Globalization, Trade & Wages: What Does History tell us about China?

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September 2008
Version 1.2

Keywords: International trade, Stolper-Samuelson, Hechscher-Ohlin-Vanek, China, economic development
JEL Classification Numbers: F15, F33, N20, N23, N40

Preliminary Draft. Please do not cite or quote without the authors' permission.

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One of the most contentious issues with respect to the global growth in trade is its effects on wages. Much of the debate has focused on how the expansion in trade between developing and developed countries affects the wages in the United States and Europe. The logic of trade theories such as the Heckscher-Ohlin-Vanek (HOV) model and Stolper-Samuelson (1941) suggest that an expansion of trade will raise the wages of skilled workers and lower those of unskilled workers in developed countries if these countries are relatively well endowed with skilled labor. This has led some commentators to link the growing wage inequality within the U.S. to trade with the rest of world; even more specifically, some have suggested that as U.S. trade with China grows, wages for unskilled workers in the U.S. will fall in response. An equally interesting question, and one which has received comparatively less attention, is how the growth in trade is altering wages in developing countries. For example, trade models based on factor endowments predict that the skill premium should be falling in rapidly developing countries like China. Empirical evidence suggesting that trade has increased wage inequality within developed countries or decreased it within developing countries is at best mixed.

Determining the sources for wage inequality today is complicated by many factors. First, trade has become much more complicated than what is typically described in the simple framework of HOV models. The growth in intra-industry trade, outsourcing and offshoring, and multinationals are some factors which perhaps cast doubt on the reliability of estimates that are based on the predictions of theoretical models produced more than 50 years ago. More generally, there are many confounding influences that make the task of causal inference extremely challenging. For example, in thinking about the impact of expanding trade on the wage premium in developing countries today, empirical researchers may also need to account for declining union power, falling minimum wages, increased rates of immigration of unskilled workers, and greater skill-biased technological change. Analyses that instead focused on important developing countries, like China, would also face an array of challenging empirical issues that make identification difficult, including assessing the impacts of technological change, foreign direct investment, and state intervention on factor prices.

A number of scholars have suggested that the late nineteenth and early twentieth centuries may be better periods for testing the empirical implications of Stolper-Samuelson theorem and HOV models than today. Estevadeordal and Taylor (2002) argue that low barriers to trade (especially in simple manufactured goods and agriculture), more skewed factor endowments, less trade in differentiated products and services, and minimal intra-industry trade are some characteristics of the first era of globalization that may make a good laboratory for testing factor endowment models of trade. O'Rourke and Williamson (1994, 1999) have provided empirical evidence of factor price convergence and other predictions of these models during the great expansion of trade in the late nineteenth century.

In this paper, we use the lens of history to better understand two issues of interest to policymakers and economists today. First, when a relatively closed economy opens up its borders to trade, how does a rapid expansion in trade affect the skill premium for a developing country? Second, given its importance in the global economy today, how will globalization and trade affect the skill premium in China? We assemble new data sets on Chinese trade and wages for the period from 1903 to 1928 to shed light on these two questions as well as on the economic history of China during an earlier era of globalization.

During the first three decades of the twentieth century, China experienced a tremendous growth in trade with the rest of the world. The nominal value of exports sextupled and imports rose roughly by the same amount (Figure 1). Although China had been forcibly opened to trade in the 1840s, the scale of trade was quite small until the Treaty of Shimonoseki and the cessation of hostilities with Japan. The beginning of our sample period corresponds to China's entry into the global trade boom of the late nineteenth and early twentieth centuries. Like the current period of globalization, China's economy dramatically opened up to world trade: total trade as a share of GDP almost tripled during our sample period, an increase that is roughly comparable what China has experienced since 1980.

We marshal new data on the factor content of Chinese trade to show that China's export boom in the first three decades was characterized by a rapid expansion in the production and sale of unskilled-intensive products to the rest of the world. China's growth in exports of unskilled-intensive manufactures, mining, and agricultural products also benefited from an exogenous shock to demand during the second decade of the twentieth century. Whereas World War I disrupted trade in many other parts of the rest of the world, it further boosted Chinese exports, creating demand in new markets that had previously been serviced by belligerent countries. Employing unit value data from Chinese trade statistics, we show that the prices of its key exports rose rapidly during the first three decades of the twentieth century, even during the period right after World War I when many other countries suffered from the global glut in agricultural commodities. As demand for Chinese products from the rest of the world grew, its exports were integrated into the global trade network: higher prices reflected overseas demand for its products. Rising export prices drove up factors used intensively in the export sector and led to higher wages for unskilled workers. Using new data on wages for unskilled and skilled workers, we show that, as a result of China's trade boom, the skill premium flattened out in the 1910s and then fell by 8 percent between 1928 and 1928 (Figure 2). Our results suggest that sustained trade booms in developing countries can significantly impact wages.

In the next section, we provide some theoretical and historical background for our analysis of the impact of trade on wages in China. Section III describes the sources we use to construct trade statistics for China and explains our methodology for measuring factor content. Section IV assesses the relationship between factor content and export growth, calculates the change in export prices, and relates our trade data to changes in the skill premium in China. Section V provides conclusions and avenues for future research.

II. The Modern Period of Chinese Trade: Theory and Evidence

The Heckscher-Ohlin-Vanek (HOV) model predicts that when an economy that is relatively well endowed with unskilled labor opens up to foreign trade, it will specialize in producing unskilled labor intensive products for export. According to the Stolper-Samuelson theorem, as trade expands, wages for unskilled workers will rise relative to those of skilled workers. (Appendix I provides a formal, general equilibrium model showing this result.) Although HOV models and their related theorems often abstract from reality in their parsimony (two countries, two goods, two factors) and in their theoretical assumptions (constant returns to scale, perfect competition, identical production technologies, free mobility of goods, etc.), they are nevertheless useful for framing how trade based on comparative advantage affects factor prices within countries and for drawing attention to the winners and losers in trade. For example, policymakers have used the simple predictions of the 2x2x2 version of the models to explain how increased trade and globalization is impacting wages. These models have been used by economists to consider the extent to which trade is driving increased wage inequality in the U.S. (Revenga, 1992; Lawrence and Slaughter, 1993; Leamer, 1998), and similarly, in predicting the consequences that China's expanding bilateral trade with the U.S. will have on U.S. wages (Krugman, 2008; Lawrence, 2008).

Despite their theoretical elegance, testing the predictions of the HOV model and its theorems (such as Stolper-Samuelson, Rybczynski, and factor price convergence) has proved vexing. Empirical researchers often restrict their attention tests to simple versions of factor content models so that they retain clearer theoretical predictions and avoid issues such as factor substitutability. Nevertheless, there are still identification issues that make estimating the effects of trade on wages using modern data extremely challenging. Skill premiums today may be driven by a variety of factors that are difficult to disentangle, including technology, migration, and institutional changes in labor markets.

There are several reasons why the HOV-SS framework may have more power in explaining Chinese trade flows of the early twentieth century in comparison to its trade flows today. First, bulky standardized commodities, such as wheat and meat, and simple manufactures, like cotton goods, were the basis for the global growth in trade in the late nineteenth and early twentieth centuries (Findlay and O'Rourke, 2003) In contrast to the differentiated trade in goods and services today, differences in factor endowments may be sufficient for explaining the movement of raw materials and simple manufactures across national boarders (i.e., it may be unnecessary to appeal to more recent models that emphasize product differentiation or the within-industry effects of trade, such as Melitz (2003)). Second, there were fewer tariff and non-tariff barriers to trade, especially with respect to agricultural goods and low-skilled manufactured goods – two important areas of export for China during our sample period (Estevadeordal and Taylor, 2002). Third, although we cannot rule out that skill-biased technological change may have played some role during this period, it is likely that the growth in the stock of educated workers in China during the first three decades of the twentieth century was too small to alter the skill premium significantly. Enrollment rates in secondary schools rose too late in the period to have much of an effect on the wages of skilled workers (Xiong, 1990). Fourth, although workers departed Europe in large numbers and went to the Americas during the nineteenth and early twentieth centuries, China's participation in this wave of global migration was much smaller. Hence, it seems reasonable to conclude that the effects of Chinese emigration on the wages of unskilled workers during our sample period is likely much more muted than the effects that emigration might be having on wages in developing countries like China today. Fifth, unlike today, when institutions such as unions and minimum or state wages can impact observed wage rates, there is no evidence that the Chinese labor market and hence skill premium were affected by labor market institutions during the first three decades of the twentieth century.

Finally, part of the growth in Chinese exports during our sample period is the result of exogenous shocks to demand. World War I both disrupted trade and redirected trade in ways that benefited China and which led to an increase in demand for its exports (Cheng, 1956). Although China did not experience a dramatic acceleration in the growth rate of exports during World War I, this fact disguises the positive impact that the war had on Chinese exports. Many other countries experienced a contraction in trade during World War I (Glick and Taylor 2001). In China, exports fell for one year before resuming their upward trajectory. Indeed, they continued to grow at trend rather than below trend (Figure 1). Given the global disruptions to trade as a result of the war, trend growth for China was superior to the average country during this period (Glick and Taylor 2001). Moreover, Chinese exports to new trading partners like the United States and India increased rapidly. The war redirected trade between other countries to China, and allowed it to expand production and further specialize according to comparative advantage.

Our analysis focuses on the first three decades of the twentieth century as this period marks a significant expansion for Chinese trade with the rest of the world. Until the 1840s, China was largely a closed, agrarian economy. Pressure from Great Britain and other foreign powers led China to open its economy to international trade. The 1842 Treaty of Nanking permitted foreigners to trade with the Chinese in five open ports, and stipulated a general five percent ad valorem tariff on all goods leaving and entering China. However, the foreign trade of China experienced only sluggish growth until the end of the century. Between 1875 and 1895, annual growth rates of imports and exports averaged 2.95 percent and 2.54 percent respectively. During this period, the largest import commodities were opium, cotton textiles, and petroleum products (kerosene, gasoline, etc.). Major exports were tea and silk.

China's defeat in the Sino-Japanese war in 1895 ushered in further changes in Chinese production and trade. The Treaty of Shimonoseki allowed Japanese businesses to invest directly in China, and produce goods and services that could be sold to other nations as well as marketed within China. Soon after the treaty was signed, this privilege was extended to other foreign nations via most-favored-nation agreements. Foreign capital financed railroad, telecommunications, and shipping enterprises and spurred industrialization. By the early twentieth century, the number of cities open to trade had climbed to 48 cities.

The transition from a closed to an open economy, with virtually free trade policy, sparked rapid, sustained growth in international trade (Figure 1). Cheng (1956) estimates that between 1900 and 1913 the total value of trade grew twice as much as it had between 1868 and 1900. In the first 13 years of the twentieth century, the value of foreign exports nearly tripled, imports almost quadrupled, and the annual growth rate of trade averaged 7.4 percent. Imports were disrupted throughout World War I, but after declining for one year, exports resumed their upward trajectory. In the ten years from 1917 to 1927, exports grew at 7 percent annually. China's trade growth was faster than the world average in the first three decades of the twentieth century; its share of world trade increased from 1.5 percent around 1898 to 3.44 percent by 1928. Hence, by the beginning of the twentieth century, the Chinese economy was exploiting its comparative advantage in unskilled manufactures. Indicative of this growth in trade was cotton textiles, which became one of the fastest growing industries. Trade records indicate that domestic yarn firms started to export in 1913, and by the mid 1920s, had largely displaced imports (Figure 3).

III. Chinese Trade Data

To understand the effects of this trade boom on wages, we assembled a new data set of detailed trade data from China Maritime Customs' (hereafter "CMC") trade publications. CMC was likely the only bureaucratic organization in China that operated without interruption (due to wars or funding shortages) from 1858 to 1949. Although it reported to the Chinese government, its top administration as well as mid-level managers and technocrats were largely foreigners – initially British citizens, but later on also Japanese and Americans. CMC's primary tasks were collecting customs revenue and recording and publishing data on foreign trade; however, it eventually expanded its operations to include collecting revenues from domestic trade, administering the postal system, developing inland and coastal waterways, and representing China at international fairs. CMC's geographical reach grew from just fourteen stations during the 1860s to nearly fifty during the 1920s, covering not only the coastal regions but also inland cities, including those near the border with Burma and along the Amur River on China's northern tip.

CMC is most widely known for its 160 volumes of detailed trade statistics, which span roughly 90 years of commercial transactions (1858-1949). The trade records, which were collected at the port level, include information on the quantities and the values of all commodities passing through each treaty port and, in aggregate, provide a detailed picture of China's trade with the rest of the world. In comparison to other economic or demographic data on China during this period, the quality and detail of the CMC trade data is exceptional, and rivals the trade publications of the advanced nations of the late nineteenth century.

These statistics were primarily published at the port level. The units of measurement and currency sometimes varied across ports and over time. We therefore standardized the measurement and currency units and then aggregated the product data to the national level.

IV. Measuring Factor Content

To assess the role that the expansion in trade played in reducing the skill premium in China, we first examine the factor content of Chinese exports in order to see if, according to the HOV framework, (1) Chinese exports were dominated by products that used unskilled labor intensively in their production and (2) the growth in exports was driven by increased sales of these unskilled-intensive products. We keep our factor content analysis simple, and consider differences in production based only on labor characteristics – whether workers were skilled or unskilled. Although this is clearly a simplification, it enables us to take advantage of our detailed trade data to learn something about China during an important period of Chinese history when little other information on firm or industry characteristics exists.

After creating a database of quantities and values of all the traded commodities using the CMC trade publications, we classified exports and imports based on economic activity and skill intensity. The first step was to choose a standard classification system so that we could systemize the aggregates of economic activity and then measure factor content by "industry group." This is especially important because our database covers Chinese trade for all the treaty ports over three decades, the nomenclature of traded goods sometimes changed, and the individual customhouses sometimes collected trade statistics using their own naming systems.

Since the Standard Industrial Classification System (SIC) was not adopted in major industrial surveys or censuses, it has limited usefulness for the wide variety of commodities in our Chinese trade data. Instead, we use the Index of Occupations and Industries from the 1950 Census of Population ("IND1950"). Although IND1950 recodes industries contained in the 1950 Census Bureau, the basic content of the occupational and industrial classification was largely derived from earlier censuses, in particular the 1940 Census. Thus, since IND1950 is somewhat retrospective in design, it provides a consistent set of industry codes that is broad enough to capture the trade being conducted by China between 1903 and 1928.

We next classified the industries according to skill intensity. Since there is no agreed upon methodology for determining the factor content of products or industries based on available data sources, empirical studies use a variety of approaches to proxy factor content. One approach is to rank industries according to average wages. If workers are paid their marginal products (as would prevail in competitive markets for factors and goods), then, on average, higher paying industries ought to reflect higher average productivity or skill. Another way for proxying skill intensity is to rank industries by average education levels. A third approach is to calculate the share of production workers (relative to non-production workers) in each industry.

Because U.S. historical census data offer broad industry coverage and detailed information on education and wages, our starting point for classifying skill intensity for Chinese industries was to create benchmarks based on the 1940 U.S. Census. Since the majority of goods imported and exported by China were also traded in the U.S., measures derived from the U.S. census provide a reasonable approximation of skill intensity at the industry level that can be used for our factor content analysis of trade.

The 1940 U.S. Census is the first one that collects information on both individuals' education and annual wages. The 1940 Census records each individual's highest level of educational attainment, ranging from no education to five or more years of post-secondary education. In our analysis, we classify workers with nine or more years of education as skilled workers. We then aggregated education information for all individuals in the 1940 Census by industry (using the IND1950 classification described above) and calculated the fraction of workers in each industry that had nine or more years of education.

The 1940 Census also records each individual's annual wage, allowing us to aggregate these data and obtain average industry wages (again based on IND1950 industry classification). Hence, using U.S. Census data, we are able to obtain information on skill intensity at the industry level based on (1) education and (2) wages. We report industry rankings using these two metrics in Tables 1 and 2.

V. Analyzing the Effects of the Chinese Trade Boom on Wages

A. The Factor Content of Trade

We now turn to examining how the Chinese trade boom of the first three decades of the twentieth century affected the skill premium in China. Figure 2 shows that the skill premium rose during the first decade of the trade boom (when the size of Chinese trade was miniscule as a share of its GDP), but then flattened out and declined as Chinese trade grew in importance and as the export boom continued virtually uninterrupted until 1929. Although the time series graph is broadly consistent with the view that the rapid growth in trade may have impacted the wages of skilled and unskilled workers in China, we subject this hypothesis to more scrutiny by considering whether data on the factor content of trade are consistent with the predictions of the HOV-SS framework.

The model predicts that, as China opens up to trade with the rest of the world, exports of goods that use relatively more unskilled labor (the abundant factor in China) in the production process will increase. The demand for unskilled labor will rise as the economy exports more. China will also begin to import more goods that are produced with relatively more skilled labor, thus reducing the domestic demand for skilled labor. Assuming the supply curves for labor are not perfectly elastic, the shifts in demand for skilled and unskilled workers will cause the wages of skilled workers to fall relative to unskilled workers. Hence, the model predicts that China’s trade boom will cause the skill premium to fall.

A first test in the spirit of the HOV framework would be to examine whether total exports, were becoming more unskilled-intensive in their composition over the course of our sample period. Using the data on industry averages for wages and education, we classify the industrial sectors into two broad groups, unskilled and skilled. We denoted industries where the fraction of workers with nine or more years of education exceeded 0.48 as skilled industries. We divided the data at this value since the two industries above and below this cutoff seemed most dissimilar in terms of labor force characteristics (Motor vehicles and motor vehicle equipment versus glass and glass products). Industries with log wage values greater than 2.986 are classified as skilled, which puts metal mining and pottery producing as the two industries on the dividing line. Figures 4 and 5 show the composition of exports and imports in terms of factor content. In 1903, when the magnitude of foreign trade was fairly small and China was relatively closed, most of its imports and exports were composed of unskilled-intensive products. But, as Chinese trade grew in importance over the next 25 years, we see significant movements in the ratios for both exports and imports. Using either wages or education as our measure of skill, exports became more unskilled-intensive over the entire sample period – rising from about 0.92 to 0.99 for the education ratio and from roughly 0.8 to roughly 0.9 for the wage ratio (Figure 4). In contrast, the share of unskilled imports declines substantially. For example, using the measure based on education, the share of unskilled exports falls form 0.88 to 0.75 (Figure 4). In the same vein, the fraction of imports that are skill-intensive increases from 0.11 to 0.25 over the sample period (Figure 5).

Another way of assessing the general factor content of trade is to examine the detailed industry data. In Figures 6-9, we display the value of exports and imports for each industry on the y-axis and its corresponding skill intensity on the x-axis for four years: 1903, 1913, 1919, and 1928. Skill intensity increases as we move in a rightward direction along the x-axis. We present this evidence for skill intensity based on education (Panel A of Figures 6-9) and log wages (Panel B of Figures 6-9). The figures show that exports are largely clustered at the lower levels of skill intensity whereas imports dominate the highest values of skill intensity. These characteristics of the figures are even more evident by 1928.

These results constitute strong evidence that trade was fundamentally responding in ways that are consistent with factor endowment models of trade. Even if we found no evidence that the that unskilled-intensive exports were rising over our sample period, the factor content data could still be consistent with the predictions of the HOV-SS models if it were true that, overall, Chinese exports grew faster for unskilled-intensive industries than for skill-intensive industries. This would indicate that the expansion in exports shown in Figure 1 was driven by unskilled-intensive exports. (Similarly, skill-intensive imports should grow faster than those for unskilled industries.)

To test this prediction, we create ten industry groups based on skill intensity and compute the growth rates for each of these industry groups. Tracking the growth in exports of individual industries might be preferable, but it is complicated by the fact that some industries lack data for our whole sample period. Using industry groupings allows us to examine industries of similar skill intensity and follow them over the entire sample period. We weight the deciles by their share of the total value of exports, and then plot the growth rate of exports for each group relative to its skill intensity.

Figures 10-11 graph the average annual growth rates for exports and imports from 1903 to 1928, where industry groups are ordered by skill intensity (using either the wage or education classifications as indicated on the graph). The figures show that the fastest growing deciles for exports tended to be those with the lowest skill intensity. On the other hand, the fastest growing deciles for imports tended to be the most skill intensive.

B. Robustness Check

In our empirical analysis, we have implicitly drawn on an assumption of the HOV model – that technology is the same across countries – to justify deriving skill intensities for Chinese industries based on 1940 U.S. census benchmarks. However, because the assumption of common technology may not have held in practice and because our U.S. skill-intensity benchmarks are based on data from 1940, we explore whether the factor content analysis is robust to an alternative classification scheme. To carry out our robustness check, we had to identify an alternative survey for deriving skill intensity at the industry level. Unfortunately, survey data at the individual, occupational, or industry level for China during the first three decades of the twentieth century is scarce.

The 1928 Shanghai Census is the earliest survey with sufficient detail to derive estimates of skill intensity at the industry level. It was administered by the Bureau of Industry, Agriculture, and Commerce of the Greater Shanghai Municipality, and included information on factory names and addresses, ownership, capitalization, number of workers, wages, raw materials, and power utilization. Unfortunately, the survey records only the highest and lowest wage rates by industry; after closer inspection, we determined that the minimum and maximum wages in each industry were insufficient to generate reliable average industry wage rates. Instead, we computed the capital-labor ratio to evaluate skill intensity of industries under the assumption that industries which use more labor are, on average, characterize by lower-skilled workers. We first classified the traded goods using the classification system adopted in the 1928 Shanghai Survey, and then calculated the capital-labor ratio by dividing the total physical capital (value of physical capital stock) by the number of workers in each industry. We then ranked the traded goods industries according to their capital-labor ratios (Table 3).

Using the 1928 Shanghai Survey, we show the growth rates of exports and imports based on grouping the industries into deciles. Figures 12 and 13 show that our results are similar to those based on the U.S. skill-intensity benchmarks. Growth rates for Chinese exports were highest for unskilled industry deciles and growth rates for imports were highest for the skilled deciles.

C. Evidence on the Price of Exports

If increased trade is driving up the wages of unskilled workers in countries that are well-endowed with unskilled labor, then, according to the model, export prices should also be rising. That is, the fact that China became more specialized in producing and exporting unskilled intensive commodities does not necessarily lead to rising unskilled wages and a declining skill premium. The expansion of export-related industries might only result in expanding employment in these industries. For wages of unskilled workers to rise, one would also need to observe rising prices for exports (assuming the marginal product of workers has not changed).

Hsiao's (1974) export price index shows that export prices grew markedly after 1913 (Figure 14). Consistent with other global studies of trade, prices of traded goods rose during World War I. Moreover, it appears that in China's case, the positive shock in demand was large enough to significantly move prices upward after a decade of little change. After a brief cessation after the war, prices resumed their upward trajectory. During the period when the skill premium was flattening out and falling, export prices roughly doubled. Rising sales and prices led to growing revenue for exporting firms, providing considerable scope for raising the wages of unskilled workers that were used intensively in their production.

We used the unit value data contained in our database to compute the growth rates in prices for China's ten most important exports (based on value). Figure 15 shows positive average annual growth rates in unit values for these major exports over the period 1903 to 1928. In addition, the commodities shown in this figure that used unskilled labor more intensively (agricultural goods and cotton yarn) experienced particularly strong rates of growth in their prices. Figure 16 shows that prices in cotton yarn grew by 275 percent after 1913. Cotton spinning was widely considered a typical unskilled-intensive manufacturing industry. China had been a large importer of cotton yarn, but by the beginning in the twentieth century, a domestic cotton textile industry began to compete with foreign products. The industry grew rapidly, and by the mid-1920s, cotton-spinning exports exceeded imports. As the cotton spinning industry expanded, it drew in large numbers of unskilled workers.

VI. Conclusion

Our findings suggest that the opening of China to trade during the first three decades of the twentieth century led to a dramatic expansion in exports. Foreign demand for Chinese goods led to greater specialization and increased production of unskilled-intensive products. Unskilled-intensive exports, already dominant in Chinese trade, increased their share of total trade over these decades. Industries that used unskilled workers intensively in their production saw the fastest growth rates in exports between 1903 and 1908. Prices of exports, especially those for unskilled goods, grew rapidly after 1913.

Although we cannot rule out alternative explanations, the evidence on factor content of trade and unit values suggests that the rapid expansion in exports from Chinese trade had a significant impact on the skill premium in China. It appears that, by the end of the second decade of the trade boom, exports had expanded sufficiently to increase the wages of unskilled workers relative to skilled workers to alter the slope of the skill premium. By the 1920s, the skill premium had reversed course and declined by roughly 8 percent. Our preliminary findings suggest that, in a world when trade was dominated by the movement of relatively homogenous goods across borders, trade may have had a considerable impact on wages. Consistent with a simple HOV-SS framework, developing countries may have seen the wages of unskilled wages rise relative to those of skilled workers.

In future work, we intend to calibrate the general equilibrium model presented in the Appendix I in order to quantify how much wages changed as a result of trade. We also intend to explore how World War I altered trade for China. Although the rate of growth of exports did not rise significantly during the war, relative to other countries, China's export growth was impressive. Export trade increased by 77 percent between 1914 and 1919. It is likely that China was able to export more to countries that had previously relied on exports from belligerents. Moreover, the fact that Chinese exports did not revert to a lower level after the war suggests that the war did not temporally boost trade.

Appendix 1

1 Model

Building off of the theoretical literature of trade based on comparative advantage and following notation introduced in Galor and Mountford (2008), in this section we construct a general-equilibrium model to understand how opening up an economy to trade impacts the wage premium. We begin by analyzing the production and consumption patterns in a closed economy. Consider an overlapping-generations economy in which economic activity is characterized by the production of two goods. These goods are produced over an infinite horizon of time (where time is measured discretely). In each period t, a skill-intensive good, Y_t^S, and a labor-intensive good, Y_t^U, are produced with two factors of production, skilled labor, H_t, and unskilled labor, L_t. The supply of skilled and unskilled labor is endogenously determined and evolves over time.

1.1 Production

The output of the labor-intensive good produced in period t, Y_t^U, is governed by a constant returns to scale production technology,

$$Y_t^U = A_t^U (L_t^U)^\eta (H_t^U)^{1-\eta}; \quad 0.5 < \eta < 1, \tag{1}$$

where L_t^U is the amount of unskilled labor employed in the production of the labor-intensive good in period t, H_t^U is the amount of skilled labor employed in the production of the labor-intensive good in period t, and A_t^U is the level of productivity in period t. η and $1-\eta$ are shares of two types of labor in the production of the unskilled-labor-intensive good. We assume $\eta > 0.5$ in order to characterize the labor-intensive production technology of this good.

The output of the skill-intensive good produced in period t, Y_t^S, is also governed by a constant returns to scale production function,

$$Y_t^S = A_t^S (L_t^S)^\theta (H_t^S)^{1-\theta}; \quad 0 < \theta < 0.5, \tag{2}$$

where L_t^S and H_t^S are the amounts of unskilled and skilled labor employed in period t in the production of the skill-intensive good, and A_t^S is the level of productivity in period t. θ and $1-\theta$ are the shares of the two types of labor used in production of the skill-intensive good.We set $\theta < 0.5$ in order to characterize the skill-intensive production of this good.

We assume that the markets for final goods and for labor are perfectly competitive. It follows that the inverse demand for unskilled and skilled labor in the labor-intensive sector are

$$w_t^{U,L} = p_t A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta-1} \tag{3}$$

and

$$w_t^{U,H} = p_t A_t^U (1-\eta) (\frac{L_t^U}{H_t^U})^{\eta}, \tag{4}$$

where $w_t^{U,L}$ and $w_t^{U,H}$ are the wages of an unskilled and a skilled labor in terms of the skill-intensive good in the labor-intensive sector, and p_t is the relative price of the labor-intensive good in terms of the skill-intensive good in period t. The inverse demand for unskilled and skilled labor in the skill-intensive sector, given (2), are

$$w_t^{S,L} = A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta - 1} \tag{5}$$

and

$$w_t^{S,H} = A_t^S (1-\theta) (\frac{L_t^S}{H_t^S})^{\theta} \ , \tag{6}$$

where $w_t^{S,L}$ and $w_t^{S,H}$ are the wages of an unskilled and a skilled labor in terms of the skill-intensive good in the skill-intensive sector.

Since the same type of workers are perfectly mobile between the two sectors, the wages of the same types of labor will be the same in the two sectors:

$$w_t^L = p_t A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta - 1} = A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta - 1} \tag{7}$$

$$w_t^H = p_t A_t^U (1-\eta) (\frac{L_t^U}{H_t^U})^{\eta} = A_t^S (1-\theta) (\frac{L_t^S}{H_t^S})^{\theta}. \tag{8}$$

The relative price of the labor-intensive good in terms of the skill-intensive good in period t, is therefore

$$p_t = \frac{A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta - 1}}{A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta - 1}} = \frac{A_t^S (1-\theta) (\frac{L_t^S}{H_t^S})^{\theta}}{A_t^U (1-\eta) (\frac{L_t^U}{H_t^U})^{\eta}}. \tag{9}$$

The skill premium is, therefore, denoted by

$$r_t = \frac{w_t^H}{w_t^L} = \frac{1-\eta}{\eta} \frac{L_t^U}{H_t^U} = \frac{1-\theta}{\theta} \frac{L_t^S}{H_t^S}. \tag{10}$$

It is evident from (10) that the skill premium is determined by two factors: relative factor endowments, $\frac{L}{H}$, and relative share of factors, $\frac{1-\eta}{\eta}$ and $\frac{1-\theta}{\theta}$. If the factor endowment is more biased toward unskilled labor, meaning that $\frac{L}{H}$ is larger and skilled labor is relatively scarce, the skill premium is higher. If skilled labor has a larger share in the production function, meaning that $\frac{1-\eta}{\eta}$ and $\frac{1-\theta}{\theta}$ are larger, the skill premium is higher.

1.2 The Household

In this model, we equate skill with education. Education or skill is attained through parental input, with parents allocating their time between rearing children and labor force participation. More educated or skilled offspring necessarily requires more parental time input.

Individuals live for two periods. In their first period of life, they consume the fraction of parental time allocated to them to acquire skills. Depending on the parents' education decisions, in the second period of life, the individuals are either endowed with one unit of skilled labor (H) or one unit of unskilled labor (L). In the second period, the individuals make decisions on time allocations among rearing of two types of children and labor force participation.

The utility of an adult member i, $i = H, L$, in period t is given by

$$u_t = \left(c_t^{i,U}\right)^{\alpha} \left(c_t^{i,S}\right)^{\beta} (w_{t+1}^H n_t^{i,H} + w_{t+1}^L n_t^{i,L})^{1-\alpha-\beta}, \tag{11}$$

where are $c_t^{i,U}$ and $c_t^{i,S}$ are individual i's consumption of the labor-intensive good and the consumption of the skill-intensive good, respectively. $w_{t+1}^H n_t^{i,H} + w_{t+1}^L n_t^{i,L}$ is the total potential income of individual i's offpring, where $n_t^{i,H}$ is the number of skilled offpring, $n_t^{i,L}$ is the number of unskilled offpring, and w_{t+1}^H and w_{t+1}^L are the wages paid to skilled and unskilled offspring in period $t+1$. α, β and $1-\alpha-\beta$ are the shares of two consumer goods and children bearing in the utility function respectively.

Individuals also choose both the number and quality of children as well as the amount of each good to consume. Denoting the time required to bring up skilled offpring as, $\tau^{i,H}$, and the time required to bring up an unskilled offpring as, $\tau^{i,L}$, where $\tau^{i,H} > \tau^{i,L}$, the budget constraint of a member i of generation t is

$$p_t c_t^{i,U} + c_t^{i,S} + w_t^i(\tau^{i,H} n_t^{i,H} + \tau^{i,L} n_t^{i,L}) \leq w_t^i. \tag{12}$$

We further assume that it requires less time for skilled labor than unskilled labor to raise skilled offspring, and for unskilled labor than skilled labor to raise unskilled offspring. Hence, we have

$$\tau^{L,H} > \tau^{H,H} > \tau^{H,L} = \tau^{L,L}. \tag{13}$$

The idea of this assumption is very natural: it is easier for parents to educate offspring to be their same type, and it is more expensive to train skilled offspring, regardless of the type of the parents.

Therefore, an adult individual i chooses $\left\{c_t^{i,U}, c_t^{i,S}, n_t^{i,H}, n_t^{i,L}\right\}$ so as to maximize the utility function:

$$\left\{c_t^{i,U}, c_t^{i,S}, n_t^{i,H}, n_t^{i,L}\right\} =$$

$$\arg\max \left(c_t^{i,A}\right)^{\alpha} \left(c_t^{i,M}\right)^{\beta} (w_{t+1}^H n_t^{i,H} + w_{t+1}^L n_t^{i,L})^{1-\alpha-\beta}$$

such that,

$$p_t c_t^{i,A} + c_t^{i,M} + w_t^i(\tau^H n_t^{i,H} + \tau^L n_t^{i,L}) \leq w_t^i.$$

The consumption of the labor-intensive good, $c_t^{i,U}$, by a member i of generation t is therefore

$$c_t^{i,U} = \alpha \frac{w_t^i}{p_t}. \tag{14}$$

The consumption of the skill-intensive good, $c_t^{i,S}$, by a member i of generation t is therefore

$$c_t^{i,S} = \beta w_t^i. \tag{15}$$

Furthermore, the number of skilled and unskilled offpring will be determined such that the aggregate time devoted by an adult member i to child bearing is

$$\tau^H n_t^{i,H} + \tau^L n_t^{i,L} = 1 - \alpha - \beta \tag{16}$$

where,

$$\begin{aligned} n_t^{i,L} &= 0 \text{ and } n_t^{i,H} > 0 \text{ if } w_{t+1}^H / w_{t+1}^L > \tau^{i,H}/\tau^{i,L} \\ n_t^{i,H} &\geq 0 \text{ and } n_t^{i,L} \geq 0 \text{ and } n_t^{i,H} + n_t^{i,L} > 0 \text{ if } w_{t+1}^H / w_{t+1}^L = \tau^{i,H}/\tau^{i,L} \\ n_t^{i,H} &= 0 \text{ and } n_t^{i,L} > 0 \text{ if } w_{t+1}^H / w_{t+1}^L < \tau^{i,H}/\tau^{i,L} \end{aligned} \tag{17}$$

1.3 Aggregate Labor Allocation and Skill Premium

We now show the equilibrium aggregate labor allocation and solve for the skill premium in equilibrium. Since preferences are such that both goods are consumed in every period, in autarky both goods must be produced in every period. Hence, an equilibrium in the goods market requires that, in a given technological state, the demand for the labor-intensive and skill-intensive goods, given by (14) and (15), equal the supply of the two goods, given by (1) and (2), which are denoted by:

$$\begin{aligned} \frac{\alpha}{p_t}(w_t^L L_t + w_t^H H_t) &= Y_t^U = A_t^U (L_t^U)^\eta (H_t^U)^{1-\eta} \\ \beta(w_t^L L_t + w_t^H H_t) &= Y_t^S = A_t^S (L_t^S)^\theta (H_t^S)^{1-\theta}. \end{aligned} \tag{18}$$

Given the optimal education investment (16) and the education costs (13), we have the following lemmas:

Lemma The skill premium r_t satisfies the following condition:

$$\frac{\tau^{H,H}}{\tau^{H,L}} \leq r_t \leq \frac{\tau^{L,H}}{\tau^{L,L}} \tag{19}$$

Proof: Suppose $\frac{\tau^{H,H}}{\tau^{H,L}} > r_t$, then the skilled wage is too low compared to unskilled wage: even skilled parents will not produce skilled children. In the next period, there will not be any skilled labor, which cannot hold since production requires skilled labor. Suppose $r_t > \frac{\tau^{L,H}}{\tau^{L,L}}$, then the skilled wage is too high compared to the unskilled wage such that even unskilled parents will not produce unskilled children. In the next period there will be no unskilled labor, which cannot hold since unskilled labor is required for production. Only when (19) holds, will both types of labor be reared by parents. *Q.E.D.*.

As long as (19) is satisfied, the optimal time an individual should allocate to education is $1-\alpha-\beta$, as given by (16). The intuition of this optimal solution is that the optimal consumption share of each commodity in the total expenses equals the its share in the utility function. Therefore, the share of aggregate unskilled and skilled labor allocated to production is $\alpha+\beta$, and the share of aggregate unskilled and skilled labor allocated to production is $1-\alpha-\beta$. This is equal to say that

$$\begin{aligned}(\alpha+\beta)L_t &= L_t^U + L_t^S \\ (\alpha+\beta)H_t &= H_t^U + H_t^S.\end{aligned} \tag{20}$$

Given the two production functions, the skill premium equalization condition (10), the market clearing condition (18) and aggregate labor allocation condition (20), we can write the following proposition:

Proposition 1 In equilibrium, the aggregate labor allocations of unskilled and skilled labor in labor-intensive and skill-intensive sectors are given by

$$\begin{aligned}H_t^U &= \frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}+1}H_t \\ H_t^S &= \frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{1-\eta}{1-\theta}+1}H_t \\ L_t^S &= \frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{\eta}{\theta}+1}L_t \\ L_t^U &= \frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{\theta}{\eta}+1}L_t,\end{aligned} \tag{21}$$

and the skill premium is given by

$$r_t = \frac{\frac{\beta}{\alpha}(1-\theta)+1-\eta}{\frac{\beta}{\alpha}\theta+\eta}\frac{L_t}{H_t} \tag{22}$$

Proof: see appendix.

Now we move to the dynamic structure of the model. The population dynamics are

$$\begin{aligned}L_{t+1} = L_t n_t^{L,L} + H_t n_t^{H,L} \\ H_{t+1} = L_t n_t^{L,H} + H_t n_t^{H,H}.\end{aligned} \tag{23}$$

With the population dynamics, commodity market clearing conditions, labor market clearing conditions and wage equalization conditions, we can obtain the steady state of the economy.

Proposition 2 There is a unique steady state in the close economy, where the skill premium $r_t = \frac{\tau^{L,H}}{\tau^{L,L}}$

In the steady state,

$$\begin{aligned} n^{H,H} &= \tfrac{1-\alpha-\beta}{\tau^{H,H}} \\ n^{H,L} &= 0 \\ n^{L,H} &= \tfrac{\beta(1-\theta)+\alpha(1-\eta)}{\alpha+\beta} \tfrac{\tau^{H,H}-\tau^{L,L}}{\tau^{H,H}\tau^{L,H}}(1-\alpha-\beta) \\ n^{L,L} &= \tfrac{(\beta\theta+\alpha\eta)\tau^{H,H}+\{\beta(1-\theta)+\alpha(1-\eta)\}\tau^{L,L}}{(\alpha+\beta)\tau^{L,L}\tau^{L,H}}(1-\alpha-\beta). \end{aligned}$$

The ratio of unskilled is

$$\frac{L}{H} = \frac{\beta\theta+\alpha\eta}{\beta(1-\theta)+\alpha(1-\eta)} \frac{\tau^{L,H}}{\tau^{L,L}},$$

and

$$\begin{aligned} H^U &= \tfrac{\alpha(1-\eta)(\alpha+\beta)}{\beta(1-\theta)+\alpha(1-\eta)} H \\ H^S &= \tfrac{\beta(1-\theta)(\alpha+\beta)}{\beta(1-\theta)+\alpha(1-\eta)} H \\ L^U &= \tfrac{\alpha\eta(\alpha+\beta)}{\beta\theta+\alpha\eta} L \\ L^S &= \tfrac{\beta\theta(\alpha+\beta)}{\beta\theta+\alpha\eta} L \end{aligned}$$

$$p_t = \frac{A_t^S}{A_t^U} \frac{\theta^\theta(1-\theta)^{1-\theta}}{\eta^\eta(1-\eta)^{1-\eta}} (\frac{\tau^{L,H}}{\tau^{L,L}})^{\theta-\eta}$$

$$\begin{aligned} \frac{Y_{t+1}^U}{Y_t^U} &= \frac{Y_{t+1}^S}{Y_t^S} \\ &= \frac{(\beta\theta+\alpha\eta)\tau^{H,H}+\{\beta(1-\theta)+\alpha(1-\eta)\}\tau^{L,L}}{(\alpha+\beta)\tau^{L,L}\tau^{L,H}}(1-\alpha-\beta)\ . \end{aligned}$$

Proof: see appendix.

Now we study the dynamics of the closed economy. We already know that

$$\frac{\tau^{H,H}}{\tau^{H,L}} \le r_t = \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta\theta+\alpha\eta} \frac{L_t}{H_t} \le \frac{\tau^{L,H}}{\tau^{L,L}}$$

Case 1: if in period t, the skill premium satisfies the condition:

$$r_t = \frac{\tau^{H,H}}{\tau^{H,L}} < \frac{\tau^{L,H}}{\tau^{L,L}},$$

then

$$n_t^{L,H} = 0$$

$$n_t^{L,L} = \frac{1-\alpha-\beta}{\tau^{L,L}}$$

$$\tau^{H,H} n_t^{H,H} + \tau^{H,L} n_t^{H,L} = 1-\alpha-\beta$$

where $n_t^{H,H} > 0$ and $n_t^{H,L} \ge 0$.

From the population dynamics, we have

$$L_{t+1} = L_t \tfrac{1-\alpha-\beta}{\tau^{L,L}} + H_t n_t^{H,L}$$
$$H_{t+1} = H_t n_t^{H,H}$$

Therefore,

$$\frac{L_{t+1}}{H_{t+1}} = \frac{1-\alpha-\beta}{\tau^{L,L} n_t^{H,H}} \frac{L_t}{H_t} + \frac{n_t^{H,L}}{n_t^{H,H}}$$

$$\begin{aligned}
r_{t+1} &= \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta\theta+\alpha\eta} \frac{L_{t+1}}{H_{t+1}} \\
&= \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta\theta+\alpha\eta} \left(\frac{1-\alpha-\beta}{\tau^{L,L} n_t^{H,H}} \frac{L_t}{H_t} + \frac{n_t^{H,L}}{n_t^{H,H}}\right) \\
&= \frac{1-\alpha-\beta}{\tau^{L,L} n_t^{H,H}} r_t + \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta\theta+\alpha\eta} \frac{n_t^{H,L}}{n_t^{H,H}} \\
&> r_t = \frac{\tau^{H,H}}{\tau^{H,L}}
\end{aligned}$$

Therefore, the economy evolves automatically to Case 2.
Case 2: if

$$\frac{\tau^{H,H}}{\tau^{H,L}} < r_t = \frac{w_t^H}{w_t^L} < \frac{\tau^{L,H}}{\tau^{L,L}}$$

In this case, each type of labor only produces their own type of children, which means $n_t^{L,H} = 0$, $n_t^{L,L} = \frac{1-\alpha-\beta}{\tau^{L,L}}$, $n_t^{H,H} = \frac{1-\alpha-\beta}{\tau^{H,H}}$ and $n_t^{H,L} = 0$.

Therefore,

$$L_{t+1} = L_t \tfrac{1-\alpha-\beta}{\tau^{L,L}}$$
$$H_{t+1} = H_t \tfrac{1-\alpha-\beta}{\tau^{H,H}}$$

$$\frac{L_{t+1}}{H_{t+1}} = \frac{\tau^{H,H}}{\tau^{L,L}} \frac{L_t}{H_t} > \frac{L_t}{H_t}$$

$$\begin{aligned}
r_{t+1} &= \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta\theta+\alpha\eta} \frac{L_{t+1}}{H_{t+1}} \\
&= \frac{\tau^{H,H}}{\tau^{L,L}} r_t > r_t
\end{aligned}$$

Similarly, the economy automatically evolves to Case 3.

1.4 Open Economy

We now expand our simple overlapping generations model to consider the effects of trade on the skill premium for a developing economy (i.e., China). We show that international trade promotes specialization and changes the equilibrium skill premium.

Suppose that the world economy consists of two economies that are identical in every respect except for their factor endowments. In particular, economy A is more abundant in skilled labor while economy B is more abundant in unskilled labor:

$$(\frac{L_t}{H_t})^A < (\frac{L_t}{H_t})^B. \tag{24}$$

Proposition 3 Everything else equal, the autarkic relative price of the labor-intensive good, p_t^A, in economy A, is higher than the autarkic relative price, p_t^B, in economy B.

Proof: see appendix.

As international trade is established between the two countries, the international equilibrium relative price of the labor-intensive good, p_t^*, is determined in between the autarkic equilibrium prices in the two economies:

$$p_t^B \leq p_t^* \leq p_t^A. \tag{25}$$

International trade therefore causes each of the countries to specialize relative to their position in autarky. Furthermore, one of the economies completely specializes in production (If $p_t^B < p_t^* < p_t^A$, the two economies completely specialize in production). From the viewpoint of the economy, B, there is an increase in the relative price of the labor-intensive good and producers are induced to produce more of the labor-intensive good. International trade, therefore induces economy B to fully specialize in the production of the labor-intensive good.

Therefore, the production of economy B is fully characterized by

$$Y_t^U = A_t^U (L_t^U)^\eta (H_t^U)^{1-\eta}; \quad 0.5 < \eta < 1, \tag{26}$$

As established before, the wages of unskilled and skilled labor are

$$w_t^L = p_t^* A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta-1} \tag{27}$$

and

$$w_t^H = p_t^* A_t^S (1-\eta)(\frac{L_t^S}{H_t^S})^\eta, \tag{28}$$

where p_t^* as the international equilibrium price of the labor-intensive good in terms of the skill-intensive good in period t, which is exogenous.

The skill premium is, therefore,

$$r_t = \frac{w_t^H}{w_t^L} = \frac{1-\eta}{\eta} \frac{L_t^U}{H_t^U} \tag{29}$$

The household's problem is similar to the autarkic problem: an adult member i in period t chooses $\left\{c_t^{i,U}, c_t^{i,S}, n_t^{i,H}, n_t^{i,L}\right\}$ so as to maximize the utility function:

$$\left\{c_t^{i,U}, c_t^{i,S}, n_t^{i,H}, n_t^{i,L}\right\} =$$

$$\arg\max \left(c_t^{i,U}\right)^{\alpha} \left(c_t^{i,S}\right)^{\beta} (w_{t+1}^H n_t^{i,H} + w_{t+1}^L n_t^{i,L})^{1-\alpha-\beta}$$

such that,

$$p_t^* c_t^{i,U} + c_t^{i,S} + r_t^i(\tau^H n_t^{i,H} + \tau^L n_t^{i,L}) \leq r_t^i.$$

The consumption of the labor-intensive good, $c_t^{i,U}$, by an adult member i in period t is therefore

$$c_t^{i,U} = \alpha \frac{r_t^i}{p_t^*}. \tag{30}$$

The consumption of the manufactured good, $c_t^{i,S}$, by an adult member i in period t is therefore

$$c_t^{i,S} = \beta r_t^i. \tag{31}$$

Furthermore, the number of skilled and unskilled offpring will be determined such that the aggregate time devoted by an adult member i in period t to child rearing is

$$\tau^H n_t^{i,H} + \tau^L n_t^{i,L} = 1 - \alpha - \beta \tag{32}$$

where,

$$\begin{aligned} n_t^{i,L} &= 0 \text{ if } w_{t+1}^H / w_{t+1}^L > \tau^H / \tau^L \\ n_t^{i,H} &> 0 \text{ and } n_t^{i,L} > 0 \text{ if } w_{t+1}^H / w_{t+1}^L = \tau^H / \tau^L \\ n_t^{i,H} &= 0 \text{ if } w_{t+1}^H / w_{t+1}^L < \tau^H / \tau^L \end{aligned}$$

Proposition 4 In the open economy equilibrium, the skill premium is given by

$$r_t = \frac{1-\eta}{\eta} \frac{L_t}{H_t}$$

Proof: see appendix.

Now we study the steady state in the open economy.

Proposition 5 $\overline{r} = \frac{\tau^{L,H}}{\tau^{L,L}}$ is the unique steady value of r_t

Proof: same as Proposition 2.

Now we study the path of the open economy to the steady state. To do that, we first need to know that under what conditions the economy fully specializes and under what conditions the economy produces both commodities. For this, we have the following proposition:

Proposition 6 In the open economy, the conditions determining the specialization pattern of a economy is the following:

(i) The economy produces both commodities if and only if

$$\frac{H_t}{L_t} < (p_t^*)^{\frac{1}{\eta-\theta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}} (\frac{\eta}{\theta})^{\frac{\eta}{\eta-\theta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\eta-\theta}} < \frac{\eta}{\theta}\frac{1-\theta}{1-\eta}\frac{H_t}{L_t}.$$

(ii) The economy specializes in the production of skill-intensive commodities if and only if

$$\frac{H_t}{L_t} \geq (p_t^*)^{\frac{1}{\eta-\theta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}} (\frac{\eta}{\theta})^{\frac{\eta}{\eta-\theta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\eta-\theta}}.$$

(iii) The economy specializes in the production of labor-intensive commodities if and only if

$$\frac{\eta}{\theta}\frac{1-\theta}{1-\eta}\frac{H_t}{L_t} \leq (p_t^*)^{\frac{1}{\eta-\theta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}} (\frac{\eta}{\theta})^{\frac{\eta}{\eta-\theta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\eta-\theta}}.$$

Proof: see appendix.

We can show that, when the economy produces both commodities, the aggregate labor allocations are

$$\begin{aligned}
L_t^U &= \frac{\eta(1-\theta)}{\theta-\eta}\left[(p_t^*)^{\frac{1}{\theta-\eta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\theta-\eta}} (\frac{\eta}{\theta})^{\frac{\eta}{\theta-\eta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\theta-\eta}}(\alpha+\beta)H_t - (\alpha+\beta)L_t\right] \\
L_t^S &= \frac{\eta(1-\theta)}{\theta-\eta}\left[\frac{\theta}{\eta}\frac{1-\eta}{1-\theta}(\alpha+\beta)L_t - (p_t^*)^{\frac{1}{\theta-\eta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\theta-\eta}} (\frac{\eta}{\theta})^{\frac{\eta}{\theta-\eta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\theta-\eta}}(\alpha+\beta)H_t\right] \\
H_t^U &= \frac{\eta(1-\theta)}{\theta-\eta}\left[\frac{\theta(1-\eta)}{\eta(1-\theta)}(\alpha+\beta)H_t - (p_t^*)^{\frac{-1}{\theta-\eta}} (\frac{A_t^U}{A_t^S})^{\frac{-1}{\theta-\eta}} (\frac{\eta}{\theta})^{\frac{-\theta}{\theta-\eta}} (\frac{1-\theta}{1-\eta})^{\frac{1-\theta}{\theta-\eta}}(\alpha+\beta)L_t\right] \\
H_t^S &= \frac{\eta(1-\theta)}{\theta-\eta}\left[(p_t^*)^{\frac{-1}{\theta-\eta}} (\frac{A_t^U}{A_t^S})^{\frac{-1}{\theta-\eta}} (\frac{\eta}{\theta})^{\frac{-\theta}{\theta-\eta}} (\frac{1-\theta}{1-\eta})^{\frac{1-\theta}{\theta-\eta}}(\alpha+\beta)L_t - (\alpha+\beta)H_t\right]
\end{aligned}$$

If the economy fully specializes in production of the skill-intensive product, the labor allocations are $L_t^U = 0$, $L_t^S = L_t$, $H_t^U = 0$, and $H_t^S = H_t$.

If the economy fully specializes in production of the labor-intensive product, the labor allocations are $L_t^U = L_t$, $L_t^S = 0$, $H_t^U = H_t$, and $H_t^S = 0$.

Therefore, the skill premium $r_t = \frac{1-\theta}{\theta}\frac{L_t}{H_t}$ if the economy specializes in the production of skill-intensive product; $r_t = (\overline{p^*})^{\frac{1}{\theta-\eta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\theta-\eta}} \frac{\eta^{\frac{\eta}{\theta-\eta}}(1-\theta)^{\frac{\theta-1}{\theta-\eta}}}{(1-\eta)^{\frac{\eta-1}{\theta-\eta}}\theta^{\frac{\theta}{\theta-\eta}}}$ if the economyproduces both commodities; $r_t = \frac{1-\eta}{\eta}\frac{L_t}{H_t}$ if the economy specializes in the production of labor-intensive product.

Appendix 2

Proof of Proposition 1
The definitions of unskilled and skilled wages are

$$\begin{aligned} w_t^L &= p_t A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta-1} = A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta-1} \\ w_t^H &= p_t A_t^U (1-\eta)(\frac{L_t^U}{H_t^U})^{\eta} = A_t^S (1-\theta)(\frac{L_t^S}{H_t^S})^{\theta}. \end{aligned}$$

With these two equations, the market clearing conditions (**??**) can be simplified to be

$$\begin{aligned} \eta(\frac{L_t^U}{H_t^U})^{\eta-1} L_t + (1-\eta)(\frac{L_t^U}{H_t^U})^{\eta} H_t &= \frac{1}{\alpha}(L_t^U)^{\eta}(H_t^U)^{1-\eta} \\ \theta(\frac{L_t^S}{H_t^S})^{\theta-1} L_t + (1-\theta)(\frac{L_t^S}{H_t^S})^{\theta} H_t &= \frac{1}{\beta}(L_t^S)^{\theta}(H_t^S)^{1-\theta}. \end{aligned}$$

Hence,

$$\begin{aligned} \eta \frac{L_t}{L_t^U} + (1-\eta)\frac{H_t}{H_t^U} &= \frac{1}{\alpha} \\ \theta \frac{L_t}{L_t^S} + (1-\theta)\frac{H_t}{H_t^S} &= \frac{1}{\beta}. \end{aligned}$$

Because

$$\begin{aligned} (\alpha+\beta)L_t &= L_t^U + L_t^S \\ (\alpha+\beta)H_t &= H_t^U + H_t^S, \end{aligned}$$

we obtain

$$\begin{aligned} \eta \frac{L_t^S}{L_t^U} + (1-\eta)\frac{H_t^S}{H_t^U} &= \frac{\beta}{\alpha} \\ \theta \frac{L_t^U}{L_t^S} + (1-\theta)\frac{H_t^U}{H_t^S} &= \frac{\alpha}{\beta}. \end{aligned}$$

Also the skill premia in two sectors are equalized,

$$r_t = \frac{1-\eta}{\eta}\frac{L_t^U}{H_t^U} = \frac{1-\theta}{\theta}\frac{L_t^S}{H_t^S},$$

which equals

$$\frac{1-\eta}{\eta}\frac{L_t^U}{L_t^S} = \frac{1-\theta}{\theta}\frac{H_t^U}{H_t^S}.$$

Therefore, we have

$$\frac{L_t^U}{L_t^S} = \frac{\eta}{1-\eta}\frac{1-\theta}{\theta}\frac{H_t^U}{H_t^S}$$

Plugging this equation into the market clearing condition, we have

$$\frac{1-\theta}{1-\eta}\frac{H_t^U}{H_t^S} = \frac{\alpha}{\beta}$$

$$H_t^U = \frac{\alpha}{\beta}\frac{1-\eta}{1-\theta}H_t^S$$

Therefore,

$$\begin{aligned}
H_t^S &= \frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}H_t^U \\
(\alpha+\beta)H_t &= (\frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}+1)H_t^U \\
H_t^U &= \frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}+1}H_t \\
H_t^S &= \frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{1-\eta}{1-\theta}+1}H_t.
\end{aligned}$$

With H_t^U and H_t^S solved, we can easily get L_t^U and L_t^S:

$$\begin{aligned}
\frac{1-\eta}{\eta}\frac{L_t^U}{L_t^S} &= \frac{1-\theta}{\theta}\frac{H_t^U}{H_t^S} = \frac{\alpha}{\beta}\frac{1-\eta}{\theta} \\
L_t^U &= \frac{\alpha}{\beta}\frac{\eta}{\theta}L_t^S \\
(\frac{\alpha}{\beta}\frac{\eta}{\theta}+1)L_t^S &= (\alpha+\beta)L_t \\
L_t^S &= \frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{\eta}{\theta}+1}L_t \\
L_t^U &= \frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{\theta}{\eta}+1}L_t.
\end{aligned}$$

Therefore we obtain the equilibrium skill premium:

$$\begin{aligned}
r_t &= \frac{1-\eta}{\eta}\frac{L_t^U}{H_t^U} = \frac{1-\theta}{\theta}\frac{L_t^S}{H_t^S} = \frac{\tau^H}{\tau^L} = \tau \\
&= \frac{1-\eta}{\eta}\frac{\frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{\theta}{\eta}+1}L_t}{\frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}+1}H_t} = \frac{1-\eta}{\eta}\frac{\frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}+1}{\frac{\beta}{\alpha}\frac{\theta}{\eta}+1}\frac{L_t}{H_t} = \frac{\frac{\beta}{\alpha}(1-\theta)+1-\eta}{\frac{\beta}{\alpha}\theta+\eta}\frac{L_t}{H_t} \\
&= \frac{1-\theta}{\theta}\frac{\frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{\eta}{\theta}+1}L_t}{\frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{1-\eta}{1-\theta}+1}H_t} = \frac{1-\theta}{\theta}\frac{\frac{\alpha}{\beta}\frac{1-\eta}{1-\theta}+1}{\frac{\alpha}{\beta}\frac{\eta}{\theta}+1}\frac{L_t}{H_t} = \frac{\frac{\alpha}{\beta}(1-\eta)+1-\theta}{\frac{\alpha}{\beta}\eta+\theta}\frac{L_t}{H_t}.
\end{aligned}$$

Q.E.D..

Proof of Proposition 2

We already know that:

$$\tau^{H,L} < \tau^{L,L} < \tau^{H,H} < \tau^{L,H}$$

and

$$\frac{\tau^{H,H}}{\tau^{H,L}} \leq r_t = \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta\theta+\alpha\eta}\frac{L_t}{H_t} \leq \frac{\tau^{L,H}}{\tau^{L,L}}$$

Case 1: if

$$r_{t+1} = \frac{\tau^{H,H}}{\tau^{H,L}} < \frac{\tau^{L,H}}{\tau^{L,L}},$$

then

$$n_t^{L,H} = 0$$

$$n_t^{L,L} = \frac{1-\alpha-\beta}{\tau^{L,L}}$$

$$\tau^{H,H} n_t^{H,H} + \tau^{H,L} n_t^{H,L} = 1-\alpha-\beta$$

where $n_t^{H,H} > 0$ and $n_t^{H,L} \geq 0$.

From the population dynamics, we have

$$\begin{array}{l} L_{t+1} = L_t \frac{1-\alpha-\beta}{\tau^{L,L}} + H_t n_t^{H,L} \\ H_{t+1} = H_t n_t^{H,H} \end{array}$$

Therefore,

$$\begin{aligned} \frac{L_{t+1}}{H_{t+1}} &= \frac{1-\alpha-\beta}{\tau^{L,L} n_t^{H,H}}\frac{L_t}{H_t} + \frac{n_t^{H,L}}{n_t^{H,H}} \\ &\geq \frac{1-\alpha-\beta}{\tau^{L,L} n_t^{H,H}}\frac{L_t}{H_t} \end{aligned}$$

Because

$$1-\alpha-\beta = \tau^{H,H} n_t^{H,H} + \tau^{H,L} n_t^{H,L}$$

We have

$$\frac{L_{t+1}}{H_{t+1}} \geq \frac{\tau^{H,H} n_t^{H,H} + \tau^{H,L} n_t^{H,L}}{\tau^{L,L} n_t^{H,H}}\frac{L_t}{H_t} > \frac{\tau^{H,H} n_t^{H,H}}{\tau^{L,L} n_t^{H,H}}\frac{L_t}{H_t} = \frac{\tau^{H,H}}{\tau^{L,L}}\frac{L_t}{H_t}$$

Clearly, this is not a steady state.

Case 2: if

$$\frac{\tau^{H,H}}{\tau^{H,L}} < r_{t+1} = \frac{w_{t+1}^H}{w_{t+1}^L} < \frac{\tau^{L,H}}{\tau^{L,L}}$$

In this case, each type of labor only produces their own type of children, which means $n_t^{L,H} = 0$, $n_t^{L,L} = \frac{1-\alpha-\beta}{\tau^{L,L}}$, $n_t^{H,H} = \frac{1-\alpha-\beta}{\tau^{H,H}}$ and $n_t^{H,L} = 0$.

Therefore,

$$L_{t+1} = L_t \tfrac{1-\alpha-\beta}{\tau^{L,L}}$$
$$H_{t+1} = H_t \tfrac{1-\alpha-\beta}{\tau^{H,H}}$$

$$\frac{L_{t+1}}{H_{t+1}} = \frac{\tau^{H,H}}{\tau^{L,L}} \frac{L_t}{H_t} > \frac{L_t}{H_t}$$

This is not a steady state either.

Case 3: if

$$\frac{\tau^{H,H}}{\tau^{H,L}} < r_{t+1} = \frac{w_{t+1}^H}{w_{t+1}^L} = \frac{\tau^{L,H}}{\tau^{L,L}}$$

Therefore, $n_t^{H,H} = \frac{1-\alpha-\beta}{\tau^{H,H}}$, $n_t^{H,L} = 0$, $\tau^{L,H} n_t^{L,H} + \tau^{L,L} n_t^{L,L} = 1 - \alpha - \beta$, where $n_t^{L,H} \geq 0$ and $n_t^{L,L} > 0$.

Because

$$L_{t+1} = L_t n_t^{L,L}$$
$$H_{t+1} = L_t n_t^{L,H} + H_t \tfrac{1-\alpha-\beta}{\tau^{H,H}}$$

$$\frac{H_{t+1}}{L_{t+1}} = \frac{1-\alpha-\beta}{\tau^{H,H} n_t^{L,L}} \frac{H_t}{L_t} + \frac{n_t^{L,H}}{n_t^{L,L}}$$

So,

$$\frac{1}{\overline{r}} = \frac{1-\alpha-\beta}{\tau^{H,H} n_t^{L,L}} \frac{1}{\overline{r}} + \frac{\beta\theta + \alpha\eta}{\beta(1-\theta) + \alpha(1-\eta)} \frac{n_t^{L,H}}{n_t^{L,L}}$$

Finally we obtain the steady state values:

$$n_t^{H,H} = \tfrac{1-\alpha-\beta}{\tau^{H,H}}$$
$$n_t^{H,L} = 0$$
$$n_t^{L,H} = \tfrac{\beta(1-\theta)+\alpha(1-\eta)}{\alpha+\beta} \tfrac{\tau^{H,H} - \tau^{L,L}}{\tau^{H,H}\tau^{L,H}} (1-\alpha-\beta)$$
$$n_t^{L,L} = \tfrac{(\beta\theta+\alpha\eta)\tau^{H,H} + \{\beta(1-\theta)+\alpha(1-\eta)\}\tau^{L,L}}{(\alpha+\beta)\tau^{L,L}\tau^{L,H}} (1-\alpha-\beta)$$

The ratio of unskilled and skilled labor is

$$\frac{L}{H} = \frac{\beta\theta + \alpha\eta}{\beta(1-\theta) + \alpha(1-\eta)} \overline{r} = \frac{\beta\theta + \alpha\eta}{\beta(1-\theta) + \alpha(1-\eta)} \frac{\tau^{L,H}}{\tau^{L,L}}$$

and

$$H_t^U = \tfrac{\alpha(1-\eta)(\alpha+\beta)}{\beta(1-\theta)+\alpha(1-\eta)} H_t$$
$$H_t^S = \tfrac{\beta(1-\theta)(\alpha+\beta)}{\beta(1-\theta)+\alpha(1-\eta)} H_t$$
$$L_t^U = \tfrac{\alpha\eta(\alpha+\beta)}{\beta\theta+\alpha\eta} L_t$$
$$L_t^S = \tfrac{\beta\theta(\alpha+\beta)}{\beta\theta+\alpha\eta} L_t$$

$$
\begin{aligned}
p_t &= \frac{A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta-1}}{A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta-1}} \\
&= \frac{A_t^S \theta}{A_t^U \eta} \{ \frac{\beta\theta(\alpha+\beta)}{\beta\theta+\alpha\eta} \frac{\beta(1-\theta)+\alpha(1-\eta)}{\beta(1-\theta)(\alpha+\beta)} \}^{\theta-1} \{ \frac{\alpha\eta(\alpha+\beta)}{\beta\theta+\alpha\eta} \frac{\beta(1-\theta)+\alpha(1-\eta)}{\alpha(1-\eta)(\alpha+\beta)} \}^{1-\eta} (\frac{L_t}{H_t})^{\theta-\eta} \\
&= \frac{A_t^S}{A_t^U} \frac{\theta^\theta (1-\theta)^{1-\theta}}{\eta^\eta (1-\eta)^{1-\eta}} (\frac{\tau^{L,H}}{\tau^{L,L}})^{\theta-\eta}
\end{aligned}
$$

and

$$
\begin{aligned}
\frac{Y_{t+1}^U}{Y_t^U} &= (\frac{L_{t+1}^U}{L_t^U})^\eta (\frac{H_{t+1}^U}{H_t^U})^{1-\eta} = (\frac{L_{t+1}}{L_t})^\eta (\frac{H_{t+1}}{H_t})^{1-\eta} \\
&= \frac{L_{t+1}}{L_t} (\frac{H_{t+1}}{L_{t+1}})^{1-\eta} (\frac{L_t}{H_t})^{1-\eta} = \frac{L_{t+1}}{L_t} \\
&= \frac{(\beta\theta+\alpha\eta)\tau^{H,H} + \{\beta(1-\theta)+\alpha(1-\eta)\}\tau^{L,L}}{(\alpha+\beta)\tau^{L,L}\tau^{L,H}} (1-\alpha-\beta)
\end{aligned}
$$

$$
\begin{aligned}
\frac{Y_{t+1}^S}{Y_t^S} &= (\frac{L_{t+1}^S}{L_t^S})^\theta (\frac{H_{t+1}^S}{H_t^S})^{1-\theta} = (\frac{L_{t+1}}{L_t})^\theta (\frac{H_{t+1}}{H_t})^{1-\theta} \\
&= \frac{L_{t+1}}{L_t} (\frac{H_{t+1}}{L_{t+1}})^{1-\theta} (\frac{L_t}{H_t})^{1-\theta} = \frac{L_{t+1}}{L_t} \\
&= \frac{(\beta\theta+\alpha\eta)\tau^{H,H} + \{\beta(1-\theta)+\alpha(1-\eta)\}\tau^{L,L}}{(\alpha+\beta)\tau^{L,L}\tau^{L,H}} (1-\alpha-\beta)
\end{aligned}
$$

Q.E.D..

Proof of Proposition 3

From (**??**), we have:

$$
\frac{L_t^S}{H_t^S} = \frac{\frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{\eta}{\theta}+1} L_t}{\frac{\alpha+\beta}{\frac{\alpha}{\beta}\frac{1-\eta}{1-\theta}+1} H_t} == \frac{\alpha\theta - \alpha\theta\eta + \beta\theta - \beta\theta^2}{\alpha\eta - \alpha\theta\eta + \beta\theta - \beta\theta^2} \frac{L_t}{H_t},
$$

and

$$
\frac{L_t^U}{H_t^U} = \frac{\frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{\theta}{\eta}+1} L_t}{\frac{\alpha+\beta}{\frac{\beta}{\alpha}\frac{1-\theta}{1-\eta}+1} H_t} = \frac{\beta\eta - \beta\theta\eta + \alpha\eta - \alpha\eta^2}{\beta\theta - \beta\theta\eta + \alpha\eta - \alpha\eta^2} \frac{L_t}{H_t}.
$$

Plugging these results into (**??**) and simplifiying, we have:

$$
p_t = \frac{A_t^M \theta (\frac{L_t^S}{H_t^S})^{\theta-1}}{A_t^A \eta (\frac{L_t^U}{H_t^U})^{\eta-1}} = \frac{A_t^M}{A_t^A} \frac{\theta}{\eta} \frac{(\frac{\alpha\theta-\alpha\theta\eta+\beta\theta-\beta\theta^2}{\alpha\eta-\alpha\theta\eta+\beta\theta-\beta\theta^2})^{\theta-1}}{(\frac{\beta\eta-\beta\theta\eta+\alpha\eta-\alpha\eta^2}{\beta\theta-\beta\theta\eta+\alpha\eta-\alpha\eta^2})^{\eta-1}} (\frac{L_t}{H_t})^{\theta-\eta}.
$$

Therefore, taking into account that the two economies are identical except for their relative factor abundance, we obtain:

$$\frac{p_t^A}{p_t^B} = (\frac{[\frac{L_t}{H_t}]^A}{[\frac{L_t}{H_t}]^B})^{\theta-\eta}.$$

Given that $(\frac{L_t}{H_t})^A < (\frac{L_t}{H_t})^B$ and $\eta > \theta$, we have

$$\frac{p_t^A}{p_t^B} > 1.$$

Q.E.D..

Proof of Proposition 4

In the open economy, the unskilled-labor-abundant country specializes in producing and export the labor-intensive product, and imports the skill-labor-abundant product. Thus, the market clearing condition no longer holds. However, Lemma 1 and Lemma 2 still hold. Given Lemma 1, Lemma 2 and the fact that all the productive labor now works in producing the labor-intensive product, we have

$$\begin{aligned}(\alpha+\beta)L_t &= L_t^U \\ (\alpha+\beta)H_t &= H_t^U.\end{aligned}$$

Plugging these into the formula for the skill premium, we obtain the skill premium in the open economy equilibrium:

$$r_t = \frac{1-\eta}{\eta}\frac{L_t^U}{H_t^U} = \frac{1-\eta}{\eta}\frac{L_t}{H_t}.$$

Q.E.D..

Proof of Proposition 6

To study the specialization patterns, we first need to study firm behaviors.

For the unskilled-intensive firm, the cost-minimizing problem is:

$$C_t^U = \min(w_t^L L_t^U + w_t^H H_t^U)$$

$$\text{s.t. } A_t^U (L_t^U)^\eta (H_t^U)^{1-\eta} \geq 1$$

The optimizing result is $C_t^{U*} = \frac{1}{A_t^U}(\frac{w_t^L}{\eta})^\eta(\frac{w_t^H}{1-\eta})^{1-\eta}$.

Similarly, for the skill-intensive firm, the minimized cost is $C_t^{S*} = \frac{1}{A_t^S}(\frac{w_t^L}{\theta})^\theta(\frac{w_t^H}{1-\theta})^{1-\theta}$.

Now we study the conditions of the three specialization patterns.

For the non-specialization pattern: first, we show that if the economy produces both commodities, the condition is satisfied.

The wages of unskilled and skilled labor in the open economy are

$$\begin{aligned} w_t^L &= p_t^* A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta-1} = A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta-1} \\ w_t^H &= p_t^* A_t^U (1-\eta)(\frac{L_t^U}{H_t^U})^{\eta} = A_t^S (1-\theta)(\frac{L_t^S}{H_t^S})^{\theta}. \end{aligned}$$

Therefore,

$$\frac{L_t^U}{H_t^U} = \frac{\eta(1-\theta)}{\theta(1-\eta)} \frac{L_t^S}{H_t^S}.$$

Because

$$p_t^* A_t^U \eta (\frac{L_t^U}{H_t^U})^{\eta-1} = A_t^S \theta (\frac{L_t^S}{H_t^S})^{\theta-1},$$

we have

$$\begin{aligned} \frac{L_t^S}{H_t^S} &= (p_t^*)(\frac{A_t^U}{A_t^S})^{\frac{1}{\theta-\eta}} (\frac{\eta}{\theta})^{\frac{\eta}{\theta-\eta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\theta-\eta}} \\ \frac{L_t^U}{H_t^U} &= (p_t^*)^{\frac{1}{\theta-\eta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\theta-\eta}} (\frac{\eta}{\theta})^{\frac{\theta}{\theta-\eta}} (\frac{1-\theta}{1-\eta})^{\frac{\theta-1}{\theta-\eta}}. \end{aligned}$$

With the aggregate labor allocation conditions:

$$\begin{aligned} L_t^U + L_t^S &= (\alpha+\beta)L_t \\ H_t^U + H_t^S &= (\alpha+\beta)H_t, \end{aligned}$$

we have

$$\begin{aligned} H_t^S &= \frac{\eta(1-\theta)}{\theta-\eta} \left[(p_t^*)^{\frac{1}{\eta-\theta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}} (\frac{\eta}{\theta})^{\frac{\theta}{\eta-\theta}} (\frac{1-\theta}{1-\eta})^{\frac{1-\theta}{\theta-\eta}} (\alpha+\beta)L_t - (\alpha+\beta)H_t \right] \\ H_t^U &= \frac{\eta(1-\theta)}{\theta-\eta} \left[\frac{\theta(1-\eta)}{\eta(1-\theta)} (\alpha+\beta)H_t - (p_t^*)^{\frac{1}{\eta-\theta}} (\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}} (\frac{\eta}{\theta})^{\frac{\theta}{\eta-\theta}} (\frac{1-\theta}{1-\eta})^{\frac{1-\theta}{\theta-\eta}} (\alpha+\beta)L_t \right]. \end{aligned}$$

Because $H_t^U > 0$, $H_t^S > 0$ and $0.5 < \eta < 1$, $0 < \theta < 0.5$, we obtain the result.

Second, we show that if the following condition is satisfied, the economy produces both commodities:

$$\frac{H_t}{L_t} < p_t^* (\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}} (\frac{\eta}{\theta})^{\frac{\eta}{\eta-\theta}} (\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\eta-\theta}} < \frac{\eta}{\theta} \frac{1-\theta}{1-\eta} \frac{H_t}{L_t}.$$

Suppose $L_t^U = 0, H_t^U = 0$, we have

$$\begin{aligned} w_t^L &= A_t^S \theta (\frac{L_t}{H_t})^{\theta-1} \\ w_t^H &= A_t^S (1-\theta)(\frac{L_t}{H_t})^{\theta}. \end{aligned}$$

Then

$$C_t^U = \frac{A_t^S}{A_t^U}(\frac{\theta}{\eta})^{\eta}(\frac{1-\theta}{1-\eta})^{1-\eta}(\frac{L_t}{H_t})^{\theta-\eta}.$$

Because

$$\frac{H_t}{L_t} < (p_t^*)^{\frac{1}{\eta-\theta}}(\frac{A_t^U}{A_t^S})^{\frac{1}{\eta-\theta}}(\frac{\eta}{\theta})^{\frac{\eta}{\eta-\theta}}(\frac{1-\theta}{1-\eta})^{\frac{\eta-1}{\eta-\theta}},$$

we have $C_t^U < p_t^*$.

Therefore,the labor-intensive good will be produced.

Similarly, if $L_t^S = 0, H_t^S = 0$, we have $C_t^S < 1$, which means the skilled-intensive good will be produced.

By the same token, we can prove the conditions for full specializations.

Appendix III. Data on the Skill Premium

Yan (2007) constructs detailed estimates of real wages and skill premia for China between 1858 and 1936. Nominal wages are collected from the records of employees in the CMC for nearly fifty Chinese cities, and the wage series are estimated from these records using the Hedonic regression method. The author also constructs group-specific cost of living indices from price data and household budget information contained in CMC trade statistics and surveys. The resulting nominal wage series and cost of living indices make it possible to estimate long-run trends in real wages and skill premia for three basic categories of Chinese workers: unskilled, skilled, and highly skilled. 44,600 wage observations are collected from CMC archives. Roughly half of the archives pertain to labor, which include surveys of local wages and standards of living, CMC wage scales, and most importantly, the Service Lists – that is, the individual personnel records of CMC employees. In each year the Service Lists recorded each employee's name, home town, year of joining the service, year of being promoted, year transfer to the current customhouse, rank, and monthly salary.

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Table 1. Ranking of Industries by Educational Attainment

IND1950	Industry	Fraction of Skilled Employees
377	Aircraft and parts	0.72
459	Printing, publishing, and allied industries	0.68
357	Office and store machines	0.64
386	Professional equipment	0.62
367	Electrical machinery, equipment and supplies	0.62
476	Petroleum refining	0.59
468	Paints, varnishes, and related products	0.58
458	Misc paper and pulp products	0.57
407	Dairy products	0.57
346	Fabricated steel products	0.55
478	Rubber products	0.54
226	Crude petroleum and natural gas extraction	0.54
466	Synthetic fibers	0.54
358	Misc machinery	0.54
469	Misc chemicals and allied products	0.53
356	Agricultural machinery and tractors	0.53
418	Beverage industries	0.52
388	Watches, clocks, and clockwork-operated devices	0.52
409	Grain-mill products	0.51
416	Bakery products	0.51
449	Misc fabricated textile products	0.49
376	Motor vehicles and motor vehicle equipment	0.49
316	Glass and glass products	0.48
338	Primary nonferrous industries	0.48
436	Knitting mills	0.48
457	Paperboard containers and boxes	0.47
426	Not specified food industries	0.47
456	Pulp, paper, and paper-board mills	0.47
417	Confectionary and related products	0.47
406	Meat products	0.46

Note: Traded goods were classified into industries using the IND1950 described in the text. Educational attainment is derived using 1940 US census. Please see the text for details.

Table 1. Ranking of Industries by Educational Attainment (continued)

IND1950	Industry	Fraction of Skilled Employees
489	Leather products, except footwear	0.46
378	Ship and boat building and repairing	0.45
487	Leather: tanned, curried, and finished	0.45
337	Other primary iron and steel industries	0.44
477	Misc petroleum and coal products	0.44
379	Railroad and misc transportation equipment	0.44
488	Footwear, except rubber	0.43
326	Misc nonmetallic mineral and stone products	0.43
408	Canning and preserving fruits, vegetables, and seafood	0.43
319	Pottery and related prods	0.43
446	Misc textile mill products	0.42
437	Dyeing and finishing textiles, except knit goods	0.42
308	Misc wood products	0.42
309	Furniture and fixtures	0.42
348	Not specified metal industries	0.41
206	Metal mining	0.41
336	Blast furnaces, steel works, and rolling mills	0.4
317	Cement, concrete, gypsum and plaster products	0.4
448	Apparel and accessories	0.39
116	Forestry	0.37
438	Carpets, rugs, and other floor coverings	0.35
318	Structural clay products	0.33
439	Yarn, thread, and fabric	0.32
246	Construction	0.31
429	Tobacco manufactures	0.3
307	Sawmills, planting mills, and mill work	0.28
236	Nonmetallic mining and quarrying, except fuel	0.27
126	Fisheries	0.26
105	Agriculture	0.22
306	Logging	0.22
216	Coal mining	0.2

Table 2. Ranking of Industries by Log Wages

IND1950	Industry	Log Wage
476	Petroleum refining	3.207
226	Crude petroleum and natural gas extraction	3.127
468	Paints, varnishes, and related products	3.126
378	Ship and boat building and repairing	3.124
459	Printing, publishing, and allied industries	3.124
357	Office and store machines	3.122
358	Misc machinery	3.109
418	Beverage industries	3.1
469	Misc chemicals and allied products	3.099
376	Motor vehicles and motor vehicle equipment	3.098
367	Electrical machinery, equipment and supplies	3.095
386	Professional equipment	3.092
478	Rubber products	3.092
336	Blast furnaces, steel works, and rolling mills	3.091
356	Agricultural machinery and tractors	3.078
346	Fabricated steel products	3.075
406	Meat products	3.07
377	Aircraft and parts	3.067
407	Dairy products	3.06
337	Other primary iron and steel industries	3.055
338	Primary nonferrous industries	3.055
456	Pulp, paper, and paper-board mills	3.048
316	Glass and glass products	3.047
348	Not specified metal industries	3.045
317	Cement, concrete, gypsum and plaster products	3.036
416	Bakery products	3.032
426	Not specified food industries	3.031
379	Railroad and misc transportation equipment	3.03
487	Leather: tanned, curried, and finished	3.028
326	Misc nonmetallic mineral and stone products	3.024
466	Synthetic fibers	3.023
388	Watches, clocks, and clockwork-operated devices	3.02

Note: Traded goods were classified into industries using the IND1950 described in the text. Log wage is derived using 1940 US census. Please see the text for details.

Table 2. Ranking of Industries by Log Wages (continued)

IND1950	Industry	Log Wage
477	Misc petroleum and coal products	3.017
409	Grain-mill products	3.011
458	Misc paper and pulp products	3.007
206	Metal mining	3.006
319	Pottery and related products	2.986
446	Misc textile mill products	2.984
438	Carpets, rugs, and other floor coverings	2.973
318	Structural clay products	2.954
457	Paperboard containers and boxes	2.953
309	Furniture and fixtures	2.943
437	Dyeing and finishing textiles, except knit goods	2.937
308	Misc wood products	2.931
489	Leather products, except footwear	2.913
417	Confectionary and related products	2.905
216	Coal mining	2.9
436	Knitting mills	2.897
488	Footwear, except rubber	2.886
429	Tobacco manufactures	2.865
236	Nonmetallic mining and quarrying, except fuel	2.85
439	Yarn, thread, and fabric	2.847
408	Canning and preserving fruits, vegetables, and seafood	2.827
307	Sawmills, planting mills, and mill work	2.815
448	Apparel and accessories	2.812
246	Construction	2.796
449	Misc fabricated textile products	2.79
306	Logging	2.703
116	Forestry	2.682
126	Fisheries	2.666
105	Agriculture	2.095

Table 3. Ranking of Industries by the 1928 Shanghai Survey

Industry Code	Industry Name	Capital-Labor Ratio Unit: Chinese Yuan per worker
93	Electric and water works	10628.86
46	Condiments	5169.01
26	Medicine	4356.16
47	Cigars and cigarettes	4298.39
71	Metal products	3746.26
27	Manufacture of paper	3118.92
31	Manufacture of varnish	2099.24
29	Manufacture of enameled ware	2009.51
73	Musical instruments and toys	1810.9
28	Match making	1668.87
91	Building material	1582.64
25	Glassware	1342.49
63	Founding	1163.01
86	Clothing	1142.16
92	Coal briquettes	1140.46
23	Cosmetics	977.14
74	Scientific apparatus	955.95
41	Wheat flour mills	900.91
43	Oil mills	881.55
45	Frozen egg products	782.83
32	Other chemical	739.37
51	Printing	727.67
81	Hats	722.83
75	Other tools and instruments	641.51
21	Dyeing and printing of textiles	618.92
48	Candies and canned food	598
49	Other food	501.96

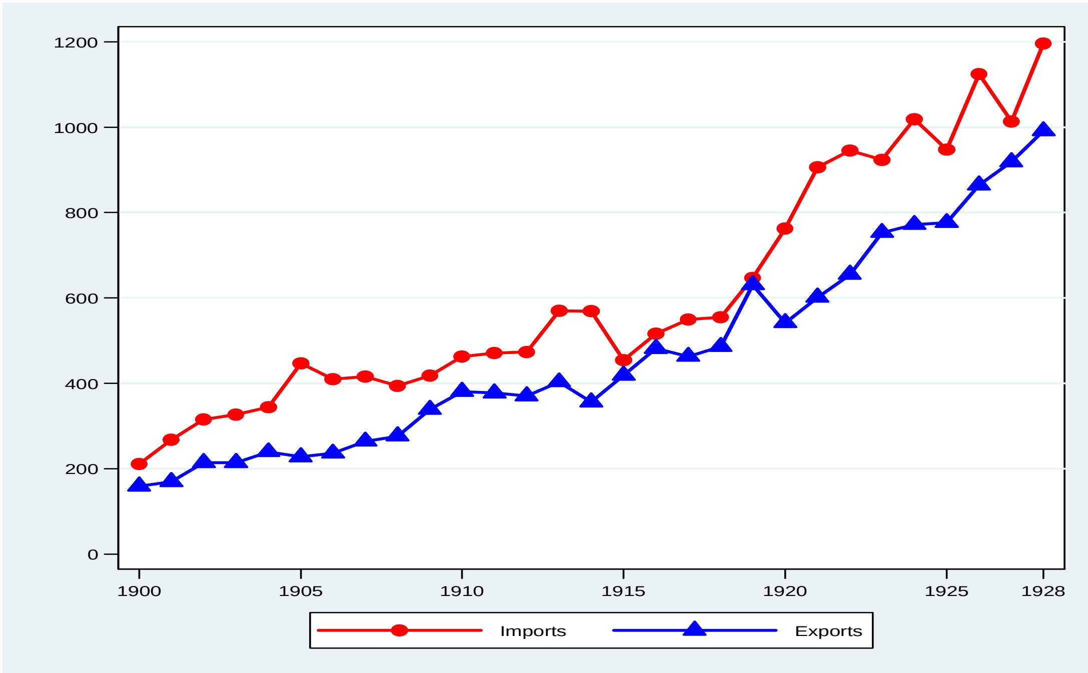
Note: Traded goods were classified into industries using the 1928 Shanghai survey data described in the text. Capital-labor ratio is derived using this survey too. Please see the text for details.

Table 3. Ranking of Industries by the 1928 Shanghai Survey (continued)

Industry Code	Industry Name	Capital-Labor Ratio
16	Knitted goods	488.5
17	Other textile	477.26
62	Manufacture of electrical instruments	396.32
94	Trimmings and ribbons	387.11
82	Umbrellas	379.27
11	Cotton spinning	357.99
97	Other miscellaneous industries	344.68
83	Brushes	325.1
84	Writing outfit	294.87
12	Cotton weaving	277.37
15	Wool weaving	258.09
22	Leather manufacturing	241.06
64	Shipbuilding	240.55
14	Silk weaving	204.25
96	Cotton ginning	203.19
85	Spectacles	188.54
72	Wooden, rattan, and bamboo articles	146.68
44	Soda water and other soft drinks	129.78
24	Soap and candles	127.62
87	Other daily necessities	114.09
61	Manufacture and repairing of machines	81.27
42	Rice mills	59.77
13	Silk reeling	47.69
95	Cartons	38.1

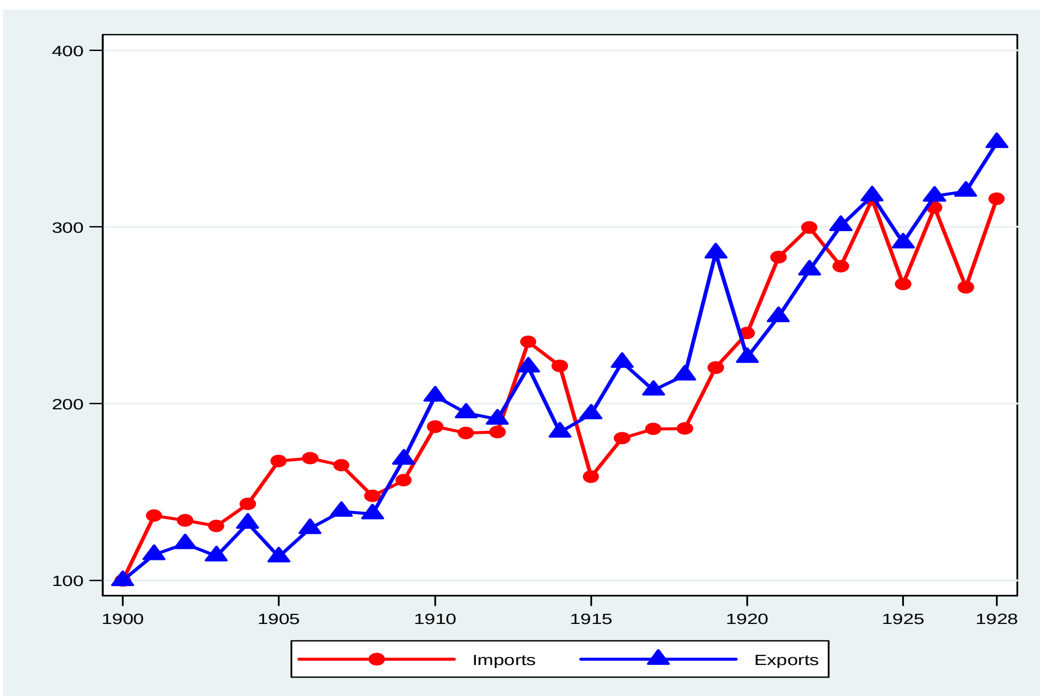
Figure 1. The Value of China's Foreign Trade

Panel A: Nominal value of trade Unit: thousand Haikwan Tael



Source: Hsiao (1974)

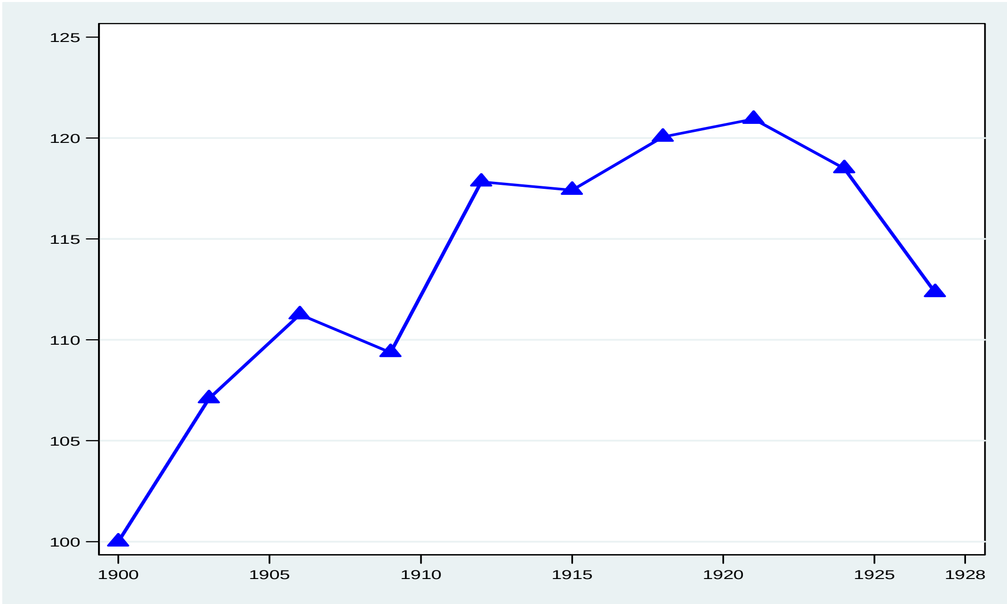
Panel B: Real value of trade Index: 1900=100



Source: Authors' calculations based on data from Hsiao (1974)

Figure 2. Real Wage Premium in China

Index: 1900=100



Source: Yan (2008)

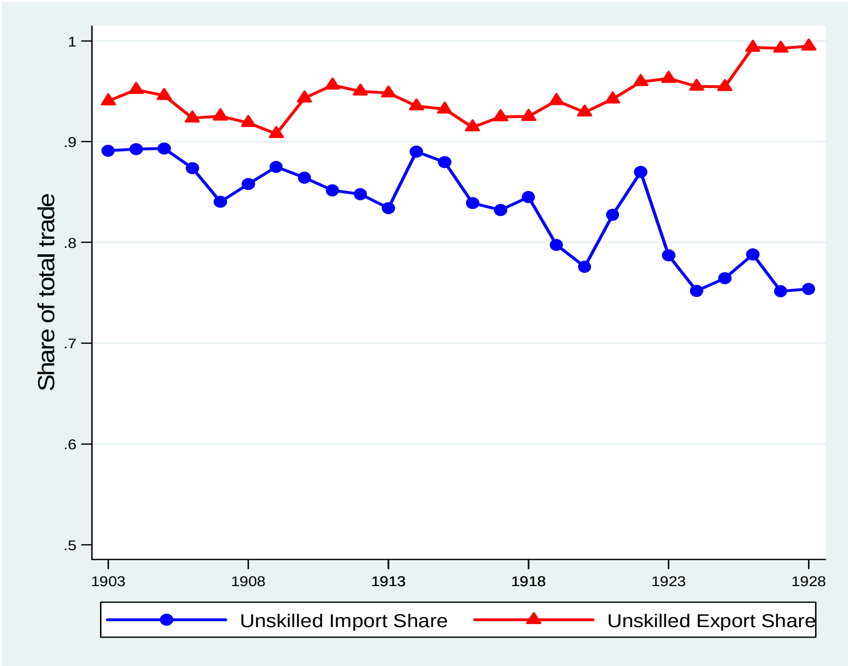
Figure 3 Quantities of Foreign Imports and Exports of Cotton Yarn, 1910-1935

Unit: thousand piculs

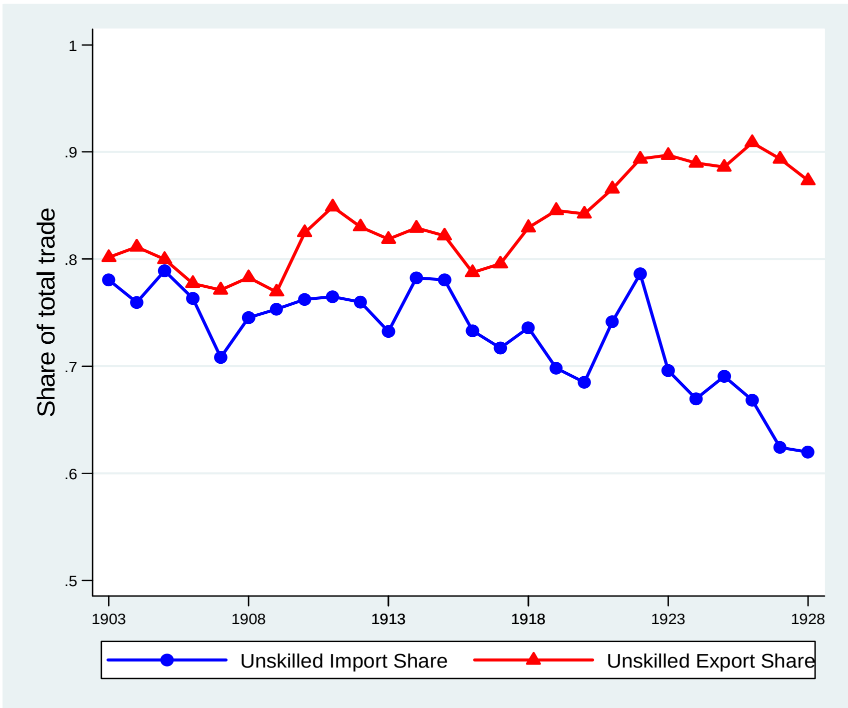
Source: Hsiao (1974)

Figure 4. Unskilled Export and Import Shares, 1903-1928

Panel A: Unskilled trade as classified by educational attainment



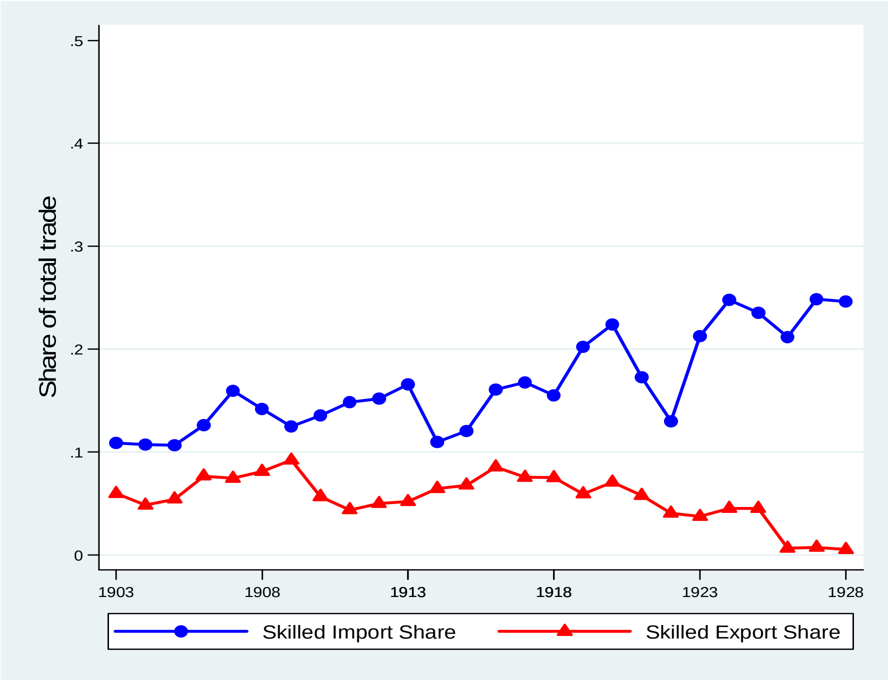
Panel B: Unskilled trade as classified by log wage



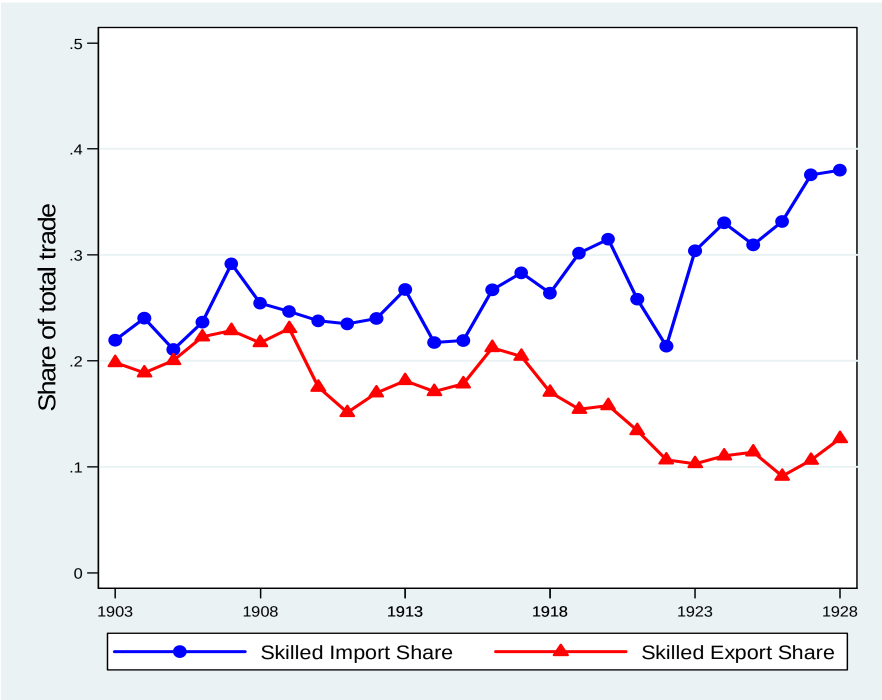
Notes: Authors' calculations based on data from the 1940 US census. See the text for a description of the educational attainment and average wages.

Figure 5. Skilled Export and Import Shares, 1903-1928

Panel A: classified by educational attainment



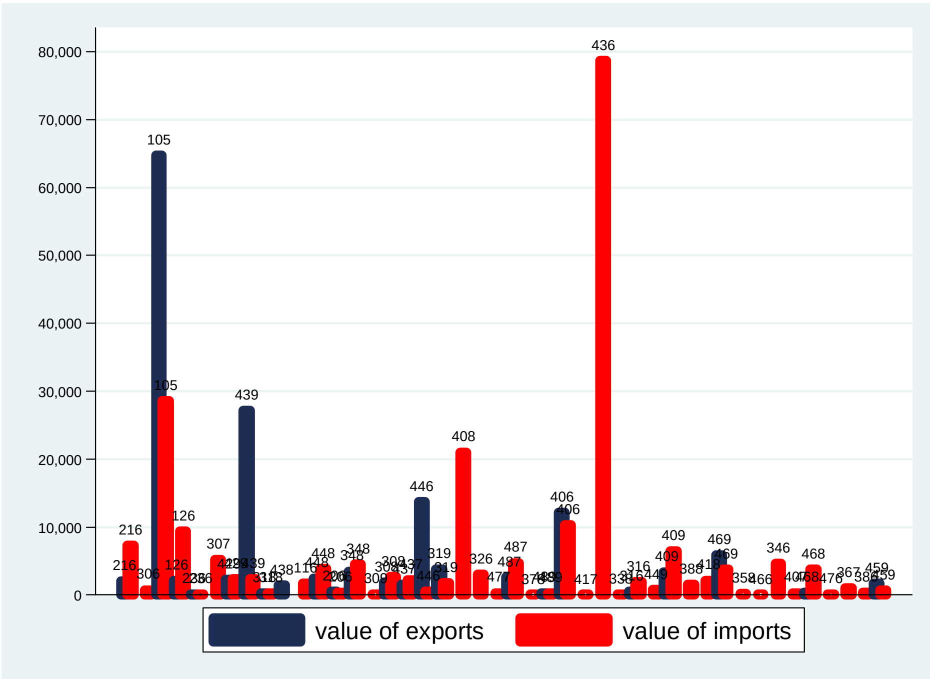
Panel B: classified by log wage



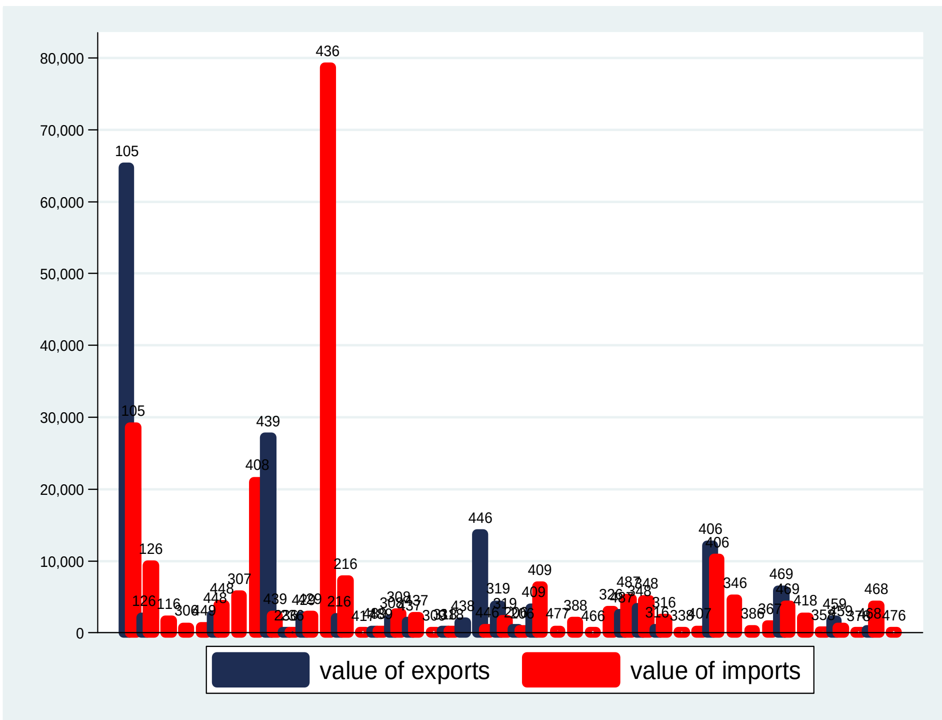
Notes: Authors' calculations are based on data from US 1940 census. See the text for the description of educational attainment and average wages.

Figure 6. Value of Exports and Imports by Skill Intensity, 1903

Panel A: classified by educational attainment Unit: thousand Haikwan Tael



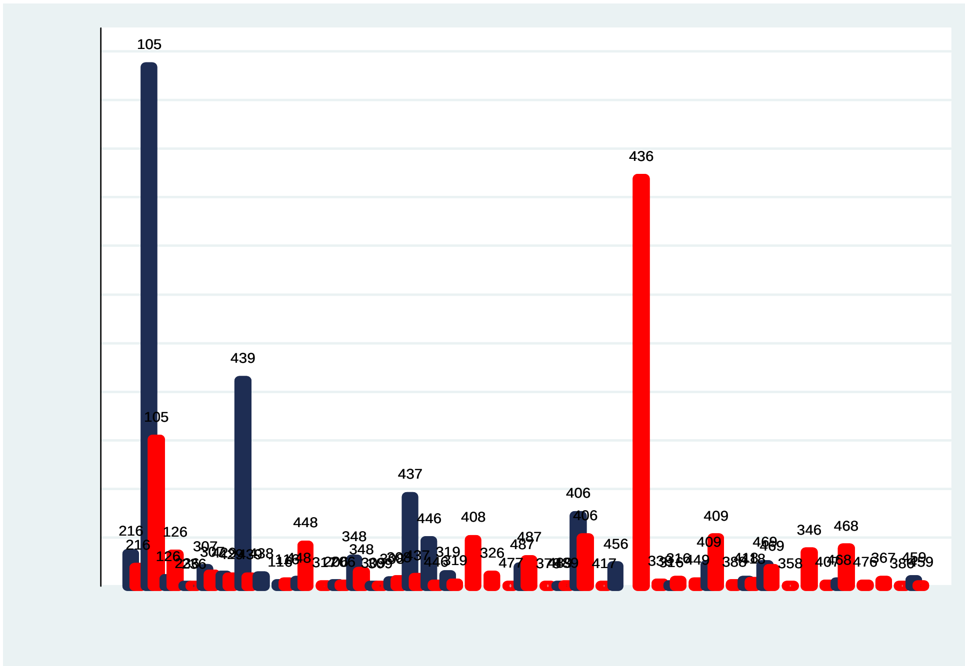
Panel B: classified by log wage Unit: thousand Haikwan Tael



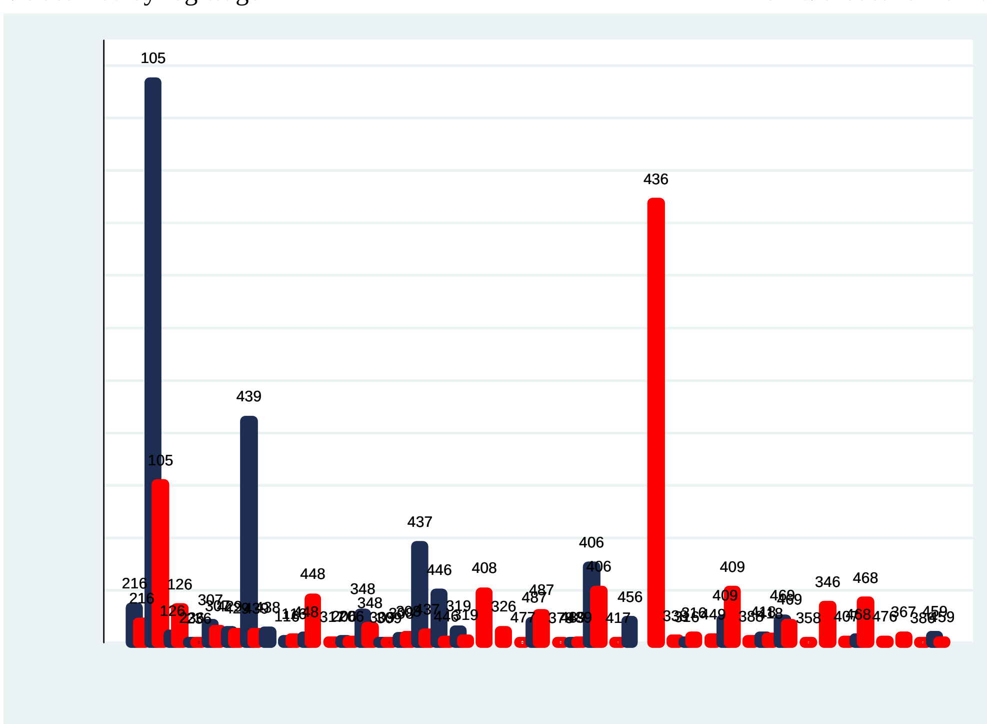
Source: Authors' calculation as described in the text. Numbers on individual bars correspond to industry codes listed in Tables 1 and 2.

Figure 7. Value of Exports and Imports by Skill Intensity, 1913

Panel A: classified by educational attainment Unit: thousand Haikwan Tael



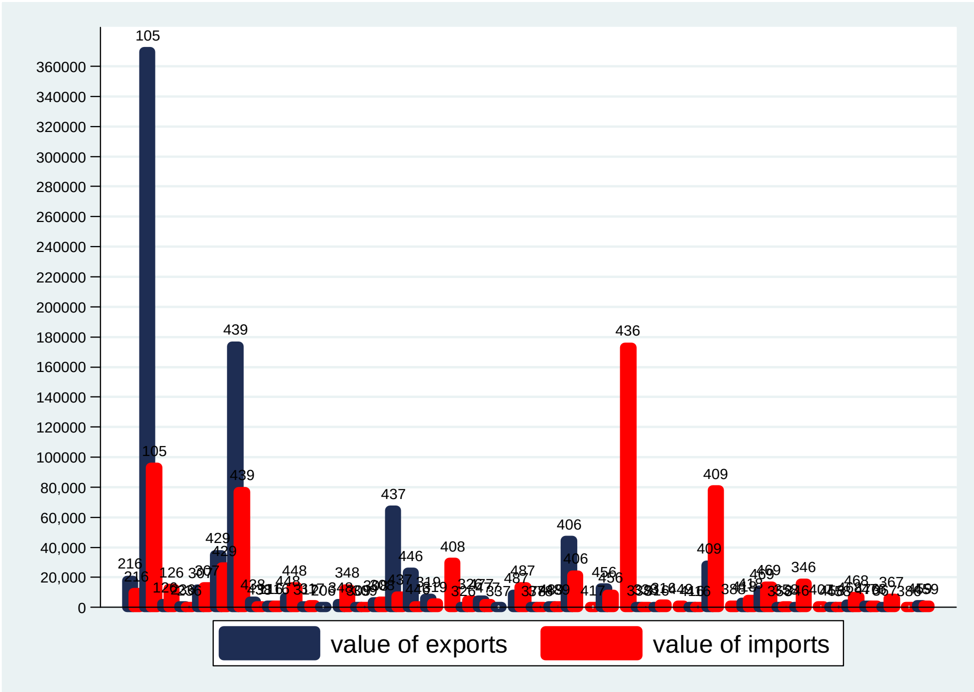
Panel B: classified by log wage Unit: thousand Haikwan Tael



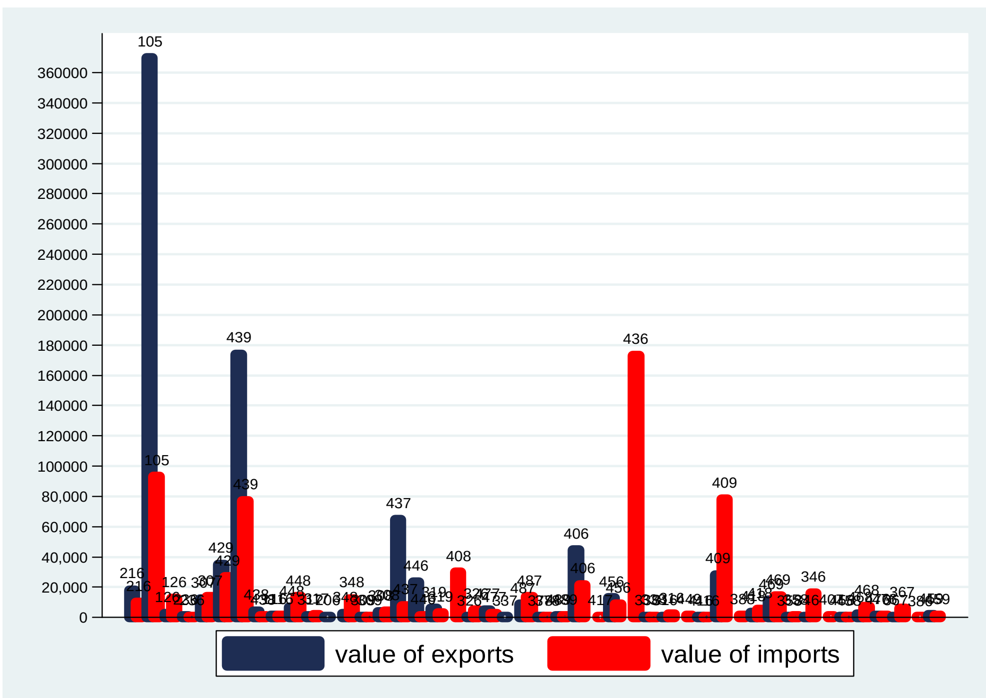
Source: Authors' calculation as described in the text. Numbers on individual bars correspond to industry codes listed in Tables 1 and 2.

Figure 8. Value of Exports and Imports by Skill Intensity, 1919

Panel A: classified by educational attainment — Unit: thousand Haikwan Tael



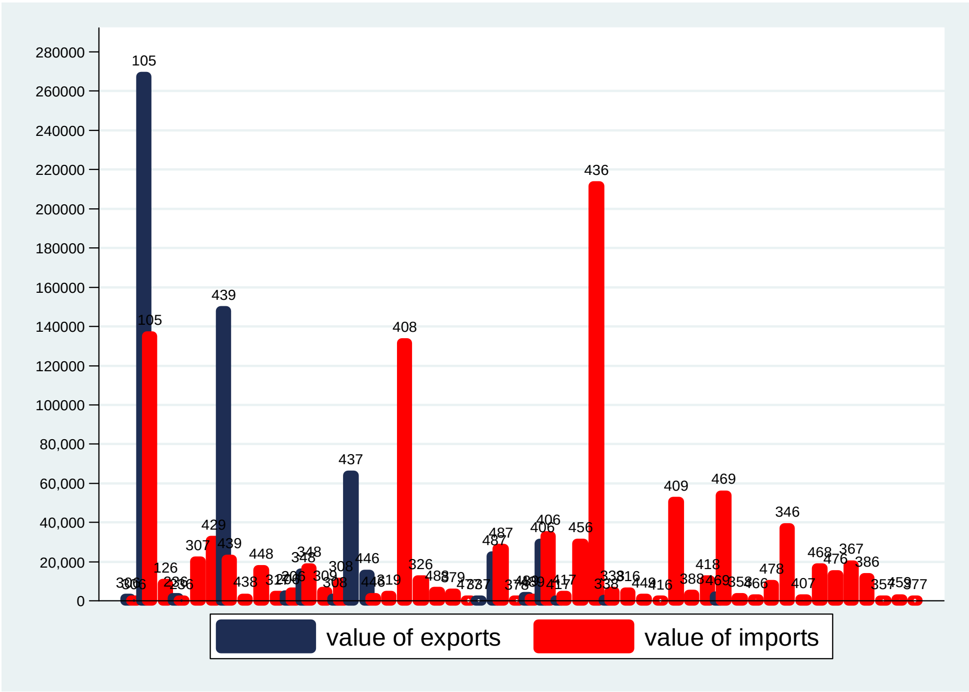
Panel B: classified by log wage — Unit: thousand Haikwan Tael



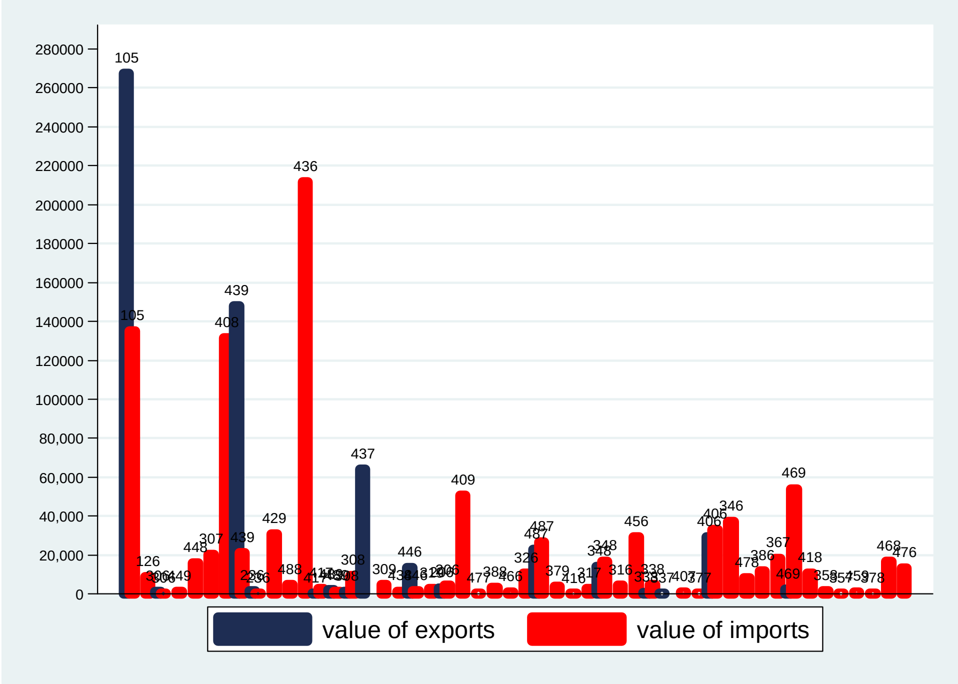
Source: Authors' calculation as described in the text. Numbers on individual bars correspond to industry codes listed in Tables 1 and 2.

Figure 9. Value of Exports and Imports by Skill Intensity, 1928

Panel A: classified by educational attainment Unit: thousand Haikwan Tael



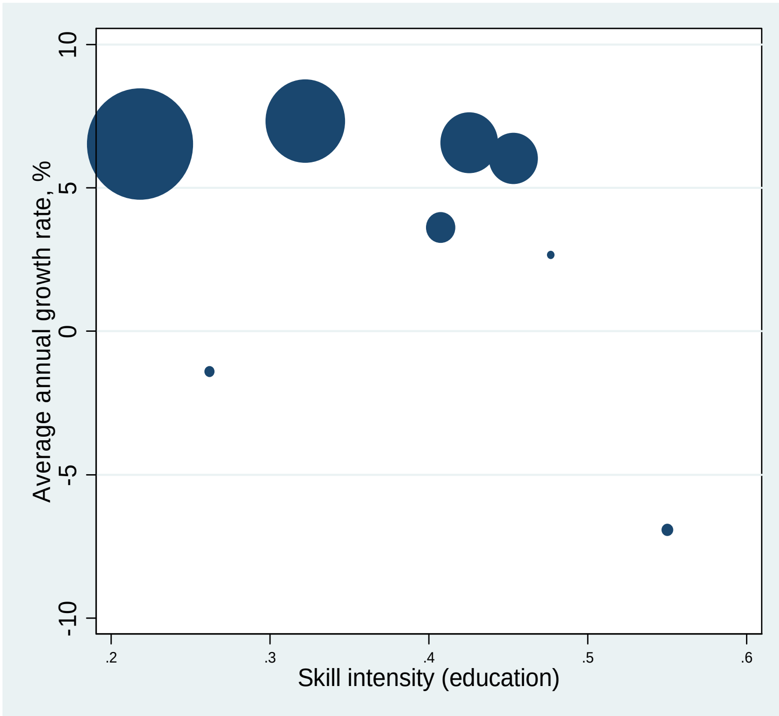
Panel B: classified by log wage Unit: thousand Haikwan Tael



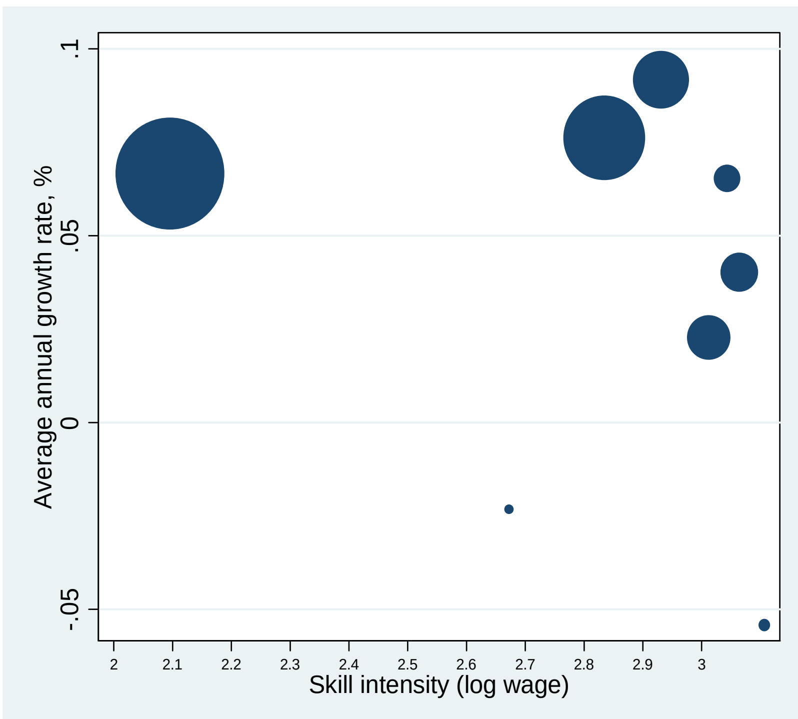
Source: Authors' calculation as described in the text. Numbers on individual bars correspond to industry codes listed in Tables 1 and 2.

Figure 10. Skill Intensity and the Growth Rate of Exports from 1903 to 1928

Panel A: classified by educational attainment



Panel B: classified by log wage

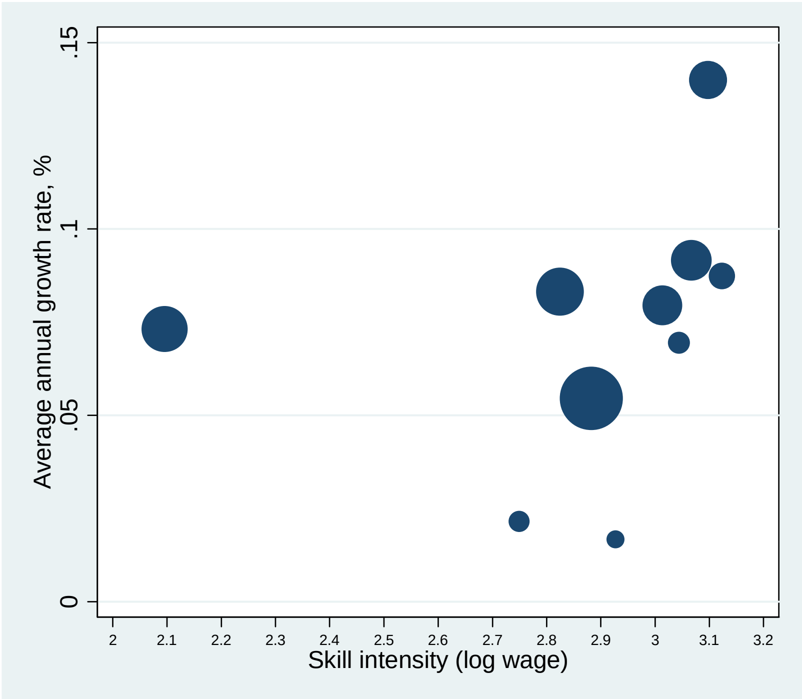


Source: Authors' calculation as described in the text. Skill intensity based on data from the 1940 US census.

Figure 11. Skill Intensity and the Growth Rate of Imports from 1903 to 1928

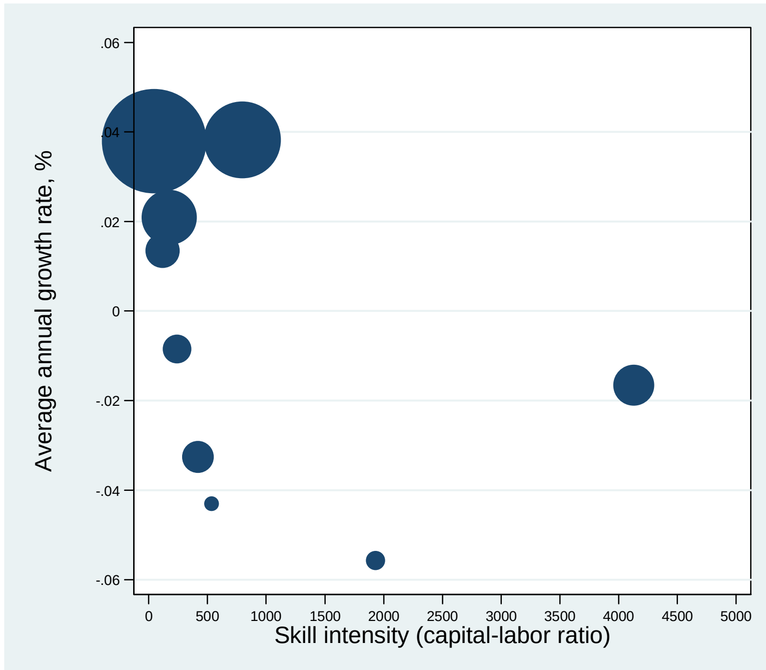
Panel A: classified by educational attainment

Panel B: classified by log wage



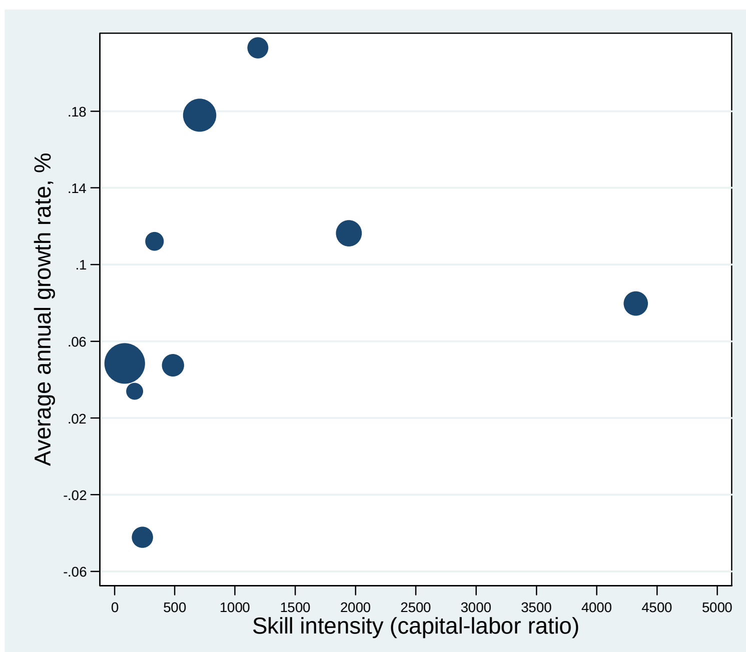
Source: Authors' calculation as described in the text. Skill intensity based on data from the 1940 US census.

Figure 12. Skill Intensity and the Growth Rate of Exports from 1903 to 1928



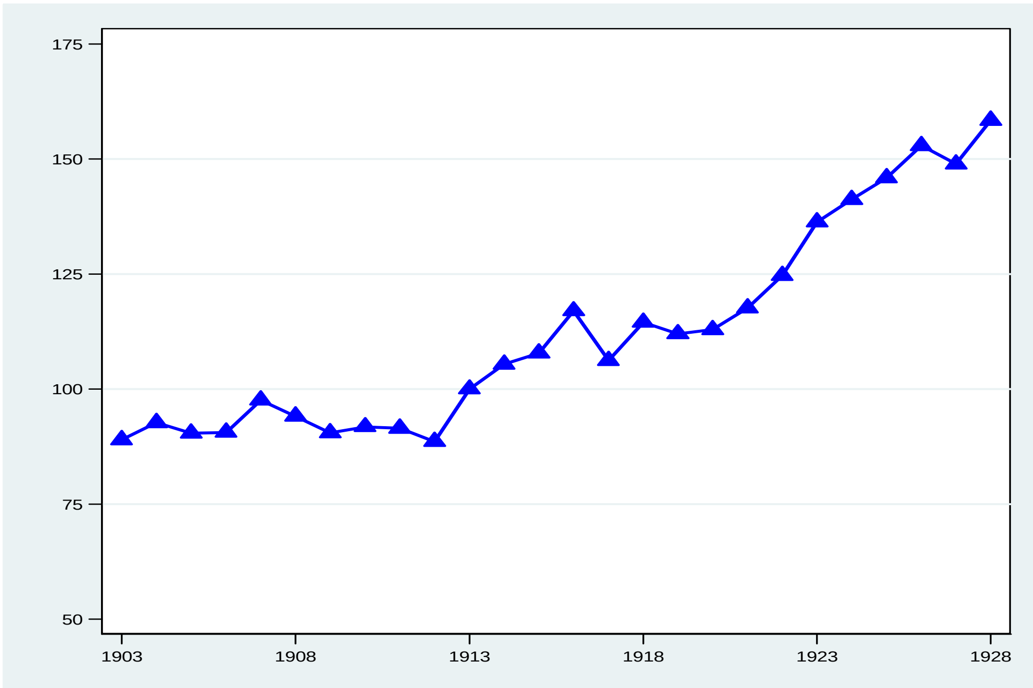
Source: Authors' calculation as described in the text. Skill intensity based on data from the 1928 Shanghai Survey

Figure 13. Skill Intensity and the Growth Rate of Imports from 1903 to 1928



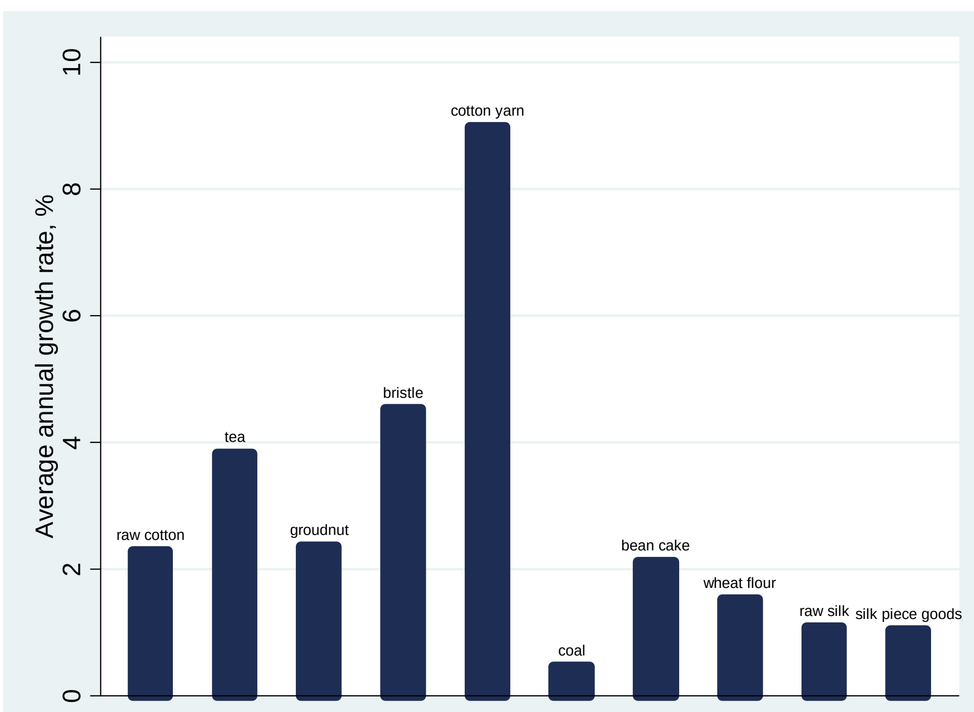
Source: Authors' calculation as described in the text. Skill intensity based on data from the 1928 Shanghai Survey.

Figure 14. Price Index of Chinese Exports, 1903 to 1928



Source: Hsiao (1974)

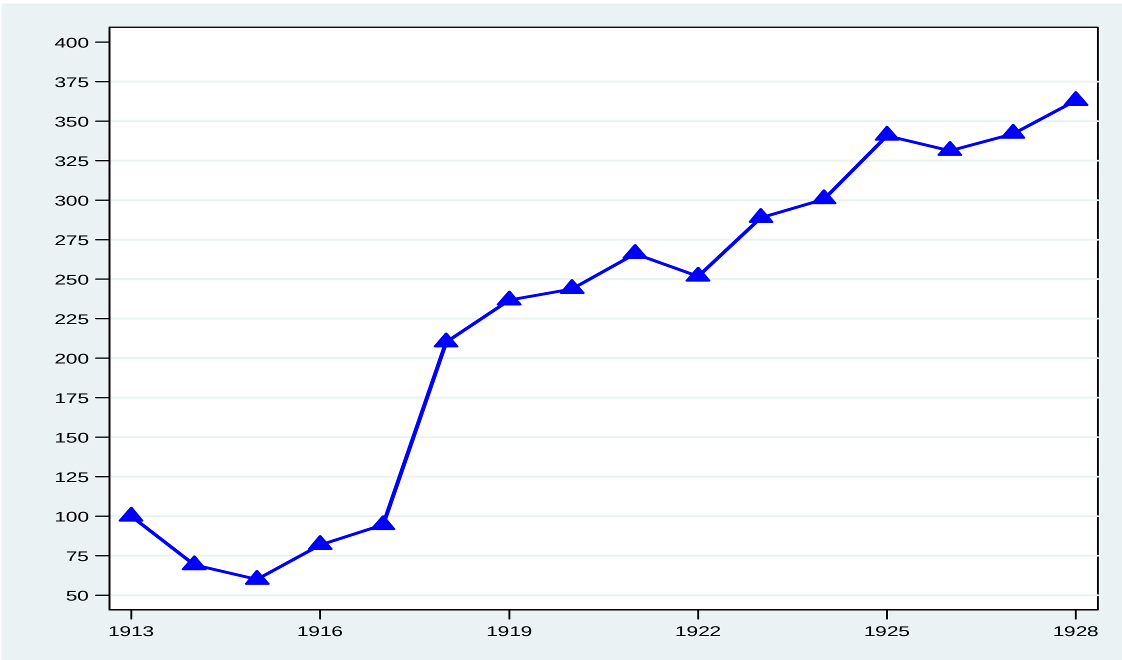
Figure 15. Growth Rates in Prices for Major Export Commodities, 1903 to 1928



Source: Authors' calculations using data from the CMC's annual trade publications

Figure 16. Export Price of Cotton Yarn

Index of unit value: 1913=100



Source: CMC annual trade publications.