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Title “The Extended Heckscher-Ohlin Model: Patterns of Trade between
the U.S. and China”

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Abstract Though there have been many attempts to extend the Heckscher-Ohlin model in order to account for empirical data, I intend to examine John Romalis’ model of factor proportions and commodity structure. The purpose of this paper is to examine Romalis’ model to see if it is supported by empirical data on trade between China and the United States. In order to do this, I will use data from the 2000 and 2005 U.S. Census trade data CD-ROM to determine if Romalis’ extended Hecksher-Ohlin model of international trade can explain the U.S.-China pattern of trade.

The Heckscher-Ohlin model has long been the central model of international trade theory, and it consists of two countries, two goods, and two factors of production. The model's prediction regarding trade patterns is that each country will export the good that intensively uses the factor of production it has in abundance, and will import the other good. More precisely, the country with higher relative proportions of a particular input factor will specialize in producing the good that intensively uses that factor, and import the other good. For example, a country with a high unskilled to skilled labor ratio will specialize in and export goods that more intensively use unskilled labor as a production input. As a result of this, they will tend to import the other good from the other country, whose relative unskilled to skilled labor ratio is exactly the inverse. The Heckscher-Ohlin trade model is centered around the idea that relative factor abundance and intensity is what drives trade patterns between countries.

Unfortunately, though this model is simple and gives easily observable predictions, the predictions are not satisfied by the empirical data. Wassily Leontief (1953) performed the first test of the Heckscher-Ohlin theorem using United States trade data from 1947. When he conducted his empirical test of the model he assumed (correctly) that in 1947 the United States was capital abundant relative to the rest of the world. According to the Heckscher-Ohlin model, Leontief's analysis should have resulted in the United States exporting capital-intensive goods and importing labor-intensive goods, however, his results showed the exact opposite trend. This empirical counterexample to the Heckscher-Ohlin model has been dubbed "Leontief's paradox." This paradox has engendered a large movement in international trade theory to develop an extended version of the Heckscher-Ohlin model that is consistent with empirical data. These extended models take into account things such as multiple countries, goods and factors,

technology and production differentiation, and human capital. Though there have been many attempts to extend the Heckscher-Ohlin model in order to account for empirical data, I intend to examine John Romalis' model of factor proportions and commodity structure. The purpose of this paper is to examine Romalis' model to see if it is supported by empirical data on trade between China and the United States. In order to do this, I will use data from the 2000 and 2005 U.S. Census trade data CD-ROM to determine if Romalis' extended Heckscher-Ohlin model of international trade can explain the U.S.-China pattern of trade.

I – *The Romalis Model Description*

The Romalis (2004) extension of the Heckscher-Ohlin model accounts for many countries with a continuum of goods. His model is a generalization of the Dornbusch-Fischer-Samuelson (1980) model, integrated with Krugman's (1980) model of intra-industry trade generated by economies of scale and product differentiation. Romalis also allows for "iceberg" transport costs, which will determine the commodity structure of production and trade. One important assumption is that there is differentiation in production techniques, which generates a failure of factor price equalization. Without factor price equalization, the commodity structure of production and trade is determined, which allows Romalis to use trade data on commodities for this analysis. Romalis goes beyond the Dornbusch-Fischer-Samuelson and Krugman models by explicitly connecting "departures from factor price equalization to factor abundance in a general-equilibrium model"¹ and he uses the implications of this departure to "examine the relationship between factor abundance and trade structure using detailed commodity trade data."² Hence, in Romalis' model, there are two forces that generate trade patterns between countries. The first of

¹ John Romalis "Factor Proportions and the Structure of Commodity Trade," *American Economic Review* 95, no. 1 (March 2004): 70.

² Ibid.

these is that countries differ in their relative factor abundance and factor proportions. The second force is economies of scale and product differentiation.

There are two main predictions of Romalis' extended model, which will be the focal points of this paper, and they are: a quasi-Heckscher-Ohlin prediction and a quasi-Rybczynski effect. The quasi-Heckscher-Ohlin prediction is that "countries capture larger shares of world production and trade in commodities that more intensively use their abundant factor."³ The quasi-Rybczynski effect is "countries that accumulate a factor faster than the rest of the world will see their production and export structure move towards commodities that more intensively use that factor."⁴ I will use Romalis' empirical methodology, using detailed commodity trade data on U.S. imports from the 2002 U.S. Economic Census, and 2002—2005 import data from the U.S. Census trade data CD-ROM in order to determine if the two predictions of his model hold in the case of Chinese exports to the U.S.

According to the quasi-Heckscher-Ohlin prediction, countries that are abundant in skilled labor and capital should capture large shares of U.S. imports in industries that most intensively use those factors. By assumption of the model, every country has the same production technology; therefore, the only causes of differentiation on production costs are factor price differences. Hence, "countries capture larger shares of world production in commodities that intensively use their *relatively inexpensive* factors."⁵ In China's case, it has a high unskilled to skilled labor force relative to the U.S., so the model predicts that U.S. import data should show China being highly represented in industries whose goods require unskilled labor more intensively. In terms of relative factor prices, since unskilled labor is abundant, it is cheaper for manufacturers relative to skilled labor. Thus, China will tend to specialize in and export goods

³ Ibid., 67.

⁴ Ibid.

⁵ Ibid., 76.

that require unskilled labor more intensively. If the Romalis model is correct, China should be highly represented in U.S. imports in low skilled intensity industries, which should be represented in the 2005 trade data. We should see a negative correlation between the skill intensity of the import industry and China's share of total U.S. imports in each industry.

Countries, such as China, that are rapidly growing have seen their export structure change towards more skill and capital-intensive industries.⁶ In order to see if there is a quasi-Rybczynski effect in China-U.S. trade patterns, we will use U.S. trade data from 2000 and compare it to 2005 trade data. In this time period, China has accumulated a significant amount of capital, while also experiencing growth in its skilled labor population in the urban sector. China also has an extremely large population, a significant percentage of which is unskilled or agrarian workers. One of the Rybczynski assumptions is that the labor market is fully employed. However, since China has such a large unskilled population, there is potential for a continued abundance of unskilled labor as agrarian workers migrate from the interior to enter the urban labor market. These factors that are unique to China could have varying effects on the predicted quasi-Rybczynski effect. Even though China has accumulated capital and skilled labor faster than the rest of the world, the Rybczynski effect might not be very strong given China's potential to sustain the growth of a large inexpensive unskilled labor force. Keeping this feature of China's labor market in mind, and comparing U.S.-China trade data between 2000 and 2005, we will be able to see if there is a quasi-Rybczynski effect as predicted by the Romalis model.

II – *Why China?*

Before we get into the data analysis, it will be useful to give some reasons behind examining China through the lens of the Romalis model. First, China is well represented in the 2005 trade data. Of the 500 NAICS (North American Industry Classification System)

⁶ Ibid., 68.

representing U.S. imports from abroad, Chinese exports to the U.S. were represented in 432 of them. Also, according to the U.S. Department of Commerce, in 2005 the U.S. trade imbalance reached a record high of \$725.8 billion, a 17.5% increase over 2004. The nation's trade deficit with China alone is \$201.6 billion, accounting for 27.8% of the total trade deficit, an all-time high for any single country.⁷ Another motivation for using China for this analysis is that it has a very large unskilled relative to skilled labor force. This means that they have a significantly extreme relative factor proportion in comparison to the U.S., which should manifest itself in the data if the model is correct.

For these reasons, China provides a stark example to use in testing Romalis' version of the extended Heckscher-Ohlin model to see if the current trade data supports the quasi-Heckscher-Ohlin prediction and quasi-Rybczynski effect predicted by the model. The intent of this paper is not to add something that was neglected by Romalis. He did include China in his analysis; however, the empirical support of his model was based on 1997 trade data, which is prior to China becoming a major international trading partner. For this reason, I think it is a significant factor that needs to be examined using current data in order to see if the empirical evidence for China still supports the Romalis model.

III—*Overview and Description of the Data*

The Heckscher-Ohlin prediction can be analyzed through regressions relating the skill intensity of each industry to China's share of U.S. imports by industry. These regressions use detailed commodity trade data from 2005 and estimates of factor intensity for each industry in the NAICS index from the 2002 Economic Census. The model assumes that there are no factor intensity reversals. Since factor shares are fixed for each industry, they can be ranked from least

⁷ David Armstrong, "U.S. Racks Up Record Trade Deficit in '05 \$725.8 Billion Total is 17.5% Increase Over 2004's Mark," *San Francisco Chronicle*, February 11, 2006.

to most intensive using factor share data for just one country, *viz.*, the United States. I follow Romalis' empirical method and his calculation of factor intensities while using updated commodity trade data.

We need a total of three factors in order to test the model's predictions by running a regression: skill intensity, capital intensity and raw material intensity of the US import industries. Beginning with a two-factor model, skill intensity z_2 is the ratio of non-production workers to total employment in each industry. The unskilled labor intensity is $u_2=1-z_2$. In the three-factor model, we account for the share of capital. Capital intensity k_3 is measured as 1 less the share of total compensation in value added. Skill intensity z_3 is now equal to $z_2(1-k_3)$, and the intensity of unskilled labor is $u_3=u_2(1-k_3)$. Many of the most capital-intensive industries are also industries that intensively use raw materials, generating the potential for an omitted variable bias if they are not included in the regression. Raw material inputs are calculated from Census of Manufactures data on intermediate inputs by industry. Similarly to Romalis, I've screened the raw material data to only include food, forestry, and mining industry output. However, I have included more

Table 1--Factor Intensity Summary Statistics⁸				
	Mean	Standard Deviation	Minimum	Maximum
z_2	0.29	0.12	0.09	0.72
z_3	0.13	0.07	0.01	0.45
z_4	0.12	0.07	0.01	0.45
u_2	0.71	0.12	0.28	0.91
u_3	0.31	0.11	0.03	0.77
u_4	0.29	0.12	0.02	0.71
k_3	0.56	0.13	0.08	0.96
k_4	0.52	0.14	0.06	0.95
m_4	0.07	0.15	0.00	0.86

industries, and the actual industries vary slightly from Romalis' m_4 . Raw material intensity m_4 is the value of raw material inputs divided by the sum of the raw materials and value added. Capital intensity becomes $k_4=k_3(1-m_4)$; skill

⁸ Data Source: U.S. Census Bureau; 2002 Economic Census, Sector 31: Ind: Detailed Statistics by Ind: 2002; generated by Mark Clements; using American Factfinder; <<http://factfinder.census.gov/>>; (12 October 2006).

intensity becomes $z_4=z_3(1-m_4)$, and unskilled labor intensity is $u_4=u_3(1-m_4)$.⁹ Table 1 reports summary statistics for the factor intensity estimates.

The model explains trade shares by the interaction of relative factor prices and relative factor intensities; relative factor prices are determined by relative factor abundance. By our assumptions regarding China's labor distribution, their relatively high factor abundance of unskilled to skilled labor will dictate low relative factor prices for unskilled labor between the U.S. and China. The coefficients are determined by relative factor rewards, which are in turn determined by relative factor abundance. The regression estimates are interpreted as the conditional expectations of China's market share of U.S. imports given the factor intensities of the industry. The regression equations for two, three, and four-factor models are:

$$\begin{aligned}
 (1) \quad & x_i = \beta_0 + \beta_1 z_{2i} + \varepsilon_i \\
 (2) \quad & x_i = \beta_0 + \beta_1 z_{3i} + \beta_2 k_{3i} + \varepsilon_i \\
 (3) \quad & x_i = \beta_0 + \beta_1 z_{4i} + \beta_2 k_{4i} + \beta_3 m_{4i} + \varepsilon_i
 \end{aligned}$$

Where x_i is the share China commands of U.S. imports in industry i , which is calculated as U.S. imports from China of industry i divided by the total imports in industry i . If the Heckscher-Ohlin prediction of Romalis' model holds for China, then we would expect the β_1 coefficients to be negative, representing a negative correlation between the skill intensity of each industry and share of Chinese exports to the U.S.

⁹ Romalis, *Factor Proportions*, 79.

IV—Analysis of the Data: The Quasi-Heckscher-Ohlin Prediction

Table—2 Regression for China's share of U.S. Imports by Industry

(Dependant Variable: x_i)			
	Two Factors	Three Factors	Four Factors
Constant	14.81 (6.46, 2.29)	27.37 (4.84, 5.65)	25.83 (4.28, 6.03)
z_2	-2.14 (-1.97, 1.09)		
z_3		-8.44 (-3.98, 2.12)	
k_3		-21.57 (-2.84, 7.60)	
z_4			-4.89 (-2.91, 1.68)
k_4			-20.11 (-2.44, 8.23)
m_4			-9.44 (-2.76, 3.42)
<i>Observations</i>	500	500	500

* (t-statistic, standard error)
 * All coefficients are at least statistically significant at the 10% level.

Data Sources: U.S. Census Bureau; 2005 U.S. Census trade data CD-ROM; 2002 Economic Census, Sector 31: Ind: Detailed Statistics by Ind: 2002; generated by Mark Clements; using American Factfinder; <<http://factfinder.census.gov/>>; (12 October 2006).

Now that the data has been described, we can run regressions (1), (2), and (3) to see what the estimated effect of factor intensities (in particular the z_i skill intensity) have on the share of Chinese imports by industry. Running these regressions yield the estimated coefficients for each factor-intensity listed in Table 2. We see from these regressions that the coefficient estimates are negative as was anticipated by the Heckscher-Ohlin prediction. For all three factor intensities, as the industry becomes more intensive the share of Chinese imports into that particular industry declines. According to the Heckscher-Ohlin prediction, our assumption that China has a high

unskilled to skilled labor ratio relative to the U.S. should result in China specializing in and exporting goods to the U.S. that use unskilled labor more intensively. This can be seen in the negative correlation between the skill intensity of the industry and the share of Chinese imports in that industry. This relationship is much more apparent in Figure 1. As the skill intensity of the industry increases, the share of U.S. imports from China in these industries declines. Though a slope of -4.89 may not seem significant, keep in mind that this graph is China's share relative to *total* U.S. imports from the rest of the world in each industry. Also, the scale of the graph makes the line to appear much flatter than it actually is because the range of

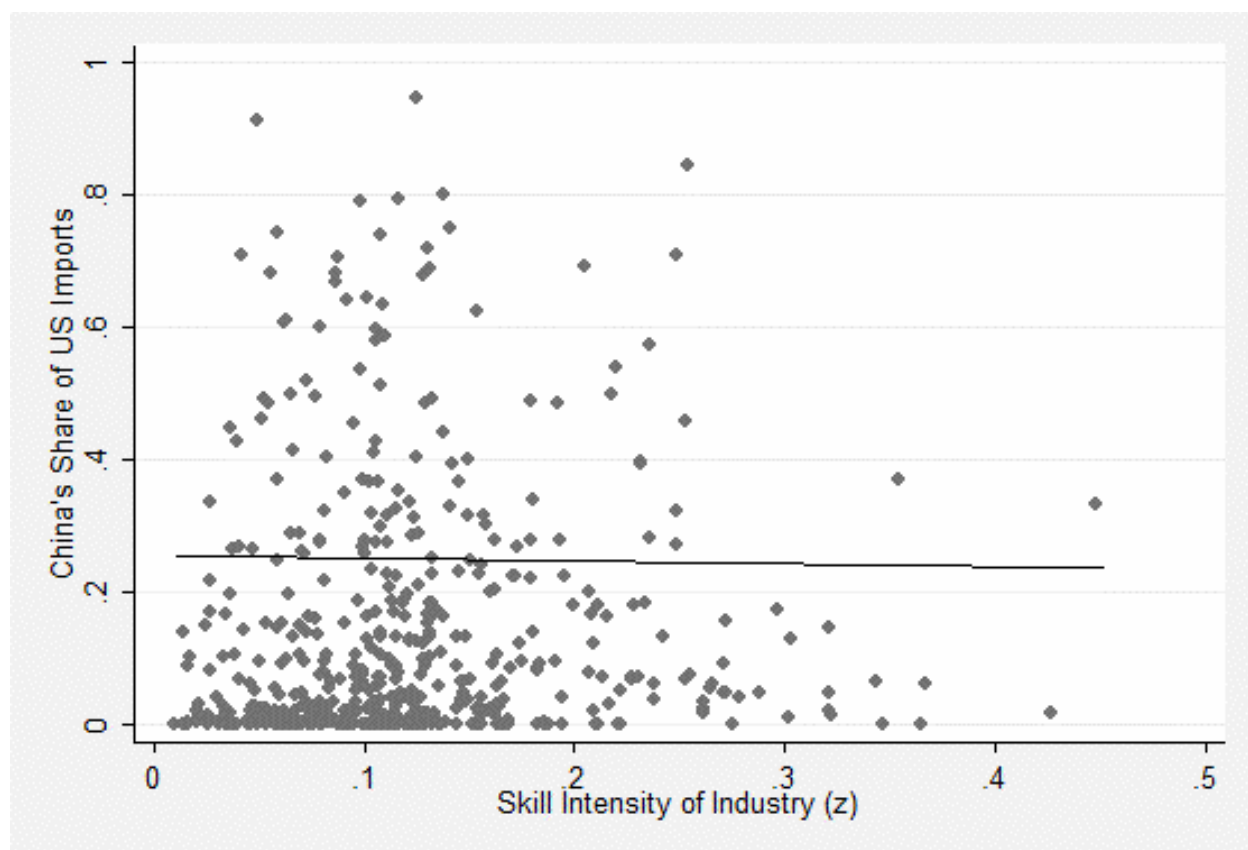


Figure 1--Factor Intensity and China's Market Share (2005)

the x-axis is bounded by the maximum value of the industries represented by Chinese exports.

This is done to spread out the data so that the distribution in industries that are *actually*

represented in import goods from China can be seen clearly. If the range went all the way up to one, the regression line would effectively look twice as steep as it does in this diagram. The important thing is that the coefficient estimate gives us the significant negative correlation trend. It is clear from the concentration of the data points toward the left of the graph that the majority of industries that are represented by Chinese exports to the U.S. are in the low skill intensity range. This result makes sense given our assumptions about the Chinese unskilled to skilled labor ratio relative to the U.S. Furthermore, it appears from this data that the quasi-Heckscher-Ohlin prediction of Romalis' model is supported by the empirical data for China, *viz.*, countries capture larger shares of world production in commodities that intensively use their abundant, relatively inexpensive factors of production. China's high unskilled to skilled labor force relative to the U.S. causes it to specialize in goods that require unskilled labor more intensively. This is reflected in the U.S. import pattern with imports from China being highly represented in low skill intensity industries. This relationship gains further support from the negative correlation between skill intensity and China's share of U.S. imports yielded from equation (3).

V—Analysis of the Data: The Quasi-Rybczynski Prediction

In order to see if there is a quasi-Rybczynski effect on the China-U.S. trade pattern, we must look at two time periods to see if China's production allocation has shifted over time. This production allocation shift will be analyzed by looking at how the coefficients of the factor intensities change between each period. To do this, I used data from the U.S. Census trade data CD-ROM for 2000 to run the same regressions {(1), (2), (3)} on China's share of U.S. imports.

**Table--3 Regression for China's Share of U.S. Imports by Industry
Comparison Between 2000 and 2005**

(Dependent Variable: x_i)

2005			
	Two Factors	Three Factors	Four Factors
Constant	14.81	27.37	25.83
z_2	-2.14		
z_3		-8.44	
k_3		-21.57	
z_4			-4.89
k_4			-20.11
m_4			-9.44
<i>Observations</i>	500	500	500

* All coefficients are at least statistically significant at the 10% level.

* See Table 2 for t-statistic and standard error values

Data Sources: U.S. Census Bureau; 2005 U.S. Census trade data CD-ROM; 2002 Economic Census, Sector 31: Ind: Detailed Statistics by Ind: 2002; generated by Mark Clements; using American Factfinder; <<http://factfinder.census.gov/>>; (12 October 2006).

2000			
	Two Factors	Three Factors	Four Factors
Constant	11.05 (5.83, 1.90)	16.17 (3.43, 4.72)	11.82 (2.36, 5.01)
z_2	-8.49 (-2.10, 4.02)		
z_3		-17.57 (-1.96, 8.97)	
k_3		-9.57 (-2.21, 4.34)	
z_4			-6.38 (-2.56, 2.50)
k_4			-5.61 (-3.16, 1.77)
m_4			6.74 (2.16, 3.12)
<i>Observations</i>	500	500	500

*(t-statistic, standard error)

* All coefficients are at least statistically significant at the 10% level.

Data Sources: U.S. Census Bureau; 2000 U.S. Census trade data CD-ROM; 2002 Economic Census, Sector 31: Ind: Detailed Statistics by Ind: 2002; generated by Mark Clements; using American Factfinder; <<http://factfinder.census.gov/>>; (12 October 2006).

Given the assumption that there are no factor intensity reversals, I can use the same 2002 commodity data for factor intensities (which are ranked from lowest to highest) for the right-hand variables in these regressions. The results of this regression using trade data from 2000 are summarized in Table 3.

The factor intensity coefficients for 2000 are still negatively correlated (except for raw materials intensity), maintaining the Heckscher-Ohlin prediction from 2000 to 2005. Skill intensity has become *less negative* from 2000 to 2005. This makes sense from a Rybczynski point of view because as China grows and continues to accumulate skilled labor and capital, it

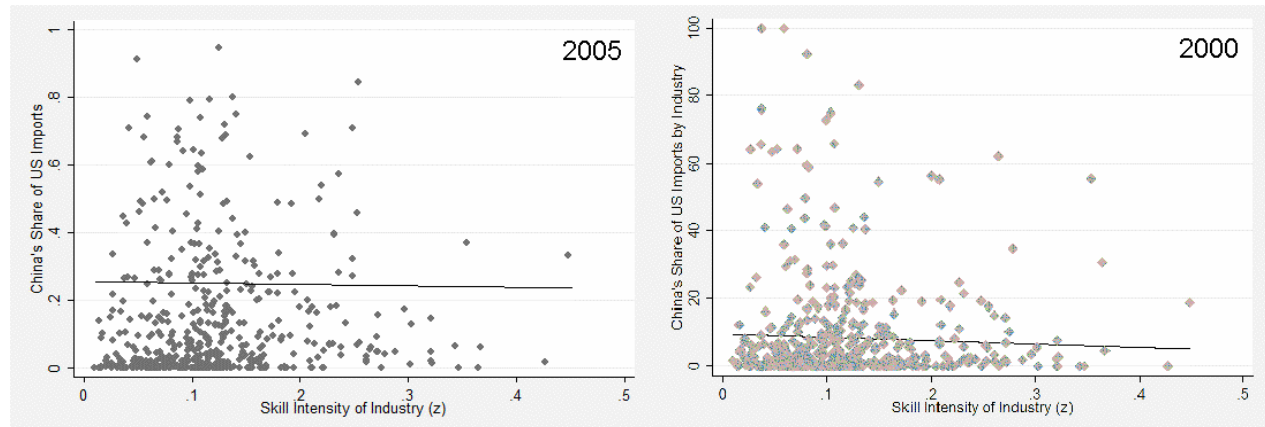


Figure 2—Skill Intensity and China’s Market Share: 2000--2005 Comparison

should gradually shift production to higher skilled and capital-intensive industries as their relative skilled to unskilled and capital to labor ratios increase. This means that less of the goods being imported from China will be low skilled intensive goods, and we should see the negative correlation between skill intensity and China’s share of imports become less negative. This difference is not remarkably apparent from the fitted regression lines in Figure 2, there seems to be a slight flattening of the curve from 2000 to 2005.¹⁰ However, this trend is much more apparent from the coefficient data in Figure 2, which demonstrates an increase in the skill

¹⁰ The changes in the slopes are remarkably apparent in these graphs due to the scale of the x-axis discussed before.

intensity coefficient between 2000 and 2005. Hence, the correlation is becoming less negative and the regression curve flattens out.

As China has grown over this five-year period, it has accumulated significant amounts of skilled-labor and capital. If we assume that the level of unskilled labor is constant, this would increase their relative skilled to unskilled labor ratio; if capital accumulates quicker than skilled labor, the capital labor ratio will also increase. According to the quasi-Rybczynski effect, these accumulations should cause China to shift production to higher skill and capital-intensive goods, which should be revealed by an increase of China's share of U.S. imports in skilled and capital-intensive industries. Essentially the Rybczynski effect would cause these regression lines to become flatter from $t = 2000$ to $t+5 = 2005$, which is the case given the empirical data here. In fact, the slope of the line becomes 23.35% less negative from 2000 to 2005. However, we should not be too quick to claim that the Rybczynski effect is the driving force behind the trend between 2000 and 2005 in *every* factor intensity because there seems to be a problem with this claim in the coefficient data for capital-intensive industries.

VI—*The Failure of the quasi-Rybczynski Effect?*

The Rybczynski effect predicts that as China grows, accumulating capital and skilled labor, they should shift production into skill and capital-intensive industries. This shift should be represented by an increase of Chinese exports to the U.S. in industries that are skill and capital-intensive. According to the coefficient data, while it is true that the coefficient of the skill-intensity factor seems to account for a Rybczynski effect by becoming less negative from 2000 to 2005, the opposite trend is seen in the capital-intensity factor. The correlation between capital-intensity and China's share of U.S. imports has become *more negative* from 2000 to 2005. This capital-intensity shift can be seen in Figure 3; as capital-intensity increases, China's

share of U.S. imports decreases and the line becomes *steeper* in 2005 than it was in 2000. This seems to contradict the Rybczynski effect since the empirical data shows an *increase* in the

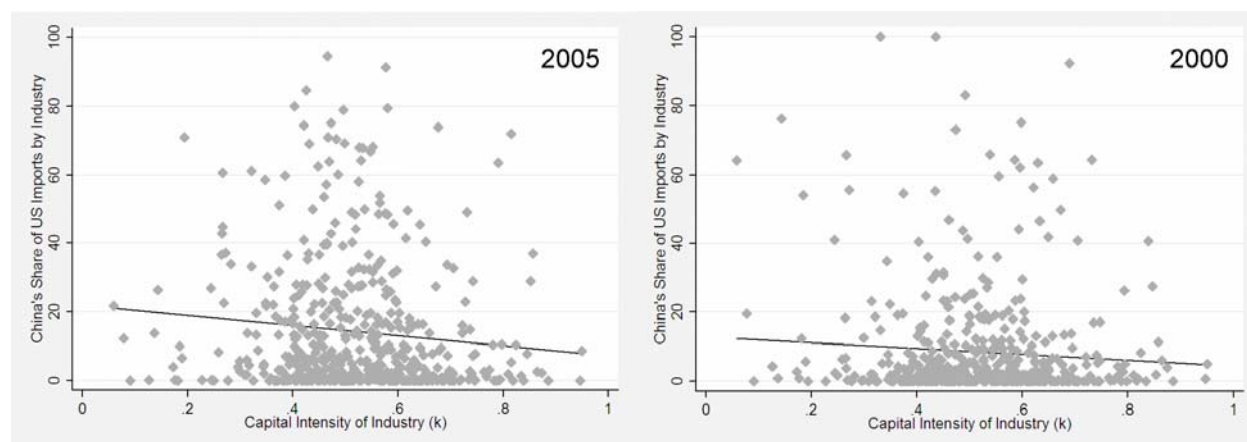


Figure 3—Capital Intensity and China's Market Share: 2000--2005 Comparison

negative correlation between China's share of U.S. imports and capital-intensity, rather than a *decrease* due to China shifting production into more capital-intensive goods. The effect seems relevant for the skill-intensity factor, but not for the capital-intensity factor. It appears from this analysis that the Rybczynski effect is only weakly represented because the empirical data shows opposite trends in 2000 and 2005 between the skill and capital-intensity coefficients.

VII—Conclusions

It appears from our analysis that the Heckscher-Ohlin prediction of the Romalis model is consistent with our data. However, the Rybczynski effect is weak, if not inconsistent because it is only represented in the data for the skill intensity factors but not for the capital intensity factors. The data shows that China is *not* shifting production into capital-intensive industries and specializing in exporting those goods. This conclusion seem to be counterintuitive when thinking about China's growth, one would think that China is producing more capital intensive

goods for export as they continue to grow. What could account for this counterintuitive, if not contradictory result in the capital-intensity coefficient?

First of all, 2005 might just be a bad year for Chinese exports of capital-intensive goods to the U.S. Though the capital-intensity coefficients are statistically significant, the time period between 2000 and 2005 is rather small, resulting in a comparison prone to statistical bias and error. Since there is a time series element to this analysis, much more data could be useful in order to obtain better and more consistent estimates. Another factor, which won't be discussed here, is that during this time period China entered the WTO. The principle of tariff reciprocity for WTO member countries could have effected China's representation in exports to the U.S. between 2000 and 2005, which could skew the results.

There is another potential cause of this inconsistency or ambiguity of the Rybczynski effect, unique to China's population and labor market: the mass population migration from the interior agricultural sector to the costal urban sector. Continued growth of the labor force as millions of Chinese leave the agricultural sector for the urban sector puts pressure on both capital and workers to leave the capital-intensive sector as labor-intensive production expands.¹¹ Because of this mass migration from the agricultural sector to the urban sector, "capital-intensive production has to contract unless additional capital is made available to combine with an increased flow of labor from the agricultural sector. The flow of labor from China's massive agricultural sector is huge—on the order of hundreds of millions of workers."¹² One of the assumptions of the Rybczynski theorem is that the labor market is fully employed. Holding labor constant as capital accumulates causes the capital-labor ratio to increase and production is shifted into capital-intensive industries. However, this mass migration from the agricultural sector is

¹¹ John H. Makin. "Does China Save and Invest Too Much?," *The Cato Journal* 26, no. 2 (Spring/Summer 2006): 310.

¹² *Ibid.*

increasing the labor supply even as capital is being accumulated. If labor accumulation outpaces capital accumulation, the capital-labor ratio will actually decline. Thus, labor becomes cheaper relative to capital and manufacturers will start substituting capital for labor. This will either cause capital-intensive industries to change their production process to one that utilizes the cheap labor, or contract production as capital as an input to production becomes relatively more expensive. If this is indeed what is going on in China then, holding the U.S.'s capital-labor ratio constant, China's capital-labor ratio will decrease and become relatively lower in 2005 than it was in 2000; as a result of this, China will shift production to labor-intensive goods and export less capital-intensive goods.

So is Romalis' extended Heckscher-Ohlin model supported by empirical evidence from current China-U.S. trade patterns? Mostly. The quasi-Heckscher-Ohlin prediction of the model is strongly verified in the empirical data by the negative correlation between skill-intensity and China's share of U.S. imports. However, due to China's growth during the past decade, the quasi-Rybczynski effect should result in China shifting production from unskilled to skilled and from labor to capital-intensive industries as it accumulates skilled labor and capital. Hence, from 2000 to 2005, the factor coefficients in regressions (1), (2), and (3) should become less negative due to this production shift. What we actually find is that the coefficients for skill-intensity fit this predicted trend, but the coefficients for capital intensity do not. Thus, the quasi-Rybczynski effect seems to be weak unless we take into account unique attributes of China's population and labor market. If our intuition is correct regarding the effect on the capital-labor ratio of Chinese agrarian migration to the urban sector, then perhaps we can salvage Romalis' Rybczynski prediction by taking into consideration this unique characteristic of China's economy. Accounting for a decrease in the capital-labor ratio by virtue of this mass migration in China

allows us to claim that the Rybczynski effect is much stronger than it appears in the data. From this analysis, if we want to use Romalis' model to predict quasi-Rybczynski effects for specific countries beyond the general case, then it must be able to account for the unique attributes of each country. In the end, the two main predictions of Romalis' model seem to be verified by the empirical evidence, but only if we are careful about interpreting the results in a framework that is specific for individual countries.

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