Structural Change in an Open Economy

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Abstract

We develop a tractable, three-sector model to study structural change in a two-country world. 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-shaped 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

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1 Introduction

Two of the most important developments affecting the world's economies in the past half-century have been globalization, particularly in international trade, and the emergence of a hump-shaped pattern in manufacturing employment shares for many upper-income countries. Employment shares in manufacturing were previously thought to be increasing monotonically, like services employment, as countries develop. But, we now know that for many countries, structural change — the evolution of sectoral employment and output shares over time — involves three distinct patterns: agriculture declines, services rise, and manufacturing follows a hump-shaped pattern.

Integration between developed and emerging market economies is often blamed for the decline in manufacturing in most developed countries. Moreover, some of the emerging market economies that joined the global trading system, such as South Korea and Taiwan, have themselves experienced a hump-shaped pattern in manufacturing employment. It is natural to wonder, then, if these two important developments are linked in some way. After all, the fundamental role of international trade is to facilitate specialization via an efficient reallocation of employment and other factors of production across sectors.

The purpose of this paper is to develop an open economy model of structural change, and to use it to understand the channels by which trade can affect structural change, particularly the hump-shaped pattern in the manufacturing employment share. To illustrate clearly these channels, we employ a simple and tractable framework building on Eaton and Kortum (2002). There are two countries and three sectors, two of which engage in international trade. Trade is motivated by Ricardian comparative advantage: relative productivity differences across countries and goods determine patterns of specialization. Each country runs a net export surplus in its sector of comparative advantage. We show that a sector's employment share equals the sum of the sector's expenditure share and the sector's net export share of total GDP — there is a direct link between trade and structural change.

Trade also affects relative prices, which affect sectoral expenditure and employment shares.

We then develop two scenarios in which the presence of trade can generate a hump-shaped pattern in the manufacturing employment share. For simplicity, consider a world in which there is no structural change in the absence of trade.[1] In the first scenario, the country with a comparative advantage in manufacturing — call it the "home" country — experiences both relative and absolute productivity growth in manufacturing over time. Because of the relative productivity growth, the home country's net export surplus in manufacturing increases, leading to a rise in manufacturing employment initially. As time passes, the home country will supply the entire world market for manufactured goods. After this point, the continuing increase in absolute manufacturing productivity growth enables the home country to supply world demand with fewer workers in each period. Hence, the initial increases in manufacturing employment is followed by an eventual decline.

In the second scenario, the primary driving force is declining trade costs over time. As trade costs 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 a comparative advantage in manufacturing (again, the "home" country). If the home country is small enough initially, over time its relative wage will increase, because the gains from specialization and trade are larger for smaller countries. The increase in home's relative wage reduces the relative purchasing power of the foreign country, which reduces the amount of home country labor needed to satisfy foreign demand for manufactured goods. As long as the home relative wage continues to increase, this relative purchasing power effect will eventually dominate the employment effects from the increasing net export surplus. Hence, the home manufacturing employment share will peak and then decline.

The above two scenarios seem plausible in which the "home" country is South Korea or Taiwan. What happens to manufacturing in the larger, foreign country? Relative to au-

[1]This would arise, for example, if the elasticity of substitution across sectors and the sectoral income elasticities of demand are all one.

tarky, the foreign country will experience a faster decline in its manufacturing employment share. The key reason is because an increasing share of its demand for manufactured goods is being supplied from abroad. Countries like the United States could plausibly fit into this category. Thus, our model can explain the recent manufacturing employment patterns in developed countries, as well as emerging market countries.

Most existing theoretical work on structural change has focused on closed economy models and relies on one of two broad mechanisms. The first mechanism, which has been the dominant one in the literature, operates on the demand side and draws from Engel's Law. Sectors differ in their income elasticities of demand; in particular, agriculture and food have an income elasticity that is less than one, while the other sectors, on net, have an income elasticity that exceeds one. A notable recent contribution in a three sector model is Kongsamut, Rebelo, and Xie (2001). The second mechanism operates more on the supply side and draws from the Baumol effect. Sectors differ in their productivity growth and elasticities of substitution between sectors are less than one. Then, employment shares fall in sectors with high productivity growth. Both mechanisms can generate the observed patterns of structural change in a closed economy setting, but both require special features in order to generate the hump-shaped pattern in manufacturing. For example, in Ngai and Pissarides (2007) manufacturing must have below average productivity growth initially and then above average productivity growth later.[2]

To highlight our transmission channels most clearly, our model employs the Baumol assumptions, as in Ngai and Pissarides (2007). A closed economy version of our model 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-shaped pattern, in emerging market nations for which manufacturing productivity growth is consistently above average. A framework allowing for international trade breaks the tight

[2]Ngai and Pissarides solve for the balanced growth equilibrium; average productivity growth changes over time, even though sectoral productivity growth is constant, owing to composition effects.

link between sectoral production and sectoral expenditure, which facilitates changes in the structure of production that are independent of changes in domestic demand. The presence of international trade transforms the process of structural change.

Until recently, the main contributions 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.[3] Matsuyama (2009) employs a simple Ricardian model to demonstrate that high manufacturing productivity growth need not lead to a decline in manufacturing employment. 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 addresses the conditions under which productivity growth and declining trade barriers can generate the hump-shaped pattern of manufacturing employment shares.

The rest of the paper is organized as follows. Section 2 shows some evidence to motivate studying structural change in an open economy. Section 3 presents the benchmark model, and Section 4 analyzes the autarky version of the model. Section 5 presents the main derivations and discusses the two scenarios that generate the hump-shaped pattern in the manufacturing labor share. Section 6 shows that our findings hold in the presence of non-homothetic preferences, intermediate goods, and capital goods. Section 7 concludes.

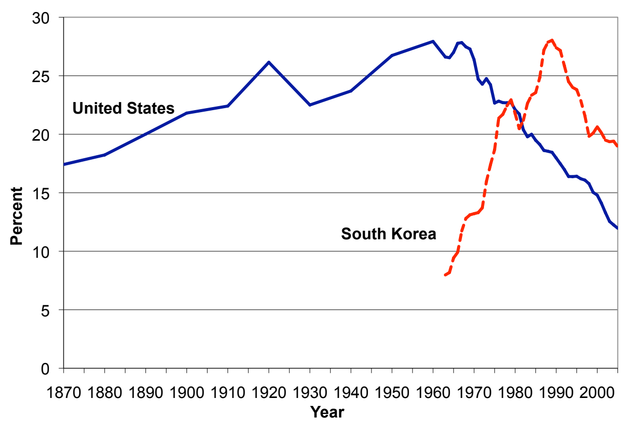
2 Motivating Evidence

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

[3]Echevarria (1995) is also an early contribution to open economy models of structural change. She employs a small open economy. Caselli and Coleman (2001) is effectively an open economy model with labor mobility and human capital. It argues that changes in the relative supply of factors of production are necessary to explain changes in both quantities and prices in the US structural change. However, its focus is on agriculture and non-agriculture; it does not highlight manufacturing. Other recent open economy models of structural change include Galor and Mountford (2008), Stefanski (2009), Teignier-Bacque (2009), Ungor (2009), and Betts, Giri, and Verma (2011). The latter four papers conduct quantitative studies involving structural change in China, India, and/or South Korea. Galor and Mountford (2008) study the effect of trade on fertility and population growth, and on human capital acquisition.

(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 these patterns, most models of structural change developed at that time were two sector models.[4] In more recent years, Maddison (1991), Buera and Kaboski (2008), and others have shown that there are three distinct sectoral allocation patterns: agriculture declines, services rises, and manufacturing follows a hump-shaped pattern, first rising, then falling, as Figure 1 shows for the United States and South Korea.[5] The hump-shaped pattern 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).[6]

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

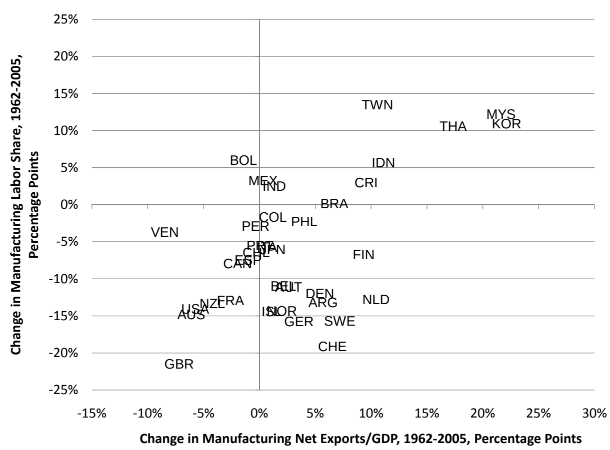
[4]The sectoral divisions were often agriculture and non-agriculture, agriculture and industry (manufacturing), or capital-intensive and labor-intensive. For recent examples of these divisions, see Caselli and Coleman (2001), Laitner (2000), and Acemoglu and Guerrieri (2008). Also, Desmet and Rossi-Hansberg (2009) develop and calibrate a spatial model of structural change in which geography influences the shift between services and manufacturing.

[5]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).

[6]Also, see Buera and Kaboski (2008, 2009), Duarte and Restuccia (2009), Echevarria (1997), 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.

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 South and Central America and East and South Asia; for each country, a fairly 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.[7] The correlation coefficient is 0.57.[8]

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, excluding Taiwan. 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

[7] We exclude Hong Kong and Singapore from the figure as they are essentially city-states and are outliers.

[8] All countries but Japan, South Korea and Taiwan are 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. The correlation in that case is 0.63.

about construction of the variables and the data sources are given in Appendix A2. We run the following regression:

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

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
Services labor share[a]	0.0801	1.23e-5	0.369	0.67	379
	(0.0289)	(1.12e-6)	(0.0251)		

[a]: Country fixed effects are included. 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. To highlight the role of trade in structural change clearly, 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 introduce intermediate goods or capital goods to production in Section 6.) Productivity and trade costs change at different rates across sectors and countries; these forces drive structural change. Trade is balanced each period. The model is thus static; we omit the time subscript unless needed.

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 is

$$Y_{is} = A_{is} L_{is}, \tag{1}$$

where Y_{is} and L_{is} denote output and labor devoted to services, and A_{is} 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 is

$$y_{iq}(z) = A_{iq}(z) l_{iq}(z), \tag{2}$$

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

Productivity $A_{iq}(z)$ is the realization of a random variable Z_{iq} drawn from the cumulative distribution function $F_{iq}(A) = Pr[Z_{iq} \leq A]$. Following Eaton and Kortum (2002), we assume that $F_{iq}(A)$ is a Fréchet distribution: $F_{iq}(A) = e^{-T_{iq}A^{-\theta}}$, where $T_{iq} > 0$, $\theta > 1$, and $q \in \{a, m\}$. The parameter T_{iq} governs the mean of the distribution; a larger T_{iq} 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_{iq}.[9] We assume that the productivity is drawn each period.[10]

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

3.2 Preferences

Period utility of the representative household in country i is given by:

$$U(C_{ia}, C_{im}, C_{is}) = \left(\omega_a C_{ia}^{\epsilon} + \omega_m C_{im}^{\epsilon} + \omega_s C_{is}^{\epsilon}\right)^{\frac{1}{\epsilon}}, \tag{3}$$

where C_{ia}, C_{im}, and C_{is} are consumption of the composite agriculture good, the composite manufacturing good, and the services good, respectively, $\epsilon < 1$, 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; the sectoral goods are substitutes. If $\epsilon < 0$, the elasticity of substitution is less than one; the sectoral goods are complements.

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

[10] 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.

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

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

where $c_{iq}(z)$ is the use of good z by country i to make the composite sectoral good $q \in \{a, m\}$, and $\eta < 1$.

The representative household maximizes his/her utility (3) and (4) subject to the following budget constraint in each period:

$$P_{ia}C_{ia} + P_{im}C_{im} + P_{is}C_{is} = w_i L_i, \tag{5}$$

$$P_{iq}C_{iq} = \int_0^1 p_{iq}(z) c_{iq}(z) dz, \quad \text{for } q \in \{a, m\}, \tag{6}$$

where w_i, P_{ia}, P_{im} and P_{is} denote the wage rate, and the prices of the agriculture composite good, the manufacturing composite good, and the services good, respectively, and $p_{iq}(z)$ denotes the price of good z in tradable good sector $q \in \{a, m\}$. The household supplies L_i inelastically and spends all labor income on consumption. The budget constraints (5) and (6) 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 in each country i

$$L_i = L_{is} + L_{im} + L_{ia}, \tag{7}$$

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

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

$$Y_{is} = C_{is}, \tag{8}$$

$$y_{1a}(z) + y_{2a}(z) = d_{1a}(z)c_{1a}(z) + d_{2a}(z)c_{2a}(z), \qquad \forall z \in [0, 1], \tag{9}$$

$$y_{1m}(z) + y_{2m}(z) = d_{1m}(z)c_{1m}(z) + d_{2m}(z)c_{2m}(z), \qquad \forall z \in [0, 1]. \tag{10}$$

We define a competitive equilibrium of our model economy with country-specific and exogenous labor endowment processes $\{L_i\}$, trade cost processes $\{\tau_{ija}, \tau_{ijm}\}$, productivity processes $\{T_{ia}, T_{im}, A_{is}\}$ and structural parameters $\{\sigma, \epsilon, \eta, \beta, \theta\}$ as follows.

Definition 1. *A competitive equilibrium* is a sequence of goods and factor prices $\{p_{ia}(z)$, $p_{im}(z)$, P_{ia}, P_{im}, P_{is}, $w_i\}$ and allocations $\{l_{ia}(z)$, $l_{im}(z)$, L_{ia}, L_{im}, L_{is}, $y_{ia}(z)$, $y_{im}(z)$, Y_{is}, $c_{ia}(z)$, $c_{im}(z)$, C_{ia}, C_{im}, $C_{is}\}$ for $z \in [0, 1]$ and $i = 1, 2$, such that given prices, the allocations solve the firms' maximization problems associated with technologies (1)-(2) and the household's maximization problem characterized by (3)-(6), and satisfy the market clearing conditions (7)-(10).

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 is given by $P_{is} = \frac{w_i}{A_{is}}$. 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 in sector $q \in \{a, m\}$ produced in country j is given by $p_{ijq}(z) = \frac{\tau_{ijq} w_j}{A_{jq}(z)}$. The actual price that the consumer in country i pays for this good is $p_{iq}(z) = \min\{p_{i1q}(z), p_{i2q}(z)\}$.

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

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

and the aggregate price index P_i is given by

$$P_i = \left(\omega_a^{\frac{1}{1-\epsilon}} P_{ia}^{\frac{\epsilon}{\epsilon-1}} + \omega_m^{\frac{1}{1-\epsilon}} P_{im}^{\frac{\epsilon}{\epsilon-1}} + \omega_s^{\frac{1}{1-\epsilon}} P_{is}^{\frac{\epsilon}{\epsilon-1}}\right)^{\frac{\epsilon-1}{\epsilon}}. \tag{11}$$

We next characterize the household's optimal consumption allocation. According to the first order optimality conditions, the consumption expenditure share, $X_{iq} = \frac{P_{iq}C_{iq}}{P_i C_i}$, in sector $q \in \{a, m, s\}$ of country i is given by

$$X_{iq} = \omega_q^{\frac{1}{1-\epsilon}} \left(\frac{P_{iq}}{P_i}\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{12}$$

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

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

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. Within a sector, which goods are exported or imported 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, in each sector in each country, some goods will be imported. Each country will run a net export surplus in one sector and a net export deficit in the other 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. 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.[11] 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. We use the superscript c to denote the corresponding variables in the closed economy. It is straightforward to show for country i and each period,

$$\frac{P_{ia}^c}{w_i^c} = \frac{1}{A_{ia}}, \quad \frac{P_{im}^c}{w_i^c} = \frac{1}{A_{im}}, \quad \frac{P_{is}^c}{w_i^c} = \frac{1}{A_{is}}, \tag{13}$$

where $A_{ia} = \gamma^{-1} T_{ia}^{\frac{1}{\theta}}$, $A_{im} = \gamma^{-1} T_{im}^{\frac{1}{\theta}}$, $\gamma = (\Gamma(1 - \frac{\eta}{1-\eta}\frac{1}{\theta}))^{\frac{\eta-1}{\eta}}$, and Γ is the Gamma function.[12] Thus, the continuum of goods in the agriculture or manufacturing sector can be essentially reduced to one composite good with productivity A_{ia} or A_{im}.

The feasibility conditions imply that the sectoral labor share equals the sectoral expen-

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

[12] 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.

diture share:

$$l_{iq}^c = \frac{L_{iq}^c}{L_i} = \frac{w_i^c L_{iq}^c}{w_i^c L_i} = \frac{P_{iq}^c C_{iq}^c}{w_i^c L_i} = X_{iq}^c, \tag{14}$$

for each sector $q \in \{a, m, s\}$.[13] The sectoral labor shares depend on relative prices in the same way as the sectoral expenditures shares in (12). When the elasticity of substitution across sectors is less than one, the higher the sectoral relative price — owing to lower sectoral relative productivity — the higher the sectoral expenditure and labor shares. When the elasticity is one, the sectoral labor shares are independent of the relative prices.[14]

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

$$\hat{l}_{iqt}^c = \hat{X}_{iqt}^c = \frac{\epsilon}{\epsilon - 1}(\hat{P}_{iqt}^c - \hat{P}_{it}^c), \tag{15}$$

where $\hat{P}_{it}^c = \sum_{q \in \{a,m,s\}} X_{iqt}^c \hat{P}_{iqt}^c$. Thus, the elasticity of substitution links changes in sectoral labor shares $\hat{l}_{iqt}^c$ to changes in sectoral relative prices $\hat{P}_{iqt}^c - \hat{P}_{it}^c$. 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 (13):

$$\hat{l}_{iqt}^c = \hat{X}_{iqt}^c = \frac{\epsilon}{1 - \epsilon}(\hat{A}_{iqt} - \hat{A}_{it}^c), \tag{16}$$

where the weighted average productivity growth $\hat{A}_{it}^c = \sum_{q \in \{a,m,s\}} X_{iqt}^c \hat{A}_{iqt}$. When the elas-

[13] The sectoral labor share will equal the sectoral expenditure share even in a framework with capital and with intermediate goods, as long as the coefficient on labor in the production function is identical across sectors, and similarly for capital.

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

ticity 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. If the manufacturing sector has the fastest productivity growth among the three sectors, the manufacturing labor share declines overtime. In many developing countries, the manufacturing sector often experiences the fastest growth in productivity and a rising labor share.

5 Structural Change in an 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 scenarios that can generate a hump-shaped pattern in manufacturing employment shares. 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

$$\frac{A_{im}/\tau_{jim}}{A_{jm}} > \frac{A_{ia}/\tau_{jia}}{A_{ja}}.$$

Our definition is thus the traditional definition augmented by trade costs.[15] 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 a 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 Trade Patterns

We start our analysis with the trade patterns implied by comparative advantage. 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_{ijq}, captures intra-sector trade and is given by

$$\pi_{ijq} = \frac{(\tau_{ijq} w_j / A_{jq})^{-\theta}}{(\tau_{ijq} w_j / A_{jq})^{-\theta} + (w_i / A_{iq})^{-\theta}} = \frac{1}{1 + (\frac{w_i / A_{iq}}{\tau_{ijq} w_j / A_{jq}})^{-\theta}}. \tag{17}$$

Equation (17) 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: $\pi_{iiq} = 1 - \pi_{ijq}$.

If country i has a comparative advantage in manufacturing and country j has a comparative advantage in agriculture, equation (17) implies that $\pi_{ijm} < \pi_{ija}$ and $\pi_{iim} > \pi_{iia}$. The share of country i's manufacturing spending that is on imports is less than the share

[15] 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 further discussion on the topic of comparative advantage in the presence of trade costs.

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. Lemma 1 summarizes this discussion.[16]

Lemma 1. (Intra-Sector Trade) *If country 1 (2) has a comparative advantage in manufacturing (agriculture), then* $\pi_{12m} < \pi_{12a}$ *and* $\pi_{21a} < \pi_{21m}$.

We now characterize the patterns of international trade. Country i's exports of sector q goods are given by $EX_{iq} = \pi_{jiq} X_{jq} w_j L_j$. It is the product of country j's expenditure devoted to sector q goods, $X_{jq} w_j L_j$, and the fraction of that expenditure that is on imports, π_{jiq}. Similarly, country i's imports of sector q goods are given by $IM_{iq} = \pi_{ijq} X_{iq} w_i L_i$. Thus, country i's net exports of sector q goods is given by $NX_{iq} = EX_{iq} - IM_{iq}$. The balanced trade condition implies that inter-sectoral trade sums to zero, i.e., $NX_{im} + NX_{ia} = 0$. We denote the sectoral net export share of total GDP, $\frac{NX_{iq}}{w_i L_i}$, by N_{iq}. We demonstrate later that the sectoral net export share is a key determinant of sectoral labor allocations.

5.1.2 Relative Prices and Expenditure Shares

We now examine the impact of trade on relative prices and expenditure shares in each country. 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 is $\frac{P_{is}}{w_i} = \frac{1}{A_{is}}$, which is the same as under autarky. For the tradable composite good q, we have:

$$\frac{P_{iq}}{w_i} = \frac{1}{A_{iq}} \left[1 + \left(\frac{\tau_{ijq} w_j / A_{jq}}{w_i / A_{iq}} \right)^{-\theta} \right]^{-\frac{1}{\theta}} = \frac{\pi_{iiq}^{\frac{1}{\theta}}}{A_{iq}}. \tag{18}$$

Comparing equation (18) to (13), one can see that the price relative to the wage is lower with trade than under autarky because $\pi_{iiq} < 1$. The lower the trade cost or foreign wage, or the higher the foreign technology, the lower is the sectoral expenditure share

[16] Proofs are omitted unless specifically stated otherwise.

on domestic goods, and the lower is the sectoral price under trade relative to autarky. Lemma 2 implies that the price gap between trade and autarky 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 $\frac{P_i}{w_i}$ is lower in the open economy compared to autarky. $\frac{w_i}{P_i}$ 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 $\frac{P_{is}}{P_i}$ 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. Lemma 2 summarizes our results for relative prices.

Lemma 2. (Open Economy Relative Prices) *In both countries,* $\frac{P_{ia}}{w_i} < \frac{P_{ia}^c}{w_i^c}$, $\frac{P_{im}}{w_i} < \frac{P_{im}^c}{w_i^c}$, $\frac{P_{is}}{w_i} = \frac{P_{is}^c}{w_i^c}$, $\frac{P_i}{w_i} < \frac{P_i^c}{w_i^c}$, *and* $\frac{P_{is}}{P_i} > \frac{P_{is}^c}{P_i^c}$. *Moreover, if country 1 (2) has a comparative advantage in manufacturing (agriculture), then* $\frac{P_{1a}}{P_1} < \frac{P_{1a}^c}{P_1^c}$ *and* $\frac{P_{2m}}{P_2} < \frac{P_{2m}^c}{P_2^c}$.

The impact of trade on sectoral relative prices 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 $\frac{P_{is}}{P_i}$ 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_{iq} 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. Lemma 3 summarizes our results for expenditure shares.

Lemma 3. (Open Economy Expenditure Shares) *Assume that $\epsilon < 0$. Then, $X_{is} > X_{is}^c$ in both countries. Moreover, if country 1 (2) has a comparative advantage in manufacturing (agriculture), then $X_{1a} < X_{1a}^c$ and $X_{2m} < X_{2m}^c$.*

5.1.3 Labor Allocations

We now study the impact of trade on sectoral labor allocations. Because the services good is non-tradable, the market clearing condition requires that $C_{is} = A_{is}L_{is} = X_{is}w_iL_i/P_{is}$.[17] Thus, we have

$$l_{is} = \frac{L_{is}}{L_i} = X_{is}.$$

In an 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 labor share, because expenditure shares are affected by trade, as shown in Lemma 3.

Using the expression for X_{is} in equation (12), P_i in equation (11), and relative prices in equation (18), we can write the service labor share as

$$l_{is}^{-1} = \omega_a^{\frac{1}{1-\epsilon}} \pi_{iia}^{\frac{1}{\theta}\frac{\epsilon}{\epsilon-1}} \left(\frac{A_{is}}{A_{ia}}\right)^{\frac{\epsilon}{\epsilon-1}} + \omega_m^{\frac{1}{1-\epsilon}} \pi_{iim}^{\frac{1}{\theta}\frac{\epsilon}{\epsilon-1}} \left(\frac{A_{is}}{A_{im}}\right)^{\frac{\epsilon}{\epsilon-1}} + \omega_s^{\frac{1}{1-\epsilon}}. \tag{19}$$

The corresponding expression for the services labor share in autarky is given by

$$l_{is}^{-1} = \omega_a^{\frac{1}{1-\epsilon}} \left(\frac{A_{is}}{A_{ia}}\right)^{\frac{\epsilon}{\epsilon-1}} + \omega_m^{\frac{1}{1-\epsilon}} \left(\frac{A_{is}}{A_{im}}\right)^{\frac{\epsilon}{\epsilon-1}} + \omega_s^{\frac{1}{1-\epsilon}}.$$

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. Moreover, the lower

[17] 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.

the sectoral expenditure on domestic goods, or the more a country imports from abroad, the higher is the labor share relative to autarky. This implication is consistent with the regression evidence presented in Table 1; even though services are non-traded, trade affects this sector's labor share through general equilibrium effects on relative prices.

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: $w_1 L_{1q} = \pi_{11q} P_{1q} C_{1q} + \pi_{21q} P_{2q} C_{2q}$. This implies

$$l_{1q} = \frac{L_{1q}}{L_1} = \pi_{11q} X_{1q} + \pi_{21q} X_{2q} \frac{w_2 L_2}{w_1 L_1}. \tag{20}$$

Three forces determine the share of country 1's labor devoted to sector q. It depends on the expenditure share of each country on sector q goods, X_{1q} and X_{2q}. In addition, it depends on the extent of specialization, i.e., the share of each country's spending on sector q goods that is on goods produced by country 1, π_{11q} and π_{21q}. 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. These three forces drive the dynamics of structural change in our model, as we will see in sections 5.2 and 5.3.

Substituting $1 - \pi_{12q}$ for π_{11q}, we can rewrite (20) as follows:

$$l_{1q} = X_{1q} + \frac{\pi_{21q} X_{2q} w_2 L_2 - \pi_{12q} X_{1q} w_1 L_1}{w_1 L_1} = X_{1q} + N_{1q}. \tag{21}$$

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. The net export channel, N_{1q}, captures the direct contribution of international trade to structural change. In addition, Lemma 3 tells us that trade contributes indirectly to structural change through the expenditure channel, X_{1q}. For example, in the Baumol case, the expenditure share on the comparative disadvantage sector is lower in the open economy. Lemma 4 summarizes the effects of trade on the sectoral labor allocations.

Lemma 4. (Open Economy Labor Allocations) *In an open economy, the labor share of the tradable sector $q \in \{a, m\}$ is given by $l_{iq} = X_{iq} + N_{iq}$, and the labor share of the nontradable sector is given by $l_{is} = X_{is}$. Specifically, the service labor share is given by equation (19).*

The simplest way to see the direct contribution of trade to the sectoral labor shares is with the Cobb-Douglas case, i.e., $\epsilon = 0$. In this case, the services labor share is ω_s under both autarky and the open economy. The labor share of sector $q \in \{a, m\}$ is ω_q under autarky and is $\omega_q + N_{iq}$ in the open economy. N_{iq} is exactly 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. Assume that country 1 has a comparative advantage in manufacturing, and country 2 has a comparative advantage in agriculture. The trade balance of sector q in country 1 is given by

$$NX_{1q} = \pi_{21q}\omega_q w_2 L_2 - \pi_{12q}\omega_q w_1 L_1,$$

where the expenditure share is ω_q in both countries. The pattern of comparative advantages implies $\pi_{21m} > \pi_{21a}$ and $\pi_{12m} < \pi_{12a}$. 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 $NX_{1m} > 0$ and $NX_{1a} < 0$, and that $N_{1m} > 0$ and $N_{1a} < 0$. Hence, when a country opens up to trade, labor moves from its comparative disadvantage sector to its comparative advantage sector. We can also establish this result under CES preferences and free trade. Lemma 5 summarizes our results for inter-sector trade.[18]

[18] It is often noted that the effect of opening up to international trade is similar to the effect of a

Lemma 5. (Inter-Sector Trade) *Assume $\epsilon = 0$ or free trade. If country 1 (2) has a comparative advantage in manufacturing (agriculture), then $N_{1m} > 0$ and $N_{1a} < 0$.*

Proof: See Appendix B.

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:

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

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

$$\hat{l}_{iqt} = \frac{X_{iqt}}{l_{iqt}} \hat{X}_{iqt} + \frac{N_{iqt}}{l_{iqt}} \hat{N}_{iqt} \tag{22}$$

This is clearly different from (15). Structural change dynamics in an open economy involve changes in both the expenditure and net export channels. Note that in the Cobb-Douglas case, i.e., $\epsilon = 0$, there will be structural change as long as the net export channel evolves over time. We summarize these two results in Proposition 1.

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 typically will imply that one tradable sector experiences an increase in employment owing to trade, while the other sector experiences a decrease, even though both experience a boost in effective productivity.

Proposition 1. (Structural Change Dynamics with Trade) *In an open economy, (i) if* $\epsilon = 0$, $\hat{l}_{iqt} = \frac{N_{iqt}}{l_{iqt}}\hat{N}_{iqt}$*; (ii) if* $\epsilon < 0$, $\hat{l}_{iqt} = \frac{X_{iqt}}{l_{iqt}}\hat{X}_{iqt} + \frac{N_{iqt}}{l_{iqt}}\hat{N}_{iqt}$.

To understand better the dynamics of structural change, we consider the Cobb-Douglas case and free trade, and we study how changes in the net export channel are linked to the dynamics of comparative advantage. 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:

$$\hat{A}_{mt} > \hat{A}_{at}\frac{L_{2t}\pi_{12at} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}{L_{2t}\pi_{12mt} + \theta(w_t L_{1t} + L_{2t})\pi_{12at}\pi_{12mt}}, \tag{23}$$

where $w_t = \frac{w_{1t}}{w_{2t}}$ and $A_{qt} = \frac{A_{1qt}}{A_{2qt}}$ for $q \in \{a, m\}$.[19] 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-shaped pattern for the manufacturing employment share even when the manufacturing sector has the fastest productivity growth. Suppose that all sectoral productivity growth rates are constant over time, with manufacturing having the fastest growth in both countries. Country 1's manufacturing employment share is given by

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

which is a simplified version of equation (20). The above expression illustrates how changes in the net export channel are tied to changes in specialization, π_{11mt}, and to changes in

[19] For details, see Appendix B2. The fraction on the right hand side of equation (23) is larger than one because country 1's comparative advantage in manufacturing implies that $\pi_{12at} > \pi_{12mt}$. An endogenous mechanism to generate growth in comparative advantage over time would be learning by doing.

relative country-size, $\left(\frac{w_t L_{1t}+L_{2t}}{w_t L_{1t}}\right)$. Assume that $\hat{A}_{mt}$ and $\hat{A}_{at}$ satisfy equation (23) initially. Thus, l_{1mt} rises initially. Over time, π_{11mt} increases as each country purchases a greater fraction of its manufactured goods from country 1. In addition, if $\hat{A}_{at} > 0$, then w_t rises over time, and $\frac{w_t L_{1t}+L_{2t}}{w_t L_{1t}}$ declines as country 1 becomes larger relative to country 2. As long as the increase in specialization dominates the change in relative country-size, the manufacturing labor share continues to increase. The increase in specialization diminishes over time, however, because there are smaller further gains to employment from productivity growth. In the limiting case in which π_{11mt} reaches 1, there are no further increases in employment from this channel. The adverse employment effects of changes in relative country-size, however, continue over time. Thus, the country-size dynamics will eventually dominate the specialization dynamics, and country 1's manufacturing labor share will begin to decrease.[20] We summarize the above discussion formally in Proposition 2.

Proposition 2 (Hump in Manufacturing Labor Share) *Assume free trade, $\epsilon = 0$, constant labor endowments, and constant sectoral productivity growth rates. If country 1 has a comparative advantage in manufacturing, the relative productivity growth rates $\hat{A}_a$ and $\hat{A}_m$ satisfy equation (23) initially, and $\hat{A}_a > 0$, then its manufacturing labor share l_{1mt} displays a hump-shaped pattern over time.*

Proof: See Appendix B.

We briefly discuss the Baumol case. Now, changes in the expenditure channel affect

[20] Another way to write the manufacturing employment share in country 1 is

$$l_{1mt} = \frac{1-\omega_s}{1+\left(\frac{\omega_a}{\omega_m}\right)\left(\frac{\pi_{11at}}{\pi_{11mt}}\right)}$$

Using this expression, it can be seen that one implication of the hump-shaped pattern is that country 1 grows sufficiently large that eventually π_{11a} increases at a more rapid rate than π_{11m}. There are two reasons country 1 eventually buys an increasing fraction of its agricultural goods from local firms. First, country 1 becomes so efficient at producing manufactured goods that it eventually needs less labor to satisfy world manufacturing demand, so additional labor is available for agricultural production. Second, the demand for agricultural goods rises in country 1 as it gets richer, and country 2 eventually becomes too small to satisfy this demand.

structural change dynamics. Trade can still generate a hump-shaped pattern in the manufacturing labor share. The story is similar to that described above. Initially, with high productivity growth, and a comparative advantage in manufacturing, changes in the net export channel contribute positively to the manufacturing labor share. 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, changes in the net export channel, while remaining positive, diminishes, as discussed above. At some point in time — likely before complete specialization occurs — changes in the expenditure channel will dominate changes in the net export channel, and the manufacturing labor share will begin to decline. Owing to the expenditure channel dynamics, 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 of free trade. 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.[21] Manufacturing total factor productivity (TFP) grows 2 percent per year in 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.[22] Table 2 summarizes the relevant parameters.

Figure 3 illustrates structural change in country 1 for both the closed and open economy

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

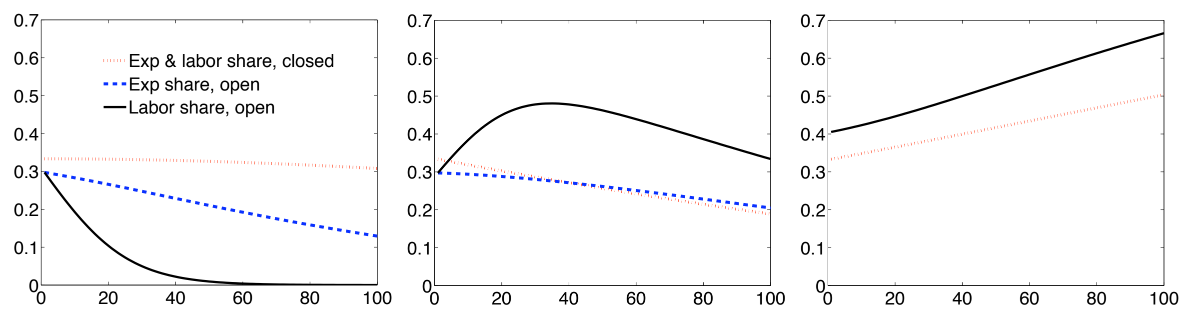
[22]The parameters σ, η, and β are irrelevant for this example.

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		
$\theta = 4.0$	$A_{1a0} = A_{1m0} = A_{1s0} = 1.0$	$A_{2a0} = A_{2m0} = A_{2s0} = (\frac{L_{20}}{L_{10}})^{\frac{1}{\theta}}$
$\hat{A}_{1at} = \hat{A}_{2mt} = 0.01$	$\hat{A}_{1mt} = \hat{A}_{2at} = 0.02$	$\hat{A}_{1st} = \hat{A}_{2st} = 0.0$

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

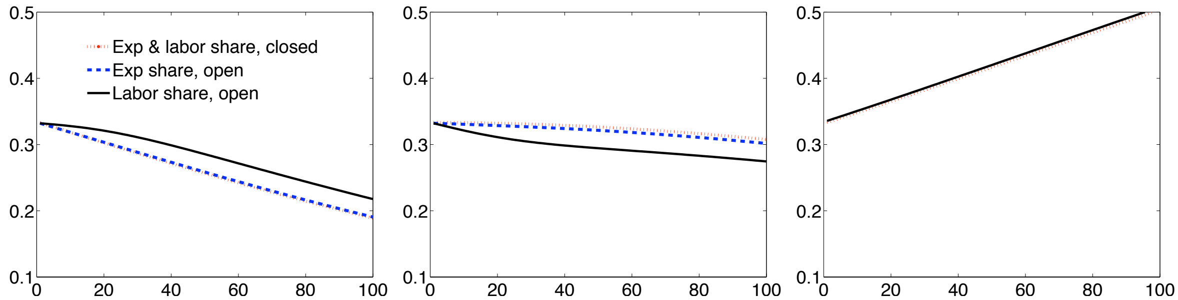
For the open economy case, the expenditure shares are shown in dashed blue lines and the labor shares are shown in solid black lines. Panel (a) shows the expenditure and labor patterns in agriculture. Country 1 has a comparative disadvantage in agriculture that grows over time; hence, a greater fraction 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. The manufacturing labor share follows a hump-shaped pattern. The increasing comparative advantage in manufacturing over time generates initially a positive contribution to manufacturing employment from increases in the net export channel. This positive contribution initially more than offsets the negative contribution to manufacturing employment from changes in the expenditure channel, and the manufacturing labor share increases. However, the increases in the net export channel diminish over time, and is eventually dominated by the decreases in the expenditure channel. The interplay of these two channels 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; after 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. Even relatively small economies can impact the pace of structural change of large economies. The manufacturing patterns in Figures 3 and 4 are consistent with the data in Figure 2. We can interpret the changes in Figure 2 as analogous to what happens when the global economy goes from autarky to trade. Then panel b in Figures 3 and 4 show that in one set of countries the manufacturing labor share and net export share both increase, while in the other set of countries, both shares decrease.

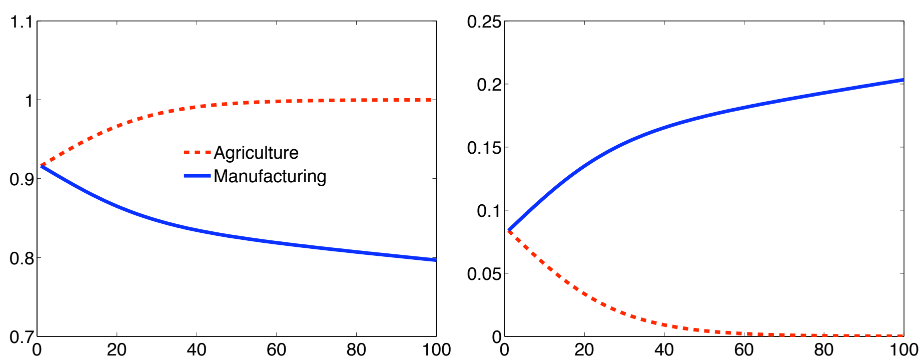
Figure 4: Structural Change in Country 2



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

Figure 5 illustrates the import shares. 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 country 1 diminish, which contributes to the declining manufacturing labor in country 1.

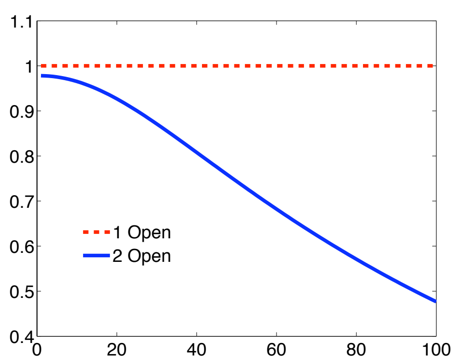
Figure 5: Import Shares



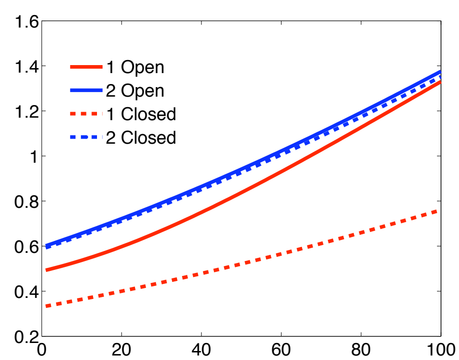
(a) Country 1 (b) Country 2

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.

Figure 6: Wages and Welfare



(a) Wages



(b) Welfare

Panel (b) illustrates the welfare effects over time. Welfare is measured as the wage rate 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 dynamics of the net export channel, we again study the Cobb-Douglas case. 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 changes in the net export channel are 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 $w_t = \frac{w_{1t}}{w_{2t}} = 1$ 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 $\pi_{12mt} = [1 + (\frac{A_{2mt}}{A_{1mt}\tau_{mt}})^{-\theta}]^{-1}$. Because $A_{1mt} > A_{2mt}$, it must be the case that $\pi_{21mt} > \pi_{12mt}$ and $N_{1mt} > 0$. The dynamics of N_{1mt} are given by

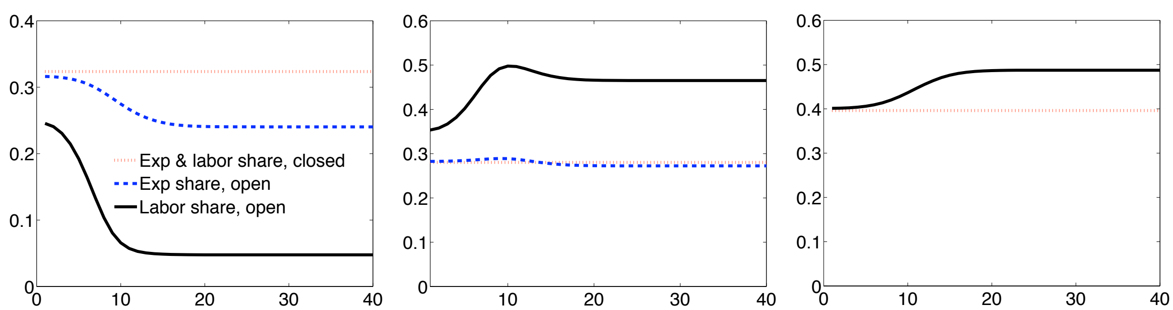
$$\hat{N}_{1mt} = \frac{\theta[\pi_{12mt}(1 - \pi_{12mt}) - \pi_{21mt}(1 - \pi_{21mt})]\hat{\tau}_{mt}}{\pi_{21mt} - \pi_{12mt}}.$$

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. Owing to the Cobb-Douglas assumption, 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. The figure shows that as trade costs decline, each country's comparative advantage is increasingly revealed, and there is increased specialization. Panel (a) shows that the agriculture expenditure share declines rapidly in the open economy. Declining trade costs allows 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.

Figure 7: Impact of Changing Trade Costs in Country 1



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

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 are from changes in the net export channel. As trade costs decline, both countries increase their import and export shares in each sector owing to increased specialization. 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 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 is needed to satisfy manufacturing demand from country 2. Initially, the rise in the net manufacturing exports arising from increases in specialization dominates the decline in net manufacturing exports arising from country 1's increasing size, and the manufacturing net export share of GDP and the manufacturing labor share rises. As the increase in specialization diminishes over time, the effect of country 1's increase in size becomes more important, and eventually leads to a reversal in the trend of net manufacturing exports. 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 extend the model in each of three directions. We consider non-homothetic preferences, we allow for intermediate goods, and we introduce capital 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:

$$U(C_{ia}, C_{im}, C_{is}) = \omega_a \log(C_{ia} - L_i\bar{c}_a) + \omega_m \log(C_{im} - L_i\bar{c}_m) + \omega_s \log(C_{is} - L_i\bar{c}_s).$$

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.[23] The consumption expenditure share for sector $q = \{a, m, s\}$ is given by

$$X_{iq} = \omega_q + \frac{P_{iq}\bar{c}_q}{w_i} - \omega_q \frac{\bar{c}_a P_{ia} + \bar{c}_m P_{im} + \bar{c}_s P_{is}}{w_i}. \tag{24}$$

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

$$l_{iq} = X_{iq} = \omega_q + \frac{\bar{c}_q}{A_{iq}} - \omega_q(\frac{\bar{c}_a}{A_{ia}} + \frac{\bar{c}_m}{A_{im}} + \frac{\bar{c}_s}{A_{is}}).$$

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

[23] However, the price index for the aggregate consumption good will be different from equation (11).

as productivities rise and countries get richer. The manufacturing labor share is ambiguous and depends on the relative magnitude of $\frac{\bar{c}_a}{A_{ia}}$ and $\frac{\bar{c}_s}{A_{is}}$. 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 (24), 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 (21). Thus, trade still affects labor allocations through an expenditure channel and a net export channel.

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_{21m}, and a lower π_{21a}, 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 increase in the expenditure channel contributes positively to the manufacturing labor share in country 1. Turning to the net export channel, 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 $t-1$.[24] Thus, while non-homothetic preferences are an additional mechanism for structural change, a hump-shaped 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 $Y_{is} = \psi A_{is} L_{is}^{\alpha} M_{is}^{1-\alpha}$, where $\psi = \alpha^{-\alpha}(1-\alpha)^{\alpha-1}$. Output Y_{is} is used for consumption or as an intermediate to produce services. The services market equilibrium condition is $Y_{is} = C_{is} + M_{is}$.

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

$$M_{iq} = \left(\int_0^1 m_{iq}(z)^{\eta} dz \right)^{1/\eta}.$$

The production function for good z in sector q is $y_{iq}(z) = \psi A_{iq}(z) l_{iq}(z)^{\alpha} M_{iq}(z)^{1-\alpha}$, where $M_{iq}(z)$ is the use of the composite intermediate good M_{iq} to make good z. The goods market equilibrium condition for any $z \in [0,1]$ is given by:

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

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

$$P_{iq} = \left[\left(\frac{w_i^{\alpha}}{A_{iq}} \right)^{-\theta} + \left(\frac{\tau_{ijq} w_j^{\alpha}}{A_{jq}} \right)^{-\theta} \right]^{-\frac{1}{\alpha\theta}}.$$

[24]For details see Appendix B3.

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

$$\pi_{ijq} = \frac{(\tau_{ijq} w_j^{\alpha}/A_{jq})^{-\theta}}{(\tau_{ijq} w_j^{\alpha}/A_{jq})^{-\theta} + (w_i^{\alpha}/A_{iq})^{-\theta}}.$$

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: $l_{is} = X_{is}$. The equilibrium condition for the manufacturing sector in country 1 implies that $w_1 L_{1m} = \alpha(\pi_{11m} P_{1m}(C_{1m} + M_{1m}) + \pi_{21m} P_{2m}(C_{2m} + M_{2m}))$. Simplifying yields the same expression for the labor share as in the benchmark model:

$$l_{1m} = L_{1m}/L_1 = \pi_{11m} X_{1m} + \pi_{21m} X_{2m} w_2 L_2/(w_1 L_1).$$

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.

6.3 Capital

We now introduce capital as an input into the production of each good and consider capital accumulation over time. Capital is perfectly mobile across sectors, but is immobile across countries. The production function for the services sector good of country i in period t is $Y_{ist} = A_{ist} K_{ist}^{\alpha} L_{ist}^{1-\alpha}$, where K_{ist} denotes capital devoted to services, and α denotes the capital share. The production function for tradable good $z \in [0, 1]$ in sector $q \in \{a, m\}$ of country i in period t is $y_{iqt}(z) = A_{iqt}(z) k_{iqt}^{\alpha}(z) l_{iqt}^{1-\alpha}(z)$, where $k_{iqt}(z)$ denotes capital devoted to this tradable good.

The key assumption in this section is that the capital share α is the same across goods, sectors, and countries. This preserves the Ricardian trade features of the model.[25] The first-order optimality conditions of the firms' problem imply the static allocation of inputs across sectors and goods:

$$\frac{k_{iat}(z)}{l_{iat}(z)} = \frac{k_{imt}(z)}{l_{imt}(z)} = \frac{K_{ist}}{L_{ist}} = \frac{\alpha w_{it}}{(1-\alpha) r_{it}},$$

where w_{it} and r_{it} denote the wage rate and the rental price of capital, respectively.

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

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

where C_{it} is final consumption, given by $U(C_{iat}, C_{imt}, C_{ist})$ in equation (3). The household supplies L_{it} inelastically and faces the following budget constraint in each period t:

$$P_{it}(C_{it} + I_{it}) = w_{it} L_{it} + r_{it} K_{it},$$

where I_{it} and K_{it} denote aggregate investment and the capital stock, respectively.

The law of motion for capital is $I_{it} = K_{it+1} - (1-\delta) K_{it}$, where δ is the depreciation rate of capital. The aggregate investment good is a composite of the sectoral goods; the functional form for the aggregator is the same as for the consumption aggregator:

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

where I_{iqt} is the composite sector-q good used to produce the investment good.

The household's optimal consumption and investment allocations are characterized by

[25] Otherwise, the model would have Heckscher-Ohlin features.

the intertemporal Euler equation:

$$C_{it}^{-\sigma} = \beta C_{it+1}^{-\sigma} \left(\frac{r_{it+1}}{P_{it+1}} + 1 - \delta \right).$$

Given final demand $Q_{it} = C_{it} + I_{it}$, the expenditure share $X_{iqt} = \frac{P_{iqt} Q_{iqt}}{P_{it} Q_{it}}$ is given by the first order optimality conditions: $X_{iqt} = \omega_q^{\frac{1}{1-\epsilon}} \left(\frac{P_{iqt}}{P_{it}} \right)^{\frac{\epsilon}{\epsilon - 1}}$.

In autarky, the feasibility conditions imply that the sectoral labor share equals the sectoral expenditure share:

$$l_{iqt} = \frac{L_{iqt}}{L_{it}} = \frac{w_{it} L_{iqt}}{w_{it} L_{it}} = \frac{(1-\alpha) P_{iqt} Q_{iqt}}{(1-\alpha) P_{it} Q_{it}} = X_{iqt},$$

for each sector $q \in \{a, m, s\}$. This implies that our benchmark results for the autarky dynamics of structural change are robust to the introduction of capital.

In the open economy, the trade patterns are similar to those in our benchmark model:

$$\pi_{ijqt} = \frac{(\tau_{ijqt} V_{jt} / A_{jqt})^{-\theta}}{(\tau_{ijqt} V_{jt} / A_{jqt})^{-\theta} + (V_{it} / A_{iqt})^{-\theta}},$$

where in each country i, the unit cost $V_{it} = \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} r_{it}^{\alpha} w_{it}^{1-\alpha}$ replaces the wage rate w_{it} in our benchmark model. The same is true for the relative prices. For the services good in country i, its price relative to the unit cost is $\frac{P_{ist}}{V_{it}} = \frac{1}{A_{ist}}$. For the tradable composite good q, $\frac{P_{iqt}}{V_{it}} = \frac{\pi_{iiqt}^{1/\theta}}{A_{iqt}}$. Thus, Lemmas 1, 2 and 3 are robust to the introduction of capital.

Turning to the sectoral labor allocations, again, the services sector's labor share equals its expenditure share:

$$l_{ist} = \frac{L_{ist}}{L_{it}} = \frac{w_{it} L_{ist}}{w_{it} L_{it}} = \frac{(1-\alpha) P_{ist} Q_{ist}}{(1-\alpha) P_{it} Q_{it}} = X_{ist}.$$

For tradable sector q, country 1's income from sector q equals expenditures of both countries on its sector-q goods:

$$\frac{w_{1t}L_{1qt}}{1-\alpha} = \pi_{11qt}P_{1qt}Q_{1qt} + \pi_{21qt}P_{2qt}Q_{2qt}.$$

As in our benchmark model, we can derive each tradable sector's labor share:

$$l_{1qt} = \frac{L_{1qt}}{L_{1t}} = \pi_{11qt}X_{1qt} + \pi_{21qt}X_{2qt}\frac{P_{2t}Q_{2t}}{P_{1t}Q_{1t}} = X_{1qt} + N_{1qt}.$$

Thus, with the inclusion of capital, the model still delivers the same expressions for the sectoral labor shares. Thus, Lemma 4, Lemma 5 and Proposition 1 also continue to hold.

7 Conclusion

International trade provides a mechanism 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.

While our framework is simple, it yields rich intuition on the role of trade in structural change. We trace through two scenarios in which a country with a comparative advantage in manufacturing can experience a hump-shaped pattern in manufacturing employment. In the first scenario, if manufacturing's productivity growth is sufficiently high, the gains to employment from an increasingly large surplus in manufacturing net export are larger than the losses to employment owing to declining manufacturing expenditure shares. The gains to employment will diminish over time, however, owing to the country's increasing size, as well as smaller increases in specialization. Eventually, either the decreases in manufacturing employment arising from the expenditure channel will dominate the increases arising from the net export channel, or the net export channel alone will contribute to decreases in employment; in both cases, employment in manufacturing will decline. In the second scenario, if trade barriers in manufacturing decline sufficiently rapidly, then, again, manufacturing employment will rise. However, once free trade is reached or once trade costs stop declining, the dynamics of the expenditure channel will dominate the now non-existent dynamics of the net export channel. The main results hold up in the presence of non-homothetic preferences, intermediate goods, and capital goods and investment.

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. In our first scenario from above, the small emerging market economy with a comparative advantage in manufacturing experiences relatively high productivity growth in that sector, and the large advanced economy with a comparative advantage in non-manufacturing experiences relatively high productivity growth in that sector. From that starting point, 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.[26] As mentioned above, 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.

[26]Stefanski (2009), Ungor (2009), and Teignier-Bacque (2009) are recent research along these lines.

Appendix A

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.[27] 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 (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 the sum of total exports and 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

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

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.)

Appendix B

Proof of Lemma 5: We first consider the case with the log preferences. In tradable sector q of country 1, exports are $\pi_{21q}X_{2q}w_2L_2$, and imports are $\pi_{12q}X_{1q}w_1L_1$. Under a unit elasticity of substitution, two countries have identical sectoral expenditure shares:

$X_{1q} = X_{2q} = \omega_q$. We can write net exports of country 1 in the manufacturing sector and the agriculture sector as:

$$NX_{1a} = \omega_a \left(\pi_{21a} w_2 L_2 - \pi_{12a} w_1 L_1 \right),$$

$$NX_{1m} = \omega_m \left(\pi_{21m} w_2 L_2 - \pi_{12m} w_1 L_1 \right).$$

The pattern of comparative advantages implies $\pi_{21m} > \pi_{21a}$ and $\pi_{12m} < \pi_{12a}$. Thus, if $NX_{1m} < 0$, it must be the case that $NX_{1a} < 0$. This would violate the balanced trade condition. Hence, it must be the case that $NX_{1m} \geq 0$ and $NX_{1a} \leq 0$. Equivalently, we have $N_{1m} \geq 0$ and $N_{1a} \leq 0$.

We then consider the case with the CES preferences and free trade. We prove by contradiction. Assume that $NX_{1m} < 0$. That is, $\pi_{21mt} X_{2mt} w_{2t} L_{2t} < \pi_{12mt} X_{1mt} w_{1t} L_{1t}$. Plugging in the expression for the expenditure shares and simple algebra give

$$\frac{\pi_{21mt}}{\pi_{12mt}} \left(\frac{P_{2mt}}{P_{1mt}} \right)^{\frac{\epsilon}{\epsilon-1}} < \left(\frac{P_{2t}}{P_{1t}} \right)^{\frac{\epsilon}{\epsilon-1}} \frac{w_{1t} L_{1t}}{w_{2t} L_{2t}}. \tag{25}$$

Under free trade, we have $P_{2mt} = P_{1mt}$ and $P_{2at} = P_{1at}$. Given the comparative advantage in country 1, we also have $\pi_{21mt} > \pi_{21at}$ and $\pi_{12at} > \pi_{12mt}$. This implies that

$$\frac{\pi_{21at}}{\pi_{12at}} \left(\frac{P_{2at}}{P_{1at}} \right)^{\frac{\epsilon}{\epsilon-1}} < \frac{\pi_{21mt}}{\pi_{12mt}} \left(\frac{P_{2mt}}{P_{1mt}} \right)^{\frac{\epsilon}{\epsilon-1}}. \tag{26}$$

From inequality (25) and (26), we have

$$\frac{\pi_{21at}}{\pi_{12at}} \left(\frac{P_{2at}}{P_{1at}} \right)^{\frac{\epsilon}{\epsilon-1}} < \left(\frac{P_{2t}}{P_{1t}} \right)^{\frac{\epsilon}{\epsilon-1}} \frac{w_{1t} L_{1t}}{w_{2t} L_{2t}}.$$

Using again the expression for the expenditure shares, we have $\pi_{21at} X_{2at} w_{2t} L_{2t} < \pi_{12at} X_{1at} w_{1t} L_{1t}$. Thus, we show that if $NX_{1mt} < 0$, then $NX_{1at} < 0$. For the balanced trade condition to hold, it must be the case that $NX_{1mt} > 0$ and $NX_{1at} < 0$. *Q.E.D.*

Proof of Proposition 2: From the balanced-trade condition, the equilibrium wage ratio $w_t = \frac{w_{1t}}{w_{2t}}$ solves:

$$\left[\omega_m \pi_{21mt} + \omega_a \pi_{21at} \right] \frac{w_t L_1 + L_2}{w_t L_1} = \omega_a + \omega_m. \tag{27}$$

Totally differentiating equation (27), we have

$$\frac{\omega_m \pi_{21mt} \hat{\pi}_{21mt} + \omega_a \pi_{21at} \hat{\pi}_{21at}}{\omega_m \pi_{21mt} + \omega_a \pi_{21at}} - \frac{L_2}{w_t L_1 + L_2} \hat{w}_t = 0,$$

where $\hat{\pi}_{21mt} = \theta \pi_{12mt} (\hat{A}_m - \hat{w}_t)$ and $\hat{\pi}_{21at} = \theta \pi_{12at} (\hat{A}_a - \hat{w}_t)$. Solving for $\hat{w}_t$ yields:

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

where $\psi_{lt} = \frac{L_2}{w_t L_1 + L_2}$, $\psi_{mt} = \frac{\theta \omega_m \pi_{12mt} \pi_{21mt}}{\omega_m \pi_{21mt} + \omega_a \pi_{21at}}$, and $\psi_{at} = \frac{\theta \omega_a \pi_{12at} \pi_{21at}}{\omega_m \pi_{21mt} + \omega_a \pi_{21at}}$. Since $\hat{A}_a$ and $\hat{A}_m$ are both positive, we have $\hat{w}_t$ is positive, which implies that the relative size of country 1 in the world economy keeps rising.

The manufacturing labor share in country 1 is given by $l_{1mt} = \omega_m \pi_{21mt} \left[\frac{w_t L_1 + L_2}{w_t L_1} \right]$. Again totally differentiating, we have:

$$\hat{l}_{1mt} = -\frac{L_2}{w_t L_1 + L_2} \hat{w}_t + \hat{\pi}_{21mt} = -\left[\frac{L_2}{w_t L_1 + L_2} + \theta \pi_{12mt} \right] \hat{w}_t + \theta \pi_{12mt} \hat{A}_m.$$

We then plug in the equation for $\hat{w}_t$ and simplify. The necessary and sufficient condition for $\hat{l}_{1mt} > 0$ is equation (23):

$$\hat{A}_m > \hat{A}_a \frac{L_2 \pi_{12at} + \theta (w_t L_1 + L_2) \pi_{12at} \pi_{12mt}}{L_2 \pi_{12mt} + \theta (w_t L_1 + L_2) \pi_{12at} \pi_{12mt}} \equiv \hat{A}_a \xi_t,$$

where $\xi_t > 1$, because Lemma 1 establishes $\pi_{12at} > \pi_{12mt}$ under the pattern of comparative advantage.

Under the assumption that initially $\hat{A}_m$ and $\hat{A}_a$ satisfy equation (23), $\hat{l}_{1mt} > 0$, i.e., the manufacturing labor share in country 1 initially rises over time. It also implies that $\hat{A}_m > \hat{A}_a$ given that $\xi_t > 1$. Moreover, $\hat{\pi}_{12mt} = \theta \pi_{21mt} (\hat{w}_t - \hat{A}_m) = -\frac{\theta \pi_{21mt} (\hat{A}_m \phi_{lt} + \phi_{at} (\hat{A}_m - \hat{A}_a))}{\psi_{lt} + \psi_{mt} + \psi_{at}} < 0$. Thus, π_{12mt} declines over time to zero, or π_{21mt} rises over time to one.

When π_{21mt} approaches one over time, l_{1mt} starts to decline because $l_{1mt} = \omega_m \pi_{21mt} \left[\frac{w_t L_1 + L_2}{w_t L_1} \right]$ and $\frac{w_t L_1 + L_2}{w_t L_1}$ always declines over time. This completes the characterization of the hump-shaped pattern of l_{1mt}. *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 (24). 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., $\hat{N}_{1mt} > 0$.

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