assume that trade costs within a country are zero, i.e., $\tau_{11at} = \tau_{22at} = 1$ and $\tau_{11mt} = \tau_{22mt} = 1$. In the case of free trade, trade costs across countries are also zero, i.e., $\tau_{12at} = \tau_{21at} = 1$ and $\tau_{12mt} = \tau_{21mt} = 1$.

[12] Z_{iqt} has geometric mean $e^{\gamma/\theta} T_{iqt}^{1/\theta}$ and its log has a standard deviation $\pi/(\theta\sqrt{6})$, where γ is Euler's constant.

[13] Alternatively, we could assume that the productivity is drawn once in the initial period, and as the T's change over time, the productivity relative to T remains constant.

3.2 Preferences

The composite good in agriculture or manufacturing is an aggregate of the individual goods as follows:

$$C_{iqt} = \left(\int_0^1 c_{iqt}(z)^{\eta} dz \right)^{\frac{1}{\eta}}, \tag{4}$$

where $c_{iqt}(z)$ is the use of good z by country i to make the composite sectoral good $q \in \{a, m\}$ in period t, and $\eta < 1$. The elasticity of substitution across individual sectoral goods is $\frac{1}{1-\eta}$.

Utility in period t is given by:

$$C_{it} = U(C_{iat}, C_{imt}, C_{ist}) = \left(\omega_a C_{iat}^{\epsilon} + \omega_m C_{imt}^{\epsilon} + \omega_s C_{ist}^{\epsilon}\right)^{\frac{1}{\epsilon}}, \tag{5}$$

where C_{it} is an aggregate of the composite agriculture good C_{iat}, the composite manufacturing good C_{imt}, and the services good C_{ist}, $\epsilon < 1$, ω_a, ω_m, $\omega_s > 0$ and $\omega_a + \omega_m + \omega_s = 1$. The elasticity of substitution across sectoral goods is $\frac{1}{1-\epsilon}$. If $\epsilon \in [0, 1)$, the elasticity of substitution exceeds or equals one; that is, the sectoral goods are substitutes. If $\epsilon < 0$, the elasticity of substitution is less than one; that is, the sectoral goods are complements.

The representative household in country i maximizes his/her intertemporal utility, which is given by

$$\sum_{t=0}^{\infty} \beta^t \frac{C_{it}^{1-\sigma} - 1}{1 - \sigma}. \tag{6}$$

The elasticity of intertemporal substitution is $\frac{1}{\sigma} > 0$.

The household supplies L_{it} inelastically and spends all labor income on consumption. The household maximizes (6), (5) and (4) subject to the following budget constraints in each period t:

$$P_{it}C_{it} = P_{iat}C_{iat} + P_{imt}C_{imt} + P_{ist}C_{ist} = w_{it}L_{it}, \tag{7}$$

$$P_{iqt}C_{iqt} = \int_0^1 p_{iqt}(z)c_{iqt}(z)dz, \quad \text{for } q \in \{a, m\}, \tag{8}$$

where w_{it}, P_{it}, P_{iat}, P_{imt} and P_{ist} denote the wage rate, and the prices of the aggregate consumption good, the agriculture composite good, the manufacturing composite good, and the services good, respectively, and $p_{iqt}(z)$ denotes the price of good z in tradable good sector $q \in \{a, m\}$. The budget constraints (7) and (8) ensure that balanced trade holds period-by-period.

3.3 Equilibrium

In a Ricardian model, trade is determined by comparative advantage, based on relative productivity differences and relative trade costs across countries. All factor and goods markets are characterized by perfect competition. Labor is perfectly mobile across sectors within a country, but immobile across countries. The following factor market clearing conditions hold in each period t in each country i

$$L_{it} = L_{ist} + L_{imt} + L_{iat}, \tag{9}$$

where $L_{imt} = \int_0^1 l_{imt}(z)dz$ and $L_{iat} = \int_0^1 l_{iat}(z)dz$.

We denote the actual trade costs that the household in country i pays for sector $q \in \{a, m\}$ good z in period t by $d_{iqt}(z)$. Specifically, $d_{iqt}(z)$ is 1 if good z is produced domestically and is τ_{ijqt}, $j \neq i$, if good z is produced abroad. The following goods markets clearing conditions hold in each period t in each country i:

$$Y_{ist} = C_{ist}, \tag{10}$$

$$y_{1at}(z) + y_{2at}(z) = d_{1at}(z)c_{1at}(z) + d_{2at}(z)c_{2at}(z), \qquad \forall z \in [0, 1], \tag{11}$$

$$y_{1mt}(z) + y_{2mt}(z) = d_{1mt}(z)c_{1mt}(z) + d_{2mt}(z)c_{2mt}(z), \qquad \forall z \in [0, 1]. \tag{12}$$

We define a competitive equilibrium of our model economy with country-specific and exogenous labor endowment processes $\{L_{it}\}_{t=0}^{\infty}$, trade cost processes $\{\tau_{ijat}, \tau_{ijmt}\}_{t=0}^{\infty}$, and productivity processes $\{T_{iat}, T_{imt}, A_{ist}\}_{t=0}^{\infty}$ and structural parameters $\{\sigma, \epsilon, \eta, \beta, \theta\}$ as follows.

Definition 1. *A competitive equilibrium* is a sequence of goods and factor prices $\{p_{iat}(z)$, $p_{imt}(z)$, P_{iat}, P_{imt}, P_{ist}, P_{it}, $w_{it}\}_{t=0}^{\infty}$ and allocations $\{l_{iat}(z)$, $l_{imt}(z)$, L_{iat}, L_{imt}, L_{ist}, $y_{iat}(z)$, $y_{imt}(z)$, Y_{ist}, $c_{iat}(z)$, $c_{imt}(z)$, C_{iat}, C_{imt}, C_{ist}, $C_{it}\}_{t=0}^{\infty}$ for $z \in [0, 1]$ and $i = 1, 2$, such that given prices, the allocations solve the firms' maximization problems associated with technologies (2)-(3) and the household's maximization problem characterized by (6)-(8), and satisfy the market clearing conditions (9)-(12).

Our model economy has a unique competitive equilibrium. We start the characterization of this equilibrium with the prices. Goods prices equal marginal costs. Specifically, the services good price in country i in period t is given by

$$P_{ist} = \frac{w_{it}}{A_{ist}}. \tag{13}$$

For tradable goods, the marginal costs include the trade costs. The price that a consumer in country i pays to purchase one unit of good z produced in country j and sector $q \in \{a, m\}$ is given by

$$p_{ijqt}(z) = \frac{\tau_{ijqt} w_{jt}}{A_{jqt}(z)}.$$

The actual price that the consumer in country i pays for one unit of good z in tradable sector q is

$$p_{iqt}(z) = \min \left\{ p_{i1qt}(z), p_{i2qt}(z) \right\}.$$

The price of the composite sector good $q \in \{a, m\}$ is given by

$$P_{iqt} = \left(\int_0^1 p_{iqt}(z)^{\frac{\eta}{\eta-1}} dz \right)^{\frac{\eta-1}{\eta}}, \tag{14}$$

and the aggregate price index P_{it} is given by

$$P_{it} = \left(\omega_a^{\frac{1}{1-\epsilon}} P_{iat}^{\frac{\epsilon}{\epsilon-1}} + \omega_m^{\frac{1}{1-\epsilon}} P_{imt}^{\frac{\epsilon}{\epsilon-1}} + \omega_s^{\frac{1}{1-\epsilon}} P_{ist}^{\frac{\epsilon}{\epsilon-1}} \right)^{\frac{\epsilon-1}{\epsilon}}. \tag{15}$$

We next characterize the household's optimal consumption allocation. According to the first order optimality conditions, the consumption expenditure share, $X_{iqt} = \frac{P_{iqt} C_{iqt}}{P_{it} C_{it}}$, in sector $q \in \{a, m, s\}$ of country i in period t is given by

$$X_{iqt} = \omega_q^{\frac{1}{1-\epsilon}} \left(\frac{P_{iqt}}{P_{it}} \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{16}$$

and the consumption expenditure share, $X_{iqt}(z)$, for good z in tradable sector q is given by

$$X_{iqt}(z) = \left(\frac{p_{iqt}(z)}{P_{iqt}} \right)^{\frac{\eta}{\eta-1}} X_{iqt}. \tag{17}$$

The sectoral expenditure shares are determined by relative prices and the preference parameter ϵ. When the elasticity of substitution across sectors is one, i.e., $\epsilon = 0$, the sectoral expenditure shares are independent of the relative prices. When this elasticity of substitution is less than one, i.e., $\epsilon < 0$, the higher is the sector-q relative price, the higher is the expenditure share of sector q.

The model generates both inter-sector and intra-sector trade based on comparative advantage. The overall productivity of each sector, T_{iqt} plays a key role in the inter-sectoral allocation, as we show in section 5. Each country will be a net exporter in either the manufacturing sector or the agriculture sector. The relative wage endogenously adjusts to ensure that the balanced-trade condition is satisfied. Labor is allocated across sectors to meet local demand for the non-traded services good and a portion of world demand for the traded goods. Which goods are exported or imported within a sector is determined by the idiosyncratic productivity draws in conjunction with the trade costs. Given our productivity distribution assumption, as long as trade costs are not prohibitively high, there will be some goods within a sector that a country will be able to produce more cheaply than the other country; hence, both countries will import some goods from abroad. We fully characterize the trade pattern and the labor allocation in the next two sections.

4 Structural Change under Autarky

We begin our analysis of the model by developing the pattern of structural change in a closed economy or under autarky.[14] Under autarky, all goods are produced domestically. We focus on the sectoral allocation of employment. The results developed here will allow us to highlight the contribution of international trade on structural change, which we study in the following section.

We start with sectoral prices; it is straightforward to show for country i and period t,

$$\frac{P_{iat}}{w_{it}} = \frac{1}{A_{iat}}, \quad \frac{P_{imt}}{w_{it}} = \frac{1}{A_{imt}}, \quad \frac{P_{ist}}{w_{it}} = \frac{1}{A_{ist}}, \tag{18}$$

where $A_{iat} = \gamma^{-1} T_{iat}^{\frac{1}{\theta}}$, $A_{imt} = \gamma^{-1} T_{imt}^{\frac{1}{\theta}}$, $\gamma = (\Gamma(1 - \frac{\eta}{1-\eta}\frac{1}{\theta}))^{\frac{\eta-1}{\eta}}$, and Γ is the Gamma function.[15] Thus, a continuum of goods in the agriculture or manufacturing sector can be essentially reduced to one composite good with productivity A_{iat} or A_{imt}.

The feasibility conditions imply that the sectoral labor share equals the sectoral expenditure share:

$$l_{iqt} = \frac{L_{iqt}}{L_{it}} = \frac{w_{it} L_{iqt}}{w_{it} L_{it}} = \frac{P_{iqt} C_{iqt}}{w_{it} L_{it}} = X_{iqt}, \tag{19}$$

for each sector $q \in \{a, m, s\}$.[16] The sectoral labor shares depend on the relative prices in the same way as the sectoral expenditures shares in (16). When the elasticity of substitution

[14] We use "autarky" and "closed" interchangeably. Autarky is a special case of our model in which the trade costs are infinitely high. The implications in this section are similar to those in Ngai and Pissarides (2007).

[15] We need to assume $\frac{1}{1-\eta} < 1 + \theta$ to have a well-defined price index. Under this assumption, the parameter η, which governs the elasticity of substitution across goods within a sector, can be ignored because it appears only in the constant term γ.

[16] The sectoral labor share will equal the sectoral expenditure share even in a framework with capital and with intermediate goods, as long as the labor shares are identical across sectors, and similarly for the capital shares.

across sectors is one, the sectoral labor shares are independent of the relative prices. When the elasticity is less than one, the higher the sectoral relative price — owing to lower sectoral relative productivity — the higher the sectoral expenditure and labor shares.[17]

Turning to dynamics, let $\hat{Z}_{iqt}$ denote the log growth rate of variable Z_{iqt}. Then, we have, for any $q \in \{a, m, s\}$,

$$\hat{l}_{iqt} = \hat{X}_{iqt} = \frac{\epsilon}{\epsilon - 1}(\hat{P}_{iqt} - \hat{P}_{it}), \tag{20}$$

where $\hat{P}_{it} = \sum_{q \in \{a,m,s\}} X_{iqt}\hat{P}_{iqt}$. Thus, the elasticity of substitution links changes in sectoral labor shares $\hat{l}_{iqt}$ to changes in sectoral relative prices $\hat{P}_{iqt} - \hat{P}_{it}$. When the elasticity of substitution across sectors is less than one, i.e., $\epsilon < 0$, a sector with declining relative prices experiences declining expenditure and labor shares over time. In the Cobb-Douglas case, i.e., $\epsilon = 0$, there is no structural change: sectoral expenditure and labor shares are constant over time.

The growth rate of sectoral labor shares can be expressed in terms of the growth rates of sectoral productivities using (18):

$$\hat{l}_{iqt} = \hat{X}_{iqt} = \frac{\epsilon}{1 - \epsilon}(\hat{A}_{iqt} - \hat{A}_{it}), \tag{21}$$

where the weighted average productivity growth $\hat{A}_{it}$ equals $\sum_{q \in \{a,m,s\}} X_{iqt}\hat{A}_{iqt}$. When the elasticity is less than one, sectors with relatively high productivity growth experience declines in employment shares. Labor moves from high productivity growth sectors to low productivity growth sectors. In a world with constant productivity growth rates, a necessary condition for a hump pattern in the manufacturing labor share, then, is that manufacturing can have neither the highest nor the lowest productivity growth.[18]

We conclude by summarizing three key implications of the autarky model. First, the sectoral labor share equals sectoral expenditure shares. Second, structural change does not occur when the elasticity of substitution equals one. Third, with the elasticity of substitution less than one, the sector with the highest (least) productivity growth has the fastest (slowest) rate of decline in prices and expenditure shares. Thus, labor moves from the most productive sector to the least productive sector.

[17]When the elasticity is greater than one, higher sectoral relative prices imply lower sectoral expenditure and labor shares.

[18]NP show that manufacturing productivity growth must be below average initially, and above average later on, for the hump to occur.

5 Structural Change in Open Economy

We now analyze the patterns of structural change in an open economy. We first examine the impact effect of an open economy, that is, how sectoral relative prices, expenditure shares, and labor shares change in the period in which a closed economy becomes open. We then study the ensuing dynamics in the open economy relative to those in the closed economy. We highlight two plausible development scenarios that can generate a hump in the manufacturing employment share. One scenario involves a country with a comparative advantage in manufacturing, and with relative manufacturing productivity growth rising over time. The second focuses on declining trade costs in the manufacturing sector. Owing to our two-country framework, relative wages, the terms of trade, and relative country sizes are endogenous; these variables play a key role in the model dynamics, as we show below.

5.1 Impact of International Trade

We begin by defining sectoral comparative advantage. Country i has a *comparative advantage in manufacturing* if and only if

$$\frac{A_{imt}/\tau_{jimt}}{A_{jmt}} > \frac{A_{iat}/\tau_{jiat}}{A_{jat}}.$$

Our definition is thus the traditional definition augmented by trade costs.[19] If country i has a comparative advantage in manufacturing, we will say it has a comparative disadvantage in agriculture, and vice versa. In the presence of trade costs, however, if country 1 has a comparative advantage in manufacturing, it is not necessarily true that country 2 has comparative advantage in agriculture. We restrict our attention to cases in which one country has a comparative advantage in manufacturing and the other country has a comparative advantage in agriculture, which is a restriction that trade costs cannot be too different across sectors and countries.

5.1.1 Relative Prices and Expenditure Shares

In order to facilitate comparisons with the autarky case, we normalize prices by the wage rate. For the services good in country i, its price relative to the wage rate in period t is

[19] Hence, it is possible for a country to have a relative disadvantage in manufacturing from the productivities alone, but, owing to sufficiently small manufacturing trade costs, an overall comparative advantage in manufacturing. See Deardorff (2004) for more discussion on the topic of comparative advantage in the presence of trade costs.

$\frac{P_{ist}}{w_{it}} = \frac{1}{A_{ist}}$, which is the same as under autarky. For the tradable composite good q, we have:

$$\frac{P_{iqt}}{w_{it}} = \frac{1}{A_{iqt}} \left[1 + \left(\frac{\tau_{ijqt} w_{jt} / A_{jqt}}{w_{it}/A_{iqt}} \right)^{-\theta} \right]^{-\frac{1}{\theta}}. \tag{22}$$

Comparing equation (22) to (18), one can see that the price relative to the wage is lower with trade than under autarky. The lower the trade cost or foreign wage or the higher the foreign technology the lower the price under trade. Relative to autarky the price decline is larger in the sector of comparative disadvantage. Trade essentially allows each country to enlarge its effective state of technology in the tradable sectors, thus leading to lower prices; moreover, the gain in effective technology is larger in the sector of comparative disadvantage.

The impact of trade on prices relative to the wage rate has direct implications for welfare. The aggregate price level relative to the wage rate $\frac{P_{it}}{w_{it}}$ is lower in the open economy compared to autarky. $\frac{w_{it}}{P_{it}}$ measures the real purchasing power of each country's income; hence, we have the well-known result from classical trade theory that opening up to trade leads to a rise in welfare in both countries.

We next examine sectoral prices relative to the aggregate price level in the open economy compared to autarky. From the above, it is clear that $\frac{P_{ist}}{P_{it}}$ is higher in the open economy in both countries; also, for the sector in which country i has a comparative disadvantage, its price relative to the aggregate price is lower in an open economy. On the other hand, in the comparative advantage sector, the sectoral price relative to the aggregate price may or may not be lower in the open economy than under autarky.

The impact of trade on sectoral prices relative to the aggregate price determines the impact of trade on expenditure shares. Consider, for example, the case of an elasticity of substitution across sectors that is less than one. Because the relative services price $\frac{P_{ist}}{P_{it}}$ is higher in the open economy in both countries, the services expenditure share is also higher in the open economy in both countries. If country i has a comparative disadvantage in sector q, the expenditure share X_{iqt} is lower in the open economy than in the closed economy. We cannot sign the expenditure share of the sector in which country i has a comparative advantage.

5.1.2 Trade Patterns

Expenditures on tradable goods are divided between domestic goods and imported goods. Under the Fréchet distribution of productivities, the share of country i's expenditure on sector q goods from country j, π_{ijqt}, captures intra-sector trade and is given by

$$\pi_{ijqt} = \frac{(\tau_{ijqt} w_{jt}/A_{jqt})^{-\theta}}{(\tau_{ijqt} w_{jt}/A_{jqt})^{-\theta} + (w_{it}/A_{iqt})^{-\theta}} = \frac{1}{1 + (\frac{w_{it}/A_{iqt}}{\tau_{ijqt} w_{jt}/A_{jqt}})^{-\theta}}. \tag{23}$$

Equation (23) shows how a lower average cost of production, inclusive of trade costs, in country j translates into a greater sectoral import share by country i. The import share also depends on the parameter θ; a higher θ implies a smaller dispersion of productivity draws, which strengthens the effect of comparative advantage on intra-sector trade. Sectoral spending that is not on imports is on domestic goods: $\pi_{iiqt} = 1 - \pi_{ijqt}$.

If country i has a comparative advantage in manufacturing and country j has a comparative advantage in agriculture, equation (23) implies that $\pi_{ijmt} < \pi_{ijat}$ and $\pi_{iimt} > \pi_{iiat}$. The share of country i's manufacturing spending that is on imports is less than the share of country i's agriculture spending that is on imports. Intuitively, a greater share of spending is on domestic goods in the comparative advantage sector relative to the comparative disadvantage sector.

We now characterize the patterns of international trade. Country i's exports of sector q goods is given by $EX_{iqt} = \pi_{jiqt} X_{jqt} w_{jt} L_{jt}$. It is the product of country j's expenditure devoted to sector q goods, $X_{jqt} w_{jt} L_{jt}$, and the fraction of that expenditure that is on imports, π_{jiqt}. Similarly, country i's imports of sector q goods is given by $IM_{iqt} = \pi_{ijqt} X_{iqt} w_{it} L_{it}$. Thus, country i's net exports of sector q goods is given by $NX_{iqt} = EX_{iqt} - IM_{iqt}$. The balanced trade condition implies that inter-sectoral trade sums to zero, i.e., $NX_{imt} + NX_{iat} = 0$. We denote the sectoral net export share of total GDP, $\frac{NX_{iqt}}{w_{it} L_{it}}$, by N_{iqt}. We demonstrate next that the sectoral net export share is a key determinant of sectoral labor allocations.

5.1.3 Labor Allocations

Because the services good is non-tradable, the market clearing condition requires that $C_{ist} = A_{ist} L_{ist} = X_{ist} w_{it} L_{it}/P_{ist}$.[20] Thus, we have

$$l_{ist} = \frac{L_{ist}}{L_{it}} = X_{ist}.$$

In the open economy, the non-tradable sector's labor share equals its expenditure share — just as in the closed economy. This does not mean that trade has no impact on the services

[20] We have not yet discussed value-added output shares. As should be clear by now, our simple framework implies that each sector's value-added output share equals its employment share.

labor share, however, because trade affects prices, which affects expenditure shares. For example, when the elasticity of substitution is less than one, which we call the "Baumol" case, the services labor share is higher in the open economy than under autarky.

We next examine the tradable sector labor shares. Country 1's income from sector q equals expenditures of both countries on its sector-q goods: $w_{1t}L_{1qt} = \pi_{11qt}P_{1qt}C_{1qt} + \pi_{21qt}P_{2qt}C_{2qt}$. This implies

$$l_{1qt} = \frac{L_{1qt}}{L_{1t}} = \pi_{11qt}X_{1qt} + \pi_{21qt}X_{2qt}\frac{w_{2t}L_{2t}}{w_{1t}L_{1t}}. \tag{24}$$

Three forces determine country 1's labor share in sector q. It depends on expenditures shares by each country on sector q goods, X_{1qt} and X_{2qt}. In addition, it depends on the share of each country's spending on sector q goods that is on goods produced by country 1, π_{11qt} and π_{21qt}. Finally, it depends on the relative size of the two economies. The smaller is country 1, the more its labor share is determined by country 2's demand.

Substituting $1 - \pi_{12qt}$ for π_{11qt}, we can rewrite (24) as follows:

$$l_{1qt} = X_{1qt} + \frac{\pi_{21qt}X_{2qt}w_{2t}L_{2t} - \pi_{12qt}X_{1qt}w_{1t}L_{1t}}{w_{1t}L_{1t}} = X_{1qt} + N_{1qt}. \tag{25}$$

Country 1's labor share in sector q equals its sectoral expenditure share plus its sectoral net export share of total GDP. Thus, the tight link that binds sectoral demand and production in the closed economy does not hold in the open economy. N_{iqt} captures the direct contribution of international trade to structural change. There is also an indirect contribution of trade on structural change through its effect on prices and the expenditure shares X_{iqt}, as we described above for the services sector. For example, when the elasticity of substitution across sectors is less than one, the expenditure share on the comparative disadvantage sector is lower in the open economy.

To see clearly the direct contribution of trade to the sectoral labor shares, consider the Cobb-Douglas case. In this case, the services labor share is ω_s under both autarky and the open economy. The labor share of tradable sector $q \in \{a, m\}$ is ω_q under autarky and is $\omega_q + N_{iqt}$ in the open economy. Moreover, a tradable sector with a positive net exports share N_{iqt} has a higher labor share in the open economy. Thus, the magnitude of the sectoral net export share tells us the impact of international trade on structural change.

Continuing with the Cobb-Douglas case, we now derive a natural, but important, implication of the model: a country will experience a net export surplus in its comparative advantage sector.[21] Assume that country 1 has a comparative advantage in manufacturing,

[21]When the elasticity of substitution differs from one, this result is difficult to prove because the expen-

and country 2 has a comparative advantage in agriculture. The trade balance of sector q in country 1 is given by

$$NX_{1qt} = \pi_{21qt}\omega_q w_{2t} L_{2t} - \pi_{12qt}\omega_q w_{1t} L_{1t},$$

where the expenditure share is ω_q in both countries. The pattern of comparative advantages implies $\pi_{21mt} > \pi_{21at}$ and $\pi_{12mt} < \pi_{12at}$. Thus, if country 1 ran a trade deficit in the manufacturing sector, it would also have to run a trade deficit in the agriculture sector. This would violate the balanced trade condition. Hence, it must be the case that $NX_{1mt} > 0$ and $NX_{1at} < 0$.[22] Equivalently, we have $N_{1mt} > 0$ and $N_{1at} < 0$. Hence, when a country opens up to trade, labor moves from its comparative disadvantage sector to its comparative advantage sector.

It is often noted that the effect of opening up to international trade is similar to the effect of a productivity shock in a closed economy. By facilitating a reallocation of resources, openness to trade leads to an increase in overall output, even though overall inputs have not changed. For the effect of an open economy on the expenditure shares, this logic is useful, as the productivity shock interpretation for the tradable sectors helps us understand why agriculture's expenditure share falls and services' expenditure share rises (when the elasticity of substitution is less than one). This logic, however, does not offer a complete picture for thinking about structural change, because in an open economy, sectoral employment is also determined by foreign demand for domestic goods. In addition, comparative advantage ensures that one sector will experience an increase in employment owing to trade, while the other sector will experience a decrease, even though both experience a boost in effective productivity.

5.2 Dynamics of Structural Change

We now study the dynamics of structural change in an open economy. The growth rate of the services labor share in country i equals the growth rate of the services expenditure share:

$$\hat{l}_{ist} = \hat{X}_{ist}. \tag{26}$$

As discussed above, while this is the same expression as in the closed economy, trade does affect the growth rate of the services labor share through its effect on the growth rates of

diture share terms are complicated. Under reasonable parameter values, however, we can show numerically that this result still holds.

[22] For the proof, see Appendix B1.

the services relative price and the services expenditure share.

The growth rate of the labor share of tradable sector q in country i is given by

$$\hat{l}_{iqt} = \frac{X_{iqt}}{l_{iqt}} \hat{X}_{iqt} + \frac{N_{iqt}}{l_{iqt}} \hat{N}_{iqt}. \tag{27}$$

This is clearly different from (20). We call the first term on the right-hand side the "expenditure" effect and the second term the "trade" effect. Trade affects the labor share dynamics directly through changes in the sectoral net export ratio. In addition, trade affects the dynamics of the expenditure shares indirectly through its impact on prices.

To illustrate transparently these effects, we turn to a special case of our model, the Cobb-Douglas sectoral elasticity and free trade. (We will relax the Cobb-Douglas assumption later.) In this case, the sectoral expenditure share is constant over time, and the expenditure effect is zero. Thus, in a closed economy, there would be no structural change. In an open economy, however, the labor share of the tradable sectors will change over time as long as the trade effect is non-zero. We now consider how the trade effect and the pattern of structural change link to the dynamics of comparative advantage across countries.

Assume that country 1 has a comparative advantage in manufacturing, i.e., $N_{1mt} > 0$. Comparative advantage is an ordinal concept. However, to economize on language we will refer to an increase in the ratio of country 1's relative productivity in manufacturing to country 1's relative productivity in agriculture as growth in country 1's comparative advantage. Our model predicts that if country 1's comparative advantage grows sufficiently fast, it will experience a rise in the manufacturing net export share and labor share. A necessary condition for $\hat{N}_{1mt} > 0$ is $\hat{A}_{mt} > \hat{A}_{at}$, and the sufficient condition is

$$\hat{A}_{mt} > \hat{A}_{at} \frac{L_{2t}\pi_{12at} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}{L_{2t}\pi_{12mt} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}, \tag{28}$$

where $w_t = \frac{w_{1t}}{w_{2t}}$ and $A_{qt} = \frac{A_{1qt}}{A_{2qt}}$ for $q \in \{a, m\}$.[23] As long as country 1's growth in its comparative advantage is sufficiently high, $\hat{N}_{1mt}$ will be positive and its manufacturing labor share will grow.

We now show how trade can generate a hump pattern for the manufacturing employment share even when the manufacturing sector has the fastest productivity growth. To see this, suppose that all sectoral productivity growth rates are constant over time, with manufacturing having the fastest growth in both countries. Country 1's manufacturing

[23] For details, see Appendix B2. The fraction on the right hand side of equation (28) is larger than one because country 1's comparative advantage in manufacturing implies that $\pi_{12at} > \pi_{12mt}$.

employment share is given by

$$l_{1mt} = \omega_m \pi_{11mt} \left(\frac{w_t L_{1t} + L_{2t}}{w_t L_{1t}} \right), \tag{29}$$

which is a simplified version of equation (24). Assume that $\hat{A}_m$ and $\hat{A}_a$ satisfy equation (28) initially. Thus, l_{1mt} rises initially. Over time, π_{11mt} grows as each country purchases a greater fraction of its manufactured goods from country 1; $\frac{w_t L_{1t}+L_{2t}}{w_t L_{1t}}$ declines as country 1 becomes larger relative to country 2. As long as the first, "specialization", force dominates the second, "country-size", force, the manufacturing labor share continues to increase. The specialization force diminishes as manufacturing becomes increasingly specialized because there are few further gains to employment from productivity growth. If π_{11mt} reaches 1, then, there are no further increases in employment from this force. The adverse employment effect of the country-size force, however, continues over time. Thus, the country-size force will eventually dominate the specialization force, and country 1's manufacturing labor share will begin to decrease.

We briefly discuss the Baumol case in which the elasticity of substitution is less than one. Now, the expenditure effect plays a role in the dynamics of the labor share of the tradable sectors. Trade can still generate a hump in the manufacturing labor share even when manufacturing has the highest productivity growth. The story is similar to that described above. Initially, with high productivity growth and a comparative advantage in manufacturing, the trade effect is positive and increasing. Labor shifts towards the manufacturing sector to produce goods to satisfy increased global demand. This inflow of labor into manufacturing more than offsets the outflow of labor owing to a declining expenditure share. Over time, the trade effect, while remaining positive, diminishes. This happens because of the diminishing importance of the specialization force described above. At some point in time — likely before complete specialization occurs — the expenditure effect will dominate the trade effect and the manufacturing labor share will begin to decline. Owing to the expenditure effect, the peak of the hump will occur earlier in time compared to the Cobb-Douglas case.

To provide further intuition, we illustrate the workings of the model with an example. One country is small, and one country is large: country 1's labor endowment is one-tenth of country 2's. The initial sectoral productivity levels are identical in per-capita terms across countries.[24] Manufacturing total factor productivity (TFP) grows 2 percent per year in

[24]In a one-sector Eaton-Kortum model, the relative wage rate will be one if the two countries have the same per-capita productivity. In our multi-sector environment, the relative wage rate depends on the expenditure shares across sectors and across countries, in addition to the relative per-capita productivity.

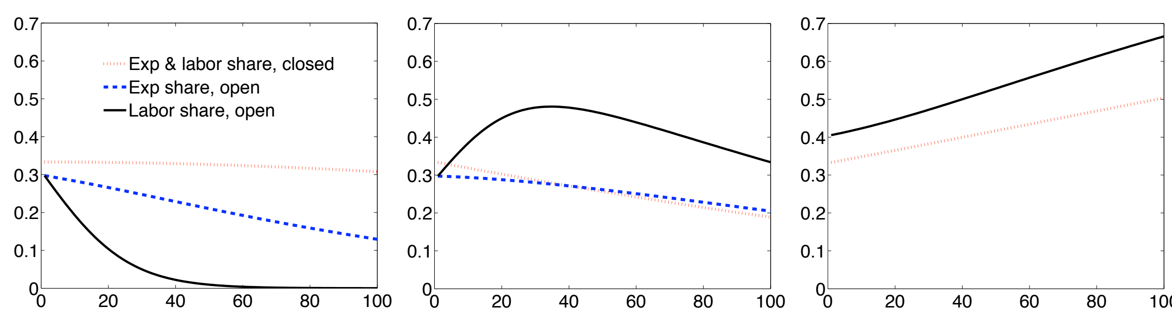
country 1, and 1 percent per year in country 2. Agriculture TFP grows 1 percent per year in country 1, and 2 percent per year in country 2. Thus, over time, country 1 develops an increasingly large comparative advantage in manufacturing, and similarly for country 2 in agriculture. In both countries, services TFP is constant over time. The elasticity of substitution across sectors is set at 0.5, i.e., we implement the Baumol case. In addition, ω_q is set at 1/3 for each sector, and θ is set at 4.[25] Table 2 summarizes the relevant parameters.

Table 2: Parameter Values

	Preferences	
$\epsilon = -1.0$	$\omega_a = \omega_m = \omega_s = 1/3$	
	Labor Endowment	
$L_{10} = 1$	$L_{20} = 10$	$\hat{L}_{1t} = \hat{L}_{1t} = 0.0$
	Sectoral Productivities	
$\theta = 4.0$	$A_{1a0} = A_{1m0} = A_{1s0} = 1.0$	$A_{2a0} = A_{2m0} = A_{2s0} = (\frac{L_{20}}{L_{10}})^{\frac{1}{\theta}}$
$\hat{A}_{1at} = \hat{A}_{2mt} = 0.01$	$\hat{A}_{1mt} = \hat{A}_{2at} = 0.02$	$\hat{A}_{1st} = \hat{A}_{2st} = 0.0$

Figure 3 illustrates structural change in country 1 for both the closed and open economy cases. The closed economy is shown in dotted red lines: the agriculture and manufacturing labor shares decline, while the services labor share increases, over time. This is because the relative price of the composite agriculture and manufactured goods both decline over time, which, with an elasticity of substitution less than one, implies declining expenditure and labor shares in these two sectors.

Figure 3: Structural Change in Country 1



(a) Agriculture (b) Manufacturing (c) Services

For the open economy case, the expenditure shares are shown in dashed blue lines and the labor shares are shown in solid black lines. Panel (a) shows the expenditure and labor

In this example, the initial relative wage rate turns out to be close to, though not exactly, one.

[25]The parameters σ, η, and β are irrelevant for this example.

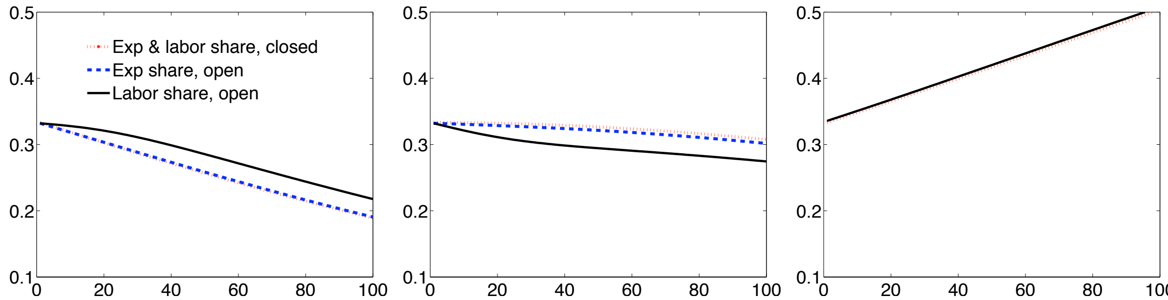
patterns in agriculture. Country 1 has a comparative disadvantage in agriculture that grows over time; hence, a greater fraction of spending on agricultural goods is on relatively inexpensive imports. This drives down the relative price of the composite agricultural goods, and hence, agriculture's expenditure share. After 100 periods, the expenditure share is less than half of the closed economy expenditure share. The increased reliance on imports shows up on the production side as a sharp drop in agriculture's employment share. The gap between the expenditure share and the employment share is the net imports of agriculture goods as a share of total GDP.

Panel (b) of Figure 3 shows the expenditure and labor shares for manufacturing. The time path of the manufacturing expenditure share is quite similar to that of the closed economy, reflecting the fact that few manufactured goods are imported from abroad. The manufacturing labor share follows a hump pattern. The increasing comparative advantage in manufacturing over time generates initially a positive trade effect, and an increasing fraction of labor is devoted to production for manufacturing exports. The trade effect, in turn, is stronger initially than the expenditure effect, and the manufacturing labor share increases. However, the strength of the trade effect diminishes over time, and is eventually dominated by the expenditure effect. The interplay of these two effects is the source of the peak and then subsequent decline in the manufacturing labor share. Further understanding of this interplay comes from panel (a). Country 1 essentially stops producing agricultural goods at some point; at that time, labor in country 1 is allocated to only two sectors, services and manufacturing. As the services sector is growing in terms of both expenditure and labor shares, owing to its increasing relative price, the manufacturing sector must be shrinking.

Figure 4 presents the structural change patterns for country 2. Because country 2 is large, the open economy patterns are similar to the closed economy patterns. However, the manufacturing sector shows a steeper decline, and the agriculture sector shows a slower decline in the open economy than in the closed economy. The manufacturing pattern is consistent with the data in Figure 2. Even relatively small economies can impact the pace of structural change of large economies.

Figure 5 illustrates the trade patterns. The import shares of the smaller country 1 are high initially. Over time, owing to the increasing comparative advantage in manufacturing and disadvantage in agriculture, country 1 imports fewer manufactured goods and more agriculture goods. In the latter sector, as mentioned above, eventually, almost all agriculture goods are imported. Figure 5 shows that country 2 imports an increasing share of its manufactured goods expenditure over time. However, its expenditure share on manufactured goods is declining over time; hence, at some point, total manufactured imports from

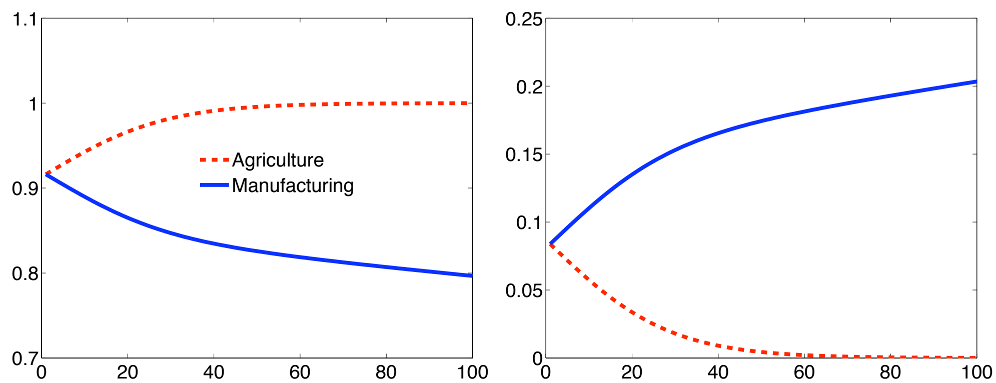
Figure 4: Structural Change in Country 2



(a) Agriculture (b) Manufacturing (c) Services

country 1 diminish, which contributes to the declining manufacturing labor in country 1.

Figure 5: Import Shares

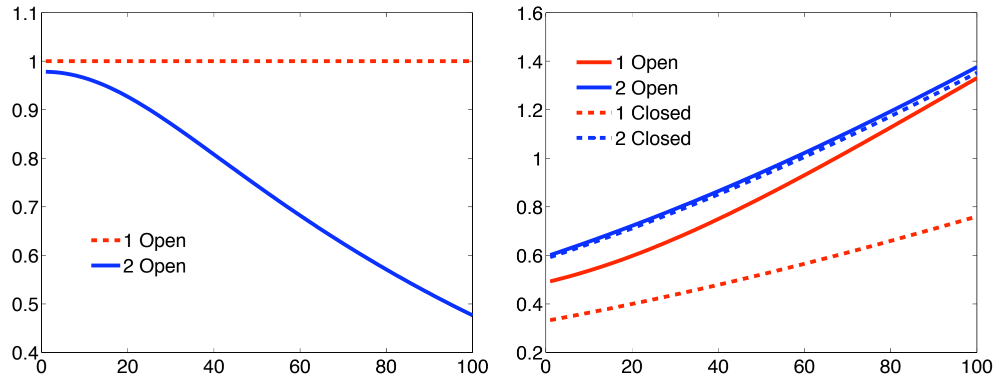


(a) Country 1 (b) Country 2

Finally, Figure 6 addresses welfare implications. Panel (a) plots wages, where country 1's wage is the numeraire. Country 1's wage relative to country 2's rises over time. To understand this, it is useful to note that, owing to symmetry in the parameters, if the two countries were the same size, the relative wage would be constant. When each country's comparative advantage sector experiences increasing comparative advantage over time, they produce more of the same good (*intensive margin*) and more goods (*extensive margin*). The rise in the intensive margin tends to lower the wage more than the rise in the extensive margin. Because country 2 initially produces almost all the goods owing to its size, its intensive margin increases faster than the extensive margin. By contrast, the extensive margin rises faster than the intensive margin in country 1. This explains why country 1's relative wage rises over time.

Panel (b) illustrates the welfare effects over time. Welfare is measured as the wage rate

Figure 6: Wages, Prices, and Welfare



(a) Wages (b) Welfare

divided by the overall price level. The two dashed lines illustrate the closed economy case. They grow at the same rate. This is a result of the symmetry between the two countries between agriculture and manufacturing. The two solid lines illustrate the open economy case. Note that opening up to trade provides a large boost to country 1, because it now has access to country 2's goods. By contrast, country 2 does not receive as much of a boost, owing to country 1's small size, and hence, fewer opportunities for importing inexpensive goods. Over time, country 1 narrows the welfare "gap" with country 2 by about 0.2 percent per year.

5.3 Dynamics with Declining Trade Costs

We now present an alternative way of generating structural change: declining trade barriers. To highlight the effect of changing trade costs on structural change, we eliminate sector-biased TFP growth. Specifically, we assume that both countries have identical and constant productivities growth across sectors and over time, i.e., $\hat{A}_{iqt} = g_a$ for all $i \in \{1, 2\}$, $q \in \{a, m, s\}$ and t. Initially, $A_{1m0} = A_{2a0} > A_{2m0} = A_{1a0}$, which implies that country 1 would have a comparative advantage in manufacturing in the absence of trade costs. To focus on the trade effect, we study the Cobb-Douglas case, i.e., the elasticity of substitution across sectors is one, which eliminates the expenditure effect. We also assume $\omega_a = \omega_m$, and both countries have identical and constant labor over time: $L_{it} = L$. Trade costs in each sector are identical across the countries. Moreover, the net trade cost of both sectors, $\tau_{qt} - 1$, declines at a constant rate of $\hat{\tau}$, which implies that $\hat{\tau}_{qt} = \frac{\tau_{qt}-1}{\tau_{qt}}\hat{\tau}$. Thus, as the net trade cost approaches zero over time, $\hat{\tau}_{qt}$ also approaches zero.

Because the trade effect is the only source of structural change dynamics, we need only derive country 1's manufacturing net export share over time. Given the symmetry across the two countries, the equilibrium relative wage rate $w_t = \frac{w_{1t}}{w_{2t}}$ is one in every period t. Thus, country 1's manufacturing net export share is $N_{1mt} = \omega_m(\pi_{21mt} - \pi_{12mt})$, where $\pi_{21mt} = [1 + (\frac{A_{1mt}}{A_{2mt}\tau_{mt}})^{-\theta}]^{-1}$ and $\pi_{12mt} = [1 + (\frac{A_{2mt}}{A_{1mt}\tau_{mt}})^{-\theta}]^{-1}$. Since $A_{1mt} > A_{2mt}$, it must be the case that $\pi_{21mt} > \pi_{12mt}$ and $N_{1mt} > 0$. The dynamics of N_{1mt} is given by

$$\hat{N}_{1mt} = \frac{\theta[\pi_{12mt}(1 - \pi_{12mt}) - \pi_{21mt}(1 - \pi_{21mt})]\hat{\tau}_{mt}}{\pi_{21mt} - \pi_{12mt}}.$$

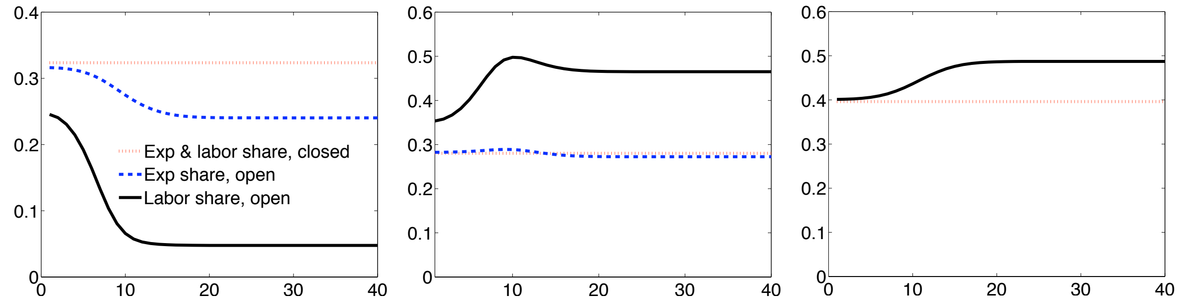
The necessary and sufficient condition for $\hat{N}_{1mt} > 0$ given $\hat{\tau}_{mt} < 0$ is $A_{1mt} > A_{2mt}$. Thus, country 1's manufacturing labor share and net export share rise as trade costs decline. When $\hat{\tau}_{mt}$ approaches zero over time, both $\hat{N}_{1mt}$ and $\hat{l}_{1mt}$ approach zero.

To further illustrate the impact of changing trade costs on dynamics of structural change, we present a numerical example with more general assumptions on the preferences and labor supply. The parameter values, except the productivities, are the same as the ones in Table 2. In particular, we continue to employ the Baumol elasticity. Initially $A_{1a0} = 1.5$, $A_{1m0} = 2.0$, $A_{2a0} = 2.0(\frac{L_{20}}{L_{10}})^{\frac{1}{\theta}}$, $A_{2m0} = 1.5(\frac{L_{20}}{L_{10}})^{\frac{1}{\theta}}$ and $A_{1s0} = A_{2s0} = 1.0$. The productivities remain constant over time in all sectors and all countries. The trade cost declines from 2.5 at a rate of 3% per period in both sectors and countries.

We present the dynamics of structural change of country 1 in Figure 7. The closed economy sectoral labor shares are shown in dotted red lines. Clearly, there is no structural change in the closed economy. The open economy sectoral expenditure shares and labor shares are shown in dashed blue lines and solid black lines, respectively. Panel (a) shows that the agriculture expenditure share declines rapidly in the open economy. Declining trade costs allow this sector, which is country 1's comparative disadvantage sector, to import more inexpensive goods from abroad. The relative price of the agriculture composite good falls rapidly, leading to the rapid decline in the expenditure share. The increased reliance on inexpensive imports also shows up as an agriculture labor share that declines even faster than the agriculture expenditure share. Again, the gap between the labor share and the expenditure share represents agriculture net exports as a share of total GDP.

Panel (b) shows that country 1's manufacturing labor share first rises and then declines in the open economy. Because the manufacturing expenditure share changes little over time, most of the labor share dynamics is from the trade effect. As trade costs decline, both countries increase their import and export shares in each sector. This contributes to increased manufacturing labor in country 1. If the labor endowments were the same across countries, the relative wage would be constant at one over time. But, because country 1 is smaller, under a constant relative wage, the increase in its total exports would exceed

Figure 7: Impact of Changing Trade Costs in Country 1



(a) Agriculture (b) Manufacturing (c) Services

the increase in its total imports. Thus, the balanced trade condition implies that the relative wage rate $w_t = \frac{w_{1t}}{w_{2t}}$ must rise over time. In other words, the purchasing power of country 2, in terms of country 1 labor, falls over time. All else equal, this would imply less country 1 labor needed to satisfy manufacturing demand from country 2. Initially, the rise in the net manufacturing exports dominates the country-size effect, and the manufacturing net export share of GDP and the manufacturing labor share rises. As the trade effect diminishes, the country-size effect becomes more important, and eventually dominates the rise in net manufacturing exports. Hence, the manufacturing net export share of GDP and the manufacturing labor share begin to decline.

Country 2's structural change in the tradable sectors is the opposite of those in country 1, qualitatively. The quantitative impact of declining trade costs on country 2 is much smaller owing to its large size. In both countries, the services labor share rises over time and converges to the level attained when trade is frictionless.

6 Extensions

We now relax each of two key assumptions in our model: homothetic preferences and no intermediate goods. We show that our main results continue to hold.

6.1 Non-homothetic Preferences

The most common way that structural change has been modeled in the past is by using preferences that capture Engel's law, the fact that the food share of consumption diminishes as a country develops. In other words, the income elasticity of demand for food is less than one, and for at least one other sector, it is greater than one. The following non-homothetic preference specification encompasses Engel's law:

$$U(C_{iat}, C_{imt}, C_{ist}) = \omega_a \log(C_{iat} - L_{it}\bar{c}_a) + \omega_m \log(C_{imt} - L_{it}\bar{c}_m) + \omega_s \log(C_{ist} - L_{it}\bar{c}_s). \quad (30)$$

If $\bar{c}_q > 0$, we interpret $\bar{c}_q$ as a per-capita subsistence requirement for sector q goods. This will generate an income elasticity of demand less than one. If, on the other hand, $\bar{c}_q < 0$, then the income elasticity of demand for the sector q good is larger than one.

We maintain the CES functional form for aggregating individual goods into the composite sectoral goods; the expressions for the prices of these composite goods are the same as before.[26] The consumption expenditure share for sector $q = \{a, m, s\}$ is given by

$$X_{iqt} = \omega_q + \frac{P_{iqt}\bar{c}_q}{w_{it}} - \omega_q \frac{\bar{c}_a P_{iat} + \bar{c}_m P_{imt} + \bar{c}_s P_{ist}}{w_{it}}. \quad (31)$$

In the closed economy, the labor shares equal the expenditure shares. Given the relationship between prices and productivities, we have

$$l_{iqt} = X_{iqt} = \omega_q + \frac{\bar{c}_q}{A_{iqt}} - \omega_q\left(\frac{\bar{c}_a}{A_{iat}} + \frac{\bar{c}_m}{A_{imt}} + \frac{\bar{c}_s}{A_{ist}}\right). \quad (32)$$

For much of the analysis below, we will take $\bar{c}_a > 0$, $\bar{c}_m = 0$, and $\bar{c}_s < 0$. This formulation is similar to that in Kongsamut, Rebelo, and Xie (2001). Thus, because $\bar{c}_a > 0$ and $\bar{c}_s < 0$, the agriculture labor share is greater than ω_a, but decreases as productivities rise and countries get richer. The services labor share is always lower than ω_s, and increases as productivities rise and countries get richer. The manufacturing labor share is ambiguous and depends on the relative magnitude of $\frac{\bar{c}_a}{A_{iat}}$ and $\frac{\bar{c}_s}{A_{ist}}$. When countries become sufficiently rich, all labor shares converge to the appropriate ω_q. Thus, non-homothetic preferences produce structural change in the closed economy, even when the elasticity of substitution across sectors is one.

We now turn to the open economy. As mentioned above, the expressions for prices of the composite sectoral goods are the same as before. Moreover, the effect of the open economy on these prices is the same, e.g., the agriculture and manufacturing prices relative to the wage rate are lower compared to autarky. Then, from (31), we can see that expenditures on agriculture are lower, and the manufacturing and services expenditure shares are higher, in the open economy than in the closed economy. Finally, the expression for labor shares is still given by equation (25). Thus, trade still affects labor allocations through an expenditure channel and a net export channel.

[26] However, the price index for the aggregate consumption good will be different from (15).

Now consider the dynamics of labor allocations in the open economy under free trade. Assume that country 1 has a comparative advantage in manufacturing. An increase in the extent of its comparative advantage in period t will lead to a higher π_{21mt}, and a lower π_{21at}, as before. These changes tend to increase manufacturing net exports and agricultural net imports, which then tends to increase the manufacturing labor share and decrease the agriculture labor share.

Specifically, consider a case in which the only variable that changes between periods $t-1$ and t is $A_{1mt} > A_{1mt-1}$. We show in Appendix B3 that the relative wage w_{1t}/w_{2t} must rise to preserve trade balance. As a result, in period t, the expenditure share of agriculture declines, while that of manufacturing rises in country 1, and the opposite happens in country 2. Thus, the expenditure effect on the manufacturing labor share is positive in country 1. Turning to the trade effect, we can show that an increase in country 1's comparative advantage still leads to an increase in N_{imt} if the underlying productivities, parameters and labor supplies are such that $\pi_{12at-1} < \theta\pi_{21at-1}$ holds in period $t-1$.[27] Thus, while non-homothetic preferences are an additional channel for structural change, a hump pattern in the manufacturing labor share is still possible.

6.2 Intermediate goods

To introduce intermediate goods in a tractable way, we assume that each sector's output is produced from labor and intermediates, and the sector's output is either consumed or used as an intermediate to produce that sector's goods. The production function for services is given by:

$$Y_{ist} = \psi A_{ist} L_{ist}^{\alpha} M_{ist}^{1-\alpha}, \tag{33}$$

where $\psi = \alpha^{-\alpha}(1-\alpha)^{\alpha-1}$. Output Y_{ist} is used for consumption or as an intermediate to produce services. The services market equilibrium condition is:

$$Y_{ist} = C_{ist} + M_{ist}, \tag{34}$$

In each tradable sector, there is a composite intermediate good that has the same functional form as the composite final good:

$$M_{iqt} = \left(\int_0^1 m_{iqt}(z)^{\eta} dz\right)^{1/\eta}, \tag{35}$$

[27]For details see Appendix B3.

The production function for good z in sector q is:

$$y_{iqt}(z) = \psi A_{iqt}(z) l_{iqt}(z)^{\alpha} M_{iqt}(z)^{1-\alpha}, \tag{36}$$

where $M_{iqt}(z)$ is the use of the composite intermediate good M_{iqt} to make good z. The goods market equilibrium conditions for any $z \in [0,1]$ is given by:

$$y_{1qt}(z) + y_{2qt}(z) = d_{1qt}(z)\left(c_{1qt}(z) + m_{1qt}(z)\right) + d_{2qt}(z)\left(c_{2qt}(z) + m_{2qt}(z)\right). \tag{37}$$

The prices of the sectoral goods in country i are given by: $P_{ist} = w_{it}/A_{ist}^{\frac{1}{\alpha}}$ and

$$P_{iqt} = \left[\left(\frac{w_{it}^{\alpha}}{A_{iqt}}\right)^{-\theta} + \left(\frac{\tau_{ijqt} w_{jt}^{\alpha}}{A_{jqt}}\right)^{-\theta}\right]^{-\frac{1}{\alpha\theta}}. \tag{38}$$

The share of country i's expenditure on sector q goods from country j, π_{ijqt}, is given by

$$\pi_{ijqt} = \frac{(\tau_{ijqt} w_{jt}^{\alpha}/A_{jqt})^{-\theta}}{(\tau_{ijqt} w_{jt}^{\alpha}/A_{jqt})^{-\theta} + (w_{it}^{\alpha}/A_{iqt})^{-\theta}}. \tag{39}$$

We now turn to the labor allocations. It is easy to show that the labor share in services is the same as in the benchmark model: $l_{ist} = X_{ist}$. The equilibrium condition for the manufacturing sector in country 1 implies that $w_{1t}L_{1mt} = \alpha(\pi_{11mt}P_{1mt}(C_{1mt} + M_{1mt}) + \pi_{21mt}P_{2mt}(C_{2mt} + M_{2mt}))$. Simplifying yields the same expression for the labor share as in the benchmark model:

$$l_{1mt} = L_{1mt}/L_{1t} = \pi_{11mt}X_{1mt} + \pi_{21mt}X_{2mt}w_{2t}L_{2t}/(w_{1t}L_{1t}). \tag{40}$$

With identical expressions for labor shares, introducing intermediate goods does not change our results from before. This is because, while intermediate goods leads to a distinction between gross output and value-added, the share of consumption spending in total output equals the share of value-added in gross output.

7 Conclusion

International trade provides a channel by which sectoral output can exceed sectoral expenditure or vice versa. In a neoclassical trading environment, comparative advantage interacts with global sectoral demand to determine patterns of expenditure, trade, production, and employment. We develop a model highlighting these themes to study the effects of an open economy on structural change. Our model draws from the closed economy structural change models based on biased sectoral productivity growth; these models naturally extend to a dynamic Ricardian trade model in an open economy.

Under an elasticity of substitution equal to or less than one, we show that there are two forces through which a country with a comparative advantage in manufacturing can experience a "hump" in manufacturing employment. First, if manufacturing's productivity growth is sufficiently high, then the gains to employment from running an increasingly large net export surplus in manufacturing can temporarily be larger than the losses to employment owing to declining expenditure shares. These gains to employment will diminish over time, however, owing to country-size effects or increasingly complete specialization. Eventually, the "expenditure" effect will dominate the "trade" effect, and employment in manufacturing will decline. Second, if trade barriers in manufacturing decline sufficiently rapidly, then, again, manufacturing employment will rise. However, once free trade is reached or when trade costs stop declining, the expenditure effect will dominate the now non-existent trade effect. Finally, we show that the main results of our model hold up in the presence of non-homothetic preferences and intermediate goods.

Matsuyama (2008) states that "the central question [on structural change in an interdependent world] is whether structural change in one country will slow down or speed up structural change in other countries." Our framework addresses this question. We focused on a scenario in which a small emerging market economy with a comparative advantage in manufacturing experiences relatively high productivity growth in that sector, in which a large advanced economy with a comparative advantage in non-manufacturing experiences relatively high productivity growth in that sector. We show that in the advanced economy, the manufacturing sector will decline at a faster rate, and the services sector will grow at a faster rate, in an open economy relative to the closed economy. Our framework can be applied to other scenarios, as well.

It is important to quantitatively assess the importance of international trade in the structural change experiences of emerging market countries, as well as of advanced countries.[28]. Buera and Kaboski (2009) demonstrate that neither of the two core closed economy models of structural change — those that emphasize Stone-Geary preferences and those that emphasize biased sectoral productivity growth — can quantitatively explain the recent experience of the United States. We are currently pursuing research to assess the extent to which trade can explain the gap between the data and the closed economy models.

[28]Stefanski (2009), Ungor (2009), and Teignier-Bacque (2009) are examples of recent research along these lines

Appendix

A.1 Data Sources and Variable Construction for Figure 2

Manufacturing employment share: This variable is constructed primarily from two data sources, the GGDC 10-sector database (Timmers and de Vries, 2007), and the OECD ALFS, rev. 2, database. The data for Hong Kong is supplemented by data from the 1971 Hong Kong Census. Some of the OECD data required interpolations, as well as imputations using ALFS rev. 3, as well as the OECD STAN database. For Portugal, STAN was the primary source. Exact calculations are available from the authors on request.

Manufacturing net exports share of total GDP: Manufacturing exports and imports data for all countries except Taiwan are downloaded from the United Nations COMTRADE database. We use SITC rev. 1 because this allows us to examine data from 1962 forward. For some countries and time periods, there are gaps in the SITC rev. 1 data; we then use SITC rev. 2 COMTRADE data.[29] Data for Belgium was combined with Luxembourg prior to 1999. For years after 1999, we add the two countries' trade data for consistency. West Germany data was used for 1962-1990, and Germany afterwards. For Taiwan, we use the NBER-UN World Trade data set for 1962-2000, and sourceOECD for 2001-2005. Details on how these data are concorded and spliced are available from the authors on request.

Manufacturing is defined in a way to ensure compatibility with the definition in the GGDC 10-sector database. The SITC rev. 1 codes for manufacturing are: 012, 013, 022, 032, 046, 047, 048, 053, 055, 061, 062, 081, 091, 099, 1, 251, 26, 332, 4, 5, 6, 7, 8.

GDP in U.S. dollars was drawn from the IMF's International Financial Statistics (IFS) (August 2008 CD). GDP in national currency was converted to U.S. dollars using period average exchange rates (Data downloaded from August 2008 IFS). For Venezuela, end of period exchange rate were used for 1960-1963. Data for Taiwan GDP is from http://61.60.106.82/pxweb/Dialog/statfile1L.asp. These data are available for all years in which manufacturing employment and net export data were available.

Countries and years covered (1962-2005, unless otherwise noted): Australia (1966-2005), Austria (1969-2005), Belgium, Canada (1970-2005), Denmark (1969-2005), Finland (1970-2005), France, Germany, Iceland (1964-2005), Italy (1970-2005), Netherlands (1970-2005), New Zealand (1964-2005), Norway, Portugal (1970-2005), Spain, Sweden (1963-2005), Switzerland, United Kingdom (1963-2005), United States, Hong Kong, Indonesia (1971-2005), India (1975-2004), Japan (1962-2003), Singapore (1970-2005), South Korea

[29] We used the concordance tables in http://cid.econ.ucdavis.edu/usixd/wp5515d.html.

(1963-2005), Peru, Philippines (1971-2005), Thailand, Taiwan (1963-2005), Venezuela, Bolivia (1962-2003), Brazil, Chile, Colombia, Costa Rica (1965-2005), Mexico, Malaysia (1975-2005), Argentina. Changes over the entire period were computed and plotted in Figure 2.

A.2 Data Sources and Variable Construction for Table 1

Trade Openness: Trade openness is equal to total exports + total imports divided by GDP, with all variables in U.S. dollars. Total imports equal total primary imports plus total manufacturing imports, and similarly for total exports. The data sources are the same as those listed above for manufacturing net exports. Primaries and manufacturing are defined in a way to ensure compatibility with the definitions of primaries and manufacturing in the GGDC database. The SITC rev. 1 codes for primaries are: 00, 011, 023, 024, 025, 031, 041, 042, 043, 044, 045, 051, 052, 054, 07, 2, 32, 331, 34, 35, MINUS 251, MINUS 26. The SITC rev. 1 codes for manufacturing are same as in A.1 above.

Countries and years covered (1962-2005, unless otherwise noted): Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rice (1965-2005), Hong Kong, India (1975-2005), Indonesia (1967-2005), Japan, Malaysia (1964-2005), Mexico, Peru, Philippines, South Korea, Singapore, Thailand (1962-2005, except 1988), Venezuela, Australia (1963-2005), Austria (1963-2005), Belgium-Luxembourg, Canada, Denmark, Finland (1963-2005), France, Germany, Iceland, Italy, Netherlands, New Zealand (1964-2005), Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States.

The data sources for GDP are the same as those listed above for manufacturing net exports share of GDP. These data are available for all years in which trade data was available.

Services Labor Share: The data sources are the same as those listed above for the manufacturing employment share. Countries and years covered (1960-2005, unless otherwise noted): Argentina, Bolivia (1960-2003), Brazil, Chile, Colombia, Costa Rica, Hong Kong, Indonesia (1961, 1971-2005), India (1960-2004), Japan, South Korea (1963-2005), Mexico, Malaysia (1975-2005), Peru, Philippines (1971-2005), Singapore (1970-2005), Thailand, Taiwan (1963-2005), Venezuela, Australia (1966-2005), Austria (1969-2005), Belgium, Canada, Denmark (1960, 1965, 1967, 1969-2005), Finland, France, Germany, Iceland (1964-2005), Italy (1970-2005), Netherlands (1970-2005), New Zealand, Norway, Portugal (1970-2005), Spain, Sweden (1963-2005), Switzerland, United Kingdom (1963-2005), United States.

Income per capita: Our income per capita variable is chained GDP per capita, PPP in constant 2005 international dollars from the Penn World Tables 6.3, RGDPCH series.

The data run from 1960-2005. Note: data for Belgium is for Belgium only. The following data is missing: Germany (1960-1969).

Four-year non-overlapping averages (except for 1960-1965) are created for each of the 3 variables. The periods are: 1960 (or earliest starting year)-1965, 1966-1969, ..., 2002-2005. Some 4-year periods contained less than four years of data. All periods with less than two years were excluded in the regression reported in the table. (As a sensitivity analysis, we ran another regression that excluded the 17 country-period observations for which the 4-year period contained less than four years of data. The estimation results were similar. For example, the coefficient on trade openness was 0.0738 compared to 0.0805 in the benchmark regression.)

B Proofs

B.1 *Assume that the elasticity of substitution across sectors is one. If country 1 has a comparative advantage in manufacturing and country 2 has a comparative advantage in agriculture, then country 1 has a trade surplus in manufacturing.*

Proof: In tradable sector q of country 1, the exports are $\pi_{21qt}X_{2qt}w_{2t}L_{2t}$, and the imports are $\pi_{12qt}X_{1qt}w_{1t}L_{1t}$. Under a unit elasticity of substitution, two countries have identical sectoral expenditure shares: $X_{1qt} = X_{2qt} = \omega_q$. We can write the net exports of country 1 in sector q as

$$NX_{1qt} = \omega_q \left(\pi_{21qt} w_{2t} L_{2t} - \pi_{12qt} w_{1t} L_{1t} \right),$$

where $\pi_{12qt} = \left[1 + \left(\frac{w_{1t}A_{2qt}}{w_{2t}\tau_{12qt}A_{1qt}} \right)^{-\theta} \right]^{-1}$ and $\pi_{21qt} = \left[1 + \left(\frac{w_{1t}\tau_{21qt}A_{2qt}}{w_{2t}A_{1qt}} \right)^{\theta} \right]^{-1}$. It is clear to see that π_{21qt} monotonically decreases with the relative wage rate $w_t = \frac{w_{1t}}{w_{2t}}$, while π_{12qt} monotonically increases with w_t. Consequently, the net exports of each tradable sector decreases with w_t. Thus, there exists a unique critical relative wage rate $\bar{w}_{qt}$ that would equate exports and imports of sector-q in country 1. Moreover, if and only if the equilibrium wage rate is below the critical $\bar{w}_{qt}$, country 1 will run a trade surplus.

Setting imports equal to exports and substituting in the expressions for π_{12qt} and π_{21qt}, we derive the following two equations, the solution to which characterize the critical relative wage rates:

$$w_t = \frac{1 + w_t^{-\theta} \left(\frac{A_{2mt}}{\tau_{12mt}A_{1mt}} \right)^{-\theta}}{1 + w_t^{\theta} \left(\frac{A_{1mt}}{\tau_{21mt}A_{2mt}} \right)^{-\theta}} \frac{L_{2t}}{L_{1t}} = g_m(w_t),$$

and

$$w_t = \frac{1 + w_t^{-\theta} \left(\frac{A_{2at}}{\tau_{12at}A_{1at}} \right)^{-\theta}}{1 + w_t^{\theta} \left(\frac{A_{1at}}{\tau_{21at}A_{2at}} \right)^{-\theta}} \frac{L_{2t}}{L_{1t}} = g_a(w_t).$$

Both functions g_a and g_m are monotonically decreasing in w_t. The assumptions of the pattern of comparative advantage imply that $\frac{A_{1mt}}{\tau_{21mt}A_{2mt}} > \frac{A_{1at}}{\tau_{21at}A_{2at}}$ and $\frac{A_{2mt}}{\tau_{12mt}A_{1mt}} < \frac{A_{2at}}{\tau_{12at}A_{1at}}$. Thus, for any relative wage rate w_t, $g_a(\cdot) < g_m(\cdot)$. Then it must be the case that $\bar{w}_{mt} > \bar{w}_{at}$. Under the balanced trade, the equilibrium wage rate must fall between $\bar{w}_{mt}$ and $\bar{w}_{at}$. Consequently, country 1 has a trade surplus in manufacturing since $w_t > \bar{w}_{mt}$. *Q.E.D.*

B.2 *Consider the free-trade case where the elasticity of substitution is one. Assume that the labor supply is constant in period t and $t+1$ in both countries and $A_{mt} > A_{at}$. Then country 1's manufacturing net export ratio rises in period $t+1$, i.e., $\hat{N}_{1mt} > 0$, if the following condition holds:*

$$\hat{A}_{mt} > \hat{A}_{at}\frac{L_{2t}\pi_{12at} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}{L_{2t}\pi_{12mt} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}},$$

where $w_t = \frac{w_{1t}}{w_{2t}}$ and $A_{qt} = \frac{A_{1qt}}{A_{2qt}}$ *for* $q \in \{a, m\}$.

Proof: The equilibrium wage ratio w_t is given by the balanced-trade condition:

$$[\omega_m \pi_{21mt} + \omega_a \pi_{21at}]\,\frac{w_t L_{1t} + L_{2t}}{w_t L_{1t}} = \omega_a + \omega_m.$$

Totally differentiating the above condition, we have

$$\frac{\omega_m \pi_{21mt}\hat{\pi}_{21mt} + \omega_a \pi_{21at}\hat{\pi}_{21at}}{\omega_m \pi_{21mt} + \omega_a \pi_{21at}} - \frac{L_{2t}}{w_t L_{1t} + L_{2t}}\hat{w}_t = 0,$$

where $\hat{\pi}_{21mt} = \theta\pi_{12mt}(\hat{A}_{mt} - \hat{w}_t)$ and $\hat{\pi}_{21at} = \theta\pi_{12at}(\hat{A}_{at} - \hat{w}_t)$. Thus, we solve for $\hat{w}_t$ as

$$\hat{w}_t = \frac{\psi_{mt}\hat{A}_{mt} + \psi_{at}\hat{A}_{at}}{\psi_{lt} + \psi_{mt} + \psi_{at}},$$

where $\psi_{lt} = \frac{L_{2t}}{w_t L_{1t} + L_{2t}}$, $\psi_{mt} = \frac{\theta\omega_m\pi_{12mt}\pi_{21mt}}{\omega_m\pi_{21mt} + \omega_a\pi_{21at}}$, and $\psi_{at} = \frac{\theta\omega_a\pi_{12at}\pi_{21at}}{\omega_m\pi_{21mt} + \omega_a\pi_{21at}}$. Clearly, the wage rate responds less than proportionately to changes in relative productivity of each sector. The same is true when both relative productivities grow at the same rate.

The manufacturing labor share in country 1 is given by $l_{1mt} = \omega_m\pi_{21mt}\left[\frac{w_t L_{1t} + L_{2t}}{w_t L_{1t}}\right]$. Again totally differentiating, we have

$$\hat{l}_{1mt} = -\frac{L_{2t}}{w_t L_{1t} + L_{2t}}\hat{w}_t + \hat{\pi}_{21mt} = -\left[\frac{L_{2t}}{w_t L_{1t} + L_{2t}} + \theta\pi_{12mt}\right]\hat{w}_t + \theta\pi_{12mt}\hat{A}_{mt}.$$

We then plug in the equation for $\hat{w}_t$ and simplify. The condition needed to have $\hat{l}_{1mt} > 0$

is as follows:

$$\hat{A}_{mt} > \hat{A}_{at}\frac{L_{2t}\pi_{12at} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}{L_{2t}\pi_{12mt} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}. \qquad Q.E.D.$$

B.3 *Consider the case with free trade and non-homothetic preferences: $\bar{c}_a > 0$, $\bar{c}_m = 0$ and $\bar{c}_s < 0$. Assume that the underlying productivities, parameters and labor supplies are such that $\pi_{12at-1} < \theta\pi_{21at-1}$, $N_{1at-1} < 0$ and $N_{1mt-1} > 0$ in period $t-1$. If the productivities and labor stocks remain constant in period t except $A_{1mt} > A_{1mt-1}$, then $\hat{N}_{1mt-1} > 0$.*

Proof: We normalize w_{1t} to be one in each period. Under free trade, we have $P_{1qt} = P_{2qt}$ for each tradable sector q. As A_{1mt} rises from A_{1mt-1} while the other underlying parameters remain unchanged, the wage rate w_{2t} must be lower than w_{2t-1} to balance the trade in period t, i.e., $\hat{w}_{2t} < 0$. Otherwise, in net country 1 will export more manufacturing goods in period t than period $t-1$ but export the same amount of agriculture goods in both periods, which leads to a trade surplus in period t. As a result, P_{1at} and P_{2at} decline from their period-t levels, i.e., $\hat{P}_{2at} = \hat{P}_{1at} < 0$. In particular,

$$\hat{P}_{2at} = \pi_{12at}\hat{w}_{2t} > \hat{w}_{2t}.$$

Now consider the agricultural net exports in country 1: $NX_{1at} = EX_{1at} - IM_{1at}$, where $EX_{1at} = \pi_{21at}X_{2at}w_{2t}L_{2t}$ and $IM_{1at} = \pi_{12at}X_{1at}w_{1t}L_{1t}$. As w_{2t} declines, π_{21at} declines and π_{12at} rises since country 2 lowers its marginal cost of agriculture production relative to country 1. Also, X_{1at} declines and X_{2at} rises according to the expenditure shares in equation (31). Let's first look at $\hat{X}_{2at}$, which is given by

$$\hat{X}_{2at} = \xi_2(\hat{P}_{2at} - \hat{w}_{2t}) = -\xi_2\pi_{21at-1}\hat{w}_{2t} > 0,$$

where $\xi_2 = \frac{P_{2at-1}\bar{c}_a(1-\omega_a)}{w_{2t-1}X_{2at-1}} \in (0,1)$. This implies that $\hat{X}_{2at} + \hat{w}_{2t} = \hat{w}_{2t}(1 - \xi_2\pi_{21at-1}) < 0$. Thus, $\hat{EX}_{1at} = \hat{\pi}_{21at} + \hat{X}_{2at} + \hat{w}_{2t} < 0$. We next study $\hat{X}_{1at}$, which is given by

$$\hat{X}_{1at} = \xi_1\hat{P}_{1at} = \xi_1\pi_{12at-1}\hat{w}_{2t} < 0,$$

where $\xi_1 = \frac{P_{1at-1}\bar{c}_a(1-\omega_a)}{w_{1t-1}X_{1at-1}} \in (0,1)$. Also we have $\hat{\pi}_{12at} = -\pi_{21at-1}\theta\hat{w}_{2t} > 0$. Under the assumption that $\pi_{12at-1} < \theta\pi_{21at-1}$, we have $\hat{IM}_{1at} = \hat{X}_{1at} + \hat{\pi}_{12at} > 0$. Since the agricultural exports decline while the agriculture imports rise, the agriculture trade deficit rises, which implies that the manufacturing trade surplus rises, i.e., $\hat{N}_{1mt} > 0$.

References

[1] Acemoglu, Daron, and Veronica Guerrieri. 2008. "Capital Deepening and Nonbalanced Economic Growth." *Journal of Political Economy*, 116, 467-498.

[2] Alvarez, Fernando, and Robert E. Lucas, Jr. 2007. "General Equilibrium Analysis of the Eaton-Kortum Model of International Trade." *Journal of Monetary Economics*, 54, 1726-1768.

[3] Baumol, William J. 1967. "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis." *American Economic Review*, 57 (3), 415-426.

[4] Buera, Francisco J. and Joseph P. Kaboski. 2009. "Can Traditional Theories of Structural Change Fit the Data?" *Journal of the European Economic Association*, 7, 469-477.

[5] Buera, Francisco J. and Joseph P. Kaboski. 2008. "Scale and the Origins of Structural Change" Manuscript, UCLA and Ohio State University.

[6] Caselli, Francesco and Wilbur John Coleman II. 2001. "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation." *Journal of Political Economy*, 109, 584-616.

[7] Chenery, Hollis and Moises Syrquin. 1975. *Patterns of Development, 1950-1970*, London: Oxford University Press.

[8] Clark, Colin. 1957. *The Conditions of Economic Progress, 3rd edition*, London: MacMillan and Company.

[9] Coleman, Wilbur John II. 2007. "Accommodating Emerging Giants" Manuscript, Duke University.

[10] Deardorff, Alan V. 2004. "Local Comparative Advantage: Trade Costs and the Pattern of Trade." Discussion Paper No. 500, University of Michigan.

[11] Desmet, Klaus and Esteban Rossi-Hansberg. 2009. "Spatial Development" Manuscript, Universidad Carlos III and Princeton University.

[12] Duarte, Margarida and Diego Restuccia. 2009. "The Role of the Structural Transformation in Aggregate Productivity" forthcoming, *Quarterly Journal of Economics.*

[13] Eaton, Jonathan, and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica*, 70, 1741-1779.

[14] Feenstra, Robert C., Robert E. Lipsey, Haiyan Deng, Alyson C. Ma, and Hengyong Mo. 2004. "World Trade Flows: 1962-2000" NBER Working Paper 11040.

[15] Foellmi, Reto, and Josef Zweimuller. 2008. "Structural Change, Engel's Consumption Cycles, and Kaldor's Facts of Economic Growth" *Journal of Monetary Economics*, 55, 1317-1328.

[16] Galor, Oded, and Andrew Mountford. 2008. "Trading Population for Productivity: Theory and Evidence." *Review of Economic Studies*, 75, 1143-1179.

[17] Herrendorf, Berthold, Richard Rogerson, and Akos Valentinyi. 2009. "Two Perspectives on Preferences and Structural Transformation." NBER Working Paper 15416.

[18] Ju, Jiandong, Justin Yifu Lin, and Yong Wang. 2009. "Endowment Structures, Industrial Dynamics, and Economic Growth." Manuscript, IMF and University of Oklahoma.

[19] Kongsamut, Piyabha, Sergio Rebelo and Danyang Xie. 2001. "Beyond Balanced Growth." *Review of Economic Studies*, 68, 869-882.

[20] Kuznets, Simon. 1957. "Quantitative Aspects of the Economic Growth of Nations: II. Industrial Distribution of National Product and Labor Force" *Economic Development and Cultural Change* 5, Supplement, 1-111.

[21] Kuznets, Simon. 1966. *Modern Economic Growth: Rate, Structure, and Spread*, New Haven: Yale University Press.

[22] Kuznets, Simon. 1967. "Quantitative Aspects of the Economic Growth of Nations: X. Level and Structure of Foreign Trade: Long-Term Trends" *Economic Development and Cultural Change* 15 (2, Part 2), 1-140.

[23] Laitner, John. 2000. "Structural Change and Economic Growth." *Review of Economic Studies*, 67, 545-561.

[24] Maddison, Angus. 1991. *Dynamic Forces in Capitalist Development: A Long-Run Comparative View*, Oxford: Oxford University Press.

[25] Matsuyama, Kiminori. 2008. "Structural Change." *The New Palgrave Dictionary of Economics. Second Edition.* Eds. Steven N. Durlauf and Lawrence E. Blume. Palgrave Macmillan, 2008.

[26] Matsuyama, Kiminori. 2009. "Structural Change in an Interdependent World: A Global View of Manufacturing Decline." *Journal of the European Economic Association*, forthcoming.

[27] Matusyma, Kiminori. 1992. "Agricultural Productivity, Comparative Advantage and Economic Growth." *Journal of Economic Theory*, 58, 317-334.

[28] Ngai, L. Rachel, and Christopher A. Pissarides. 2007. "Structural Change in a Multi-sector Model of Growth." *American Economic Review*, 97, 429-443.

[29] Restuccia, Diego, Dennis Tao Yang, and Xiaodong Zhu. "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis." *Journal of Monetary Economics*, 55, 234-250.

[30] Rogerson, Richard. 2008. "Structural Transformation and the Deterioration of European Labor Market Outcomes." *Journal of Political Economy*, 116, 235-259.

[31] Stefanski, Radoslaw. 2009. "Structural Transformation and the Oil Price." Manuscript, University of Minnesota.

[32] Teignier-Bacque, Marc. 2009. "The Role of Trade in Structural Transformation." Manuscript, University of Chicago.

[33] Timmer, Marcel P. and Gaaitzen J. de Vries. 2007. "A Cross-Country Database for Sectoral Employment and Productivity in Asia and Latin America, 1950-2005." Groningen Growth and Development Centre Research Memorandum GD-98, Groningen: University of Groningen.

[34] Ungor, Murat. 2009. "De-industrialization of the Riches and the Rise of China." Manuscript, University of Southern California.

[35] Verma, Rubina. 2008. "Productivity Driven Services Led Growth." Manuscript, ITAM.