Country Size, Economic Structure and Transaction Efficiency: 
An Asymmetric Spatial General Equilibrium Model of Income 
Differences across Nations 

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Abstract:
Income differences across countries are jointly determined by many factors. Population size and per capita resource endowments are two important natural characteristics of countries. A large population size means that the country can produce more product varieties, achieve a higher degree of division of labor and enjoy relatively more local knowledge spillover. Another significant source of the large country advantage is savings in international transaction costs. When international transaction costs are high, a large country still has a large domestic market, and therefore can have a higher per capita income than a small country. However, many factors can conspire to erode the large country advantage and as a result, a large country may not have a higher per capital income than a small country. These compromising factors include: trade openness, excessive population density and its resultant falling per capita resources, underdeveloped domestic market and high domestic transaction costs, an economic structure that excessively relies on land and natural resources, and low technology levels.

Keywords: Cross-Country Income Differences, Large Country Advantage, Economies of Specialisation, Trade Openness

JEL Classification Numbers: N10, F12, R12
1. Introduction

There are currently over 200 countries in the world, of which some are rich, and others are poor. In terms of per capita income, the difference between the richest and the poorest countries is well over 100-fold. Why are there such large income differences across countries? A consensus is yet to be reached. After Solow’s (1966) path-breaking contribution, the human capital model developed by Uzawa (1965) and Lucas (1988) are often considered to be one of the best models offering a convincing explanation for cross-country income differences. However, if one only looks at average schooling, there are some but not large differences between rich and poor countries. If human capital is the only explanation, then why cannot poor countries simply invest in human capital by large amounts to catch up with rich countries? Moreover, it should be noted that although workers in different countries may have different wage levels due to differences in human capital, workers with the same human capital levels earn vastly different wages in different countries. Obviously, at most, human capital can only partially explain income differences across countries.

Another explanation for cross-country income differences is knowledge spillovers. The early literature (Romer, 1986; Grossman and Helpman, 1991; and Helpman, 1999) has an important assumption, namely that, once knowledge is discovered, it becomes known all over the world, and the world economy grows as a result. Martin and Ottaviano (1996; 1999) contend that if knowledge spillover is global in nature, then economic growth has nothing to do with firm location. The global knowledge spillover obviously cannot explain cross-country income differences. However, if the knowledge spillover is regional, then such spillover will induce industries to agglomerate to low-cost regions, thereby stimulating regional economic growth. Martin and Ottaviano (2001) further show that innovation fosters spatial agglomeration of economic activities, which in turn
leads to lower cost of innovation and higher growth. Thus there is a circular causation between growth and spatial agglomeration. Baldwin et al. (2004), Dupont (2007), Cassar and Nicolini (2008) also demonstrate the positive effect of local knowledge spillover on regional economic growth. This local knowledge spillover effect clearly helps to explain cross-country income differences. However, it is very likely that the extent of the spillover effect is positively correlated with population size, which implies that population size may explain cross-country income differences.

At a more general level, interests in the rise and fall of nations have led some economists and historians to search for the ultimate reasons explaining differences in economic performances across nations. For example, Blaut (1998) and Wen (2005) argue that geographic environment is the root cause of cross-country income differences. The difficulty with this view is that it cannot explain why countries with similar geographic environment have very different income levels (e.g., North Korea and South Korea). Other researchers contend that totalitarian control is a key reason for economic backwardness. This view can easily slide into geographic determinism. In river civilizations, those who controlled rivers or canals controlled food. Centralized governments appeared because “the master of food was master of people” (Landes, 1998). Acemoglu and Robins (2012) argue that institutions are the reason behind cross-country income differences. In particular, inclusive political institutions encourage citizen participation, education and enterprise. In contrast, extractive political institutions dampen incentives to produce and innovate. Many economists believe that free market and private property rights are key explanatory factors of cross-country income differences. Since authoritarian governments often harm market development, countries with authoritarian governments tend to be economically backward. In reality, we do observe that free market democracies tend to enjoy better economic performance. However, free market economies and non-democracy are not
always incompatible. Mexico, Brazil and Singapore are not in fact democratic countries, but they have developed free market economies.

Lin (1995; 2012) contends that a country’s population size and the structure of its factor endowments have a significant impact on its economic development. In the pre-modern era, technological innovations mainly resulted from experiences of artisans and farmers, and scientific findings were made spontaneously by talented individuals. Thus a large population constituted an advantage. At certain level of technological development, this experience-based method reached a bottleneck, which required methodological innovation to support technological progress. At this time, the scientific and industrial revolution occurred in the West. The scientific revolution of the 17th century shifted the mode of technology invention from one that is experience-based to one that is based on controlled-experiments and mathematics. The question, which is often referred to as the “Neeham Puzzle”, is: why did the scientific revolution happen in Europe, but not in China, although the Chinese civilization was more advanced at the time? According to Lin (1995; 2012), controlled experiments require talented scientists and professionals. Since the Chinese system of civil service exams attracted Chinese intellectuals to the officialdom, scientific innovation was not supported by China's talent structure and the Chinese economy remained in the stage of an agricultural society.

Based on the literature reviewed above, we come to the following views. First, geographic environment is the ultimate source of cross-country income differences. In the long term, a country’s population size, political institutions and market development are all endogenous of the country’s geographical environment. Second, population size has a positive impact on a country’s knowledge stock and knowledge spillover, and will further influence the country’s technological innovation, human capital quality and income differences. Third, a country’s economic structure is determined by its structure of factor
endowments. Institutional design in a country (e.g., the civil service exam system in China) can obstruct the formation of a special factor (e.g., scientist groups). Consequently, the factor endowment structure of this country may not able to support the transformation of economic structure from an agricultural society to an industrial society. Fourth, the distribution of state power has a direct impact on across country income differences. It is intimately related to market development, human capital formation and the extent of knowledge spillover. All these factors in turn are often endogenous of a country’s geographic environment and population distribution.

In this paper, we develop a general equilibrium model incorporating population size, land area, international and domestic transaction costs to study the effects of these factors on a country’s per capita real income and cross-country income differences. The innovation of this paper lies in the following aspects. First, our model allows asymmetry. We assume different population sizes, land areas, technological levels, domestic transaction costs and different factor contributions in production in different countries. These asymmetric assumptions enable us to more clearly analyze the effects of various factors on cross-country income differences. Second, reduced per capita land endowment is an important reason for crowdedness. This paper introduces land into a spatial general equilibrium model. We assume that all economic activities require land. Continued expansion of labor and enterprises on a limited area of land inevitably results in diminishing returns, pushing up land rental and leading to crowdedness. Third, to capture the effect of institutions on income differences, we introduce transaction costs into our model and show that differences in domestic transaction costs have a significant effect on cross-country income differences.

The rest of the paper is organized as follows. Section 2 sets out the model, solves the general equilibrium and use numerical simulations to conduct
comparative static analysis. Section 3 applies a dynamic panel data model to test the conclusions of the theoretical model. Section 4 concludes.

2. Theoretical model

We develop an asymmetric general equilibrium model that enables us to study some main determinants of income differences across nations, namely, geography, institutions and technology. Specifically, our model also incorporates population size and land (to capture some aspects of geography); transaction cost (which reflects both geographic location and institutional quality); and fixed cost of production and industrial structure (to represent the contribution of various factors to production).

2.1 Model setup

Consider two asymmetric countries which are denoted by subscripts $r$ and $s$, respectively. The large country is endowed with $L_r$ units of labor and $R_r$ units of land. The small country is endowed with $L_s$ ($L_r > L_s$) units of labor and $R_s$ units of land. Assume that there is no labor movement between countries and that land in each country is equally distributed among all individuals in that country. All consumers have the same utility function. They consume two types of goods: a certain amount of land and a group of differentiated manufactured goods. Goods are traded domestically and internationally, but with different iceberg transaction costs. Individuals have a preference for variety in consumption. Each individual works for a wage and receives a land rent. The representative consumer in the large country has the following decision problem:
(1)

$$\max U_n = \left[ \int_0^{\lambda n} \left( \frac{B_{ri}}{t} \right)^\rho \, di + \int_0^{\frac{(1-\lambda)n}{T}} \left( \frac{B_{risj}}{T} \right)^\rho \, dj \right]^{\frac{1}{\rho}} H_n^{1-\gamma}, \quad \lambda \in [0,1], \quad \gamma, \rho \in (0,1)$$

$$\begin{align*}
st. \quad & w_n + \frac{R}{L} p_{rR} = \lambda np_n B_{ri} + (1-\lambda) np_{sj} B_{risj} + p_{rR} H_{nR} \\
& \text{where } n \text{ is the total number of manufactured varieties, } \lambda \text{ is the fraction of varieties produced in the large country; } \lambda n \text{ is the total number of manufactured varieties produced in the large country, and } (1-\lambda) n \text{ is that produced in the small country. } B_{ri} \text{ and } B_{risj} \text{ are quantities demanded of domestically and foreign made manufactured varieties; } T \text{ and } t \text{ are coefficients representing transaction costs in trade between the two countries and trade within the large country. } H_{nR} \text{ is the quantity of land demanded. } \gamma \text{ is the share of manufactured goods in consumer's total expenditure; and } \rho \text{ indicates the consumer's preference for diversity. The left-hand side of budget constraint is the sum of the consumer's wage income (} w_n \text{) and rental income from land, where } p_{rR} \text{ is land rent in the large country. The right-hand side is the total expenditure on manufactured goods and land, where } p_n \text{ and } p_{sj} \text{ are the prices of manufactured goods produced in the large country and in the small country, respectively. The representative consumer in the small country has a decision problem symmetrical to (1), and domestic trade in the small country involves transactions costs } \tau. \\
& \text{The manufactured goods are produced with a portfolio of intermediate goods, labor and land. For simplicity, the intermediate goods are assumed to be the same as the final goods, and the manufacturing industries use all the final goods as inputs to produce the manufactured goods (Fujita et al, 1999). The decision}$$
problem facing a representative firm producing the manufactured good \( i \) in the large country is:

\[
(2) \quad \max \pi = p_n q_n - \left[ \lambda np_n Z_{ri} + (1 - \lambda) np_j Z_{rj} + w_r l_r + p_r A_{R} \right],
\]

\[
st. \quad q_n = \left[ \int_{0}^{n} \left( \frac{Z_{ri}}{t} \right)^{\phi} \, dt + \int_{0}^{n} \left( \frac{Z_{rj}}{T} \right)^{\phi} \, dj \right]^{\phi/\rho} l_1^{1-\phi} A_{nR}^{\lambda}, \lambda \in [0,1], \phi, \chi, \rho \in (0,1).
\]

The meaning of (2) is that the representative firm uses various factors to produce a target output in order to maximize profit. \( Z_{ri} \) and \( Z_{rj} \) are respectively the quantities of intermediate good \( i \) produced domestically and intermediate good \( j \) produced in the small country and shipped to large country. \( l_r \) and \( A_{nR} \) are the demand of labor and land. \( \phi \) is the share of intermediate goods in the firm's total expenditure, and \( \chi \) is the cost share of land input. \( \phi \) and \( \chi \) reflect some features of the economic structure. For instance, a high \( \phi \) and a low \( \chi \) indicate a higher level of dependence on intermediate manufactured input (or capital), and therefore a more industrialized economy; conversely a low \( \phi \) and a high \( \chi \) indicate a higher level of dependence on land, and therefore a more agricultural economy.

We assume that the production technology used by the firms has the property of increasing returns in scale. Denoting the fixed and marginal input combinations of the representative firm in the large country as \( f \) and \( \alpha \), and their price index as \( P_r \), we can write the firm’s total costs as:

\[
(3) \quad C_n = (f + \alpha q_n) P_r, \quad f, \alpha > 0.
\]

The decision problem for the representative producer in the small country is symmetrical to (2). To facilitate comparison, we use \( \mu \) and \( \theta \) to denote the cost
share of intermediate input and that of land input in manufacturing in the small
country. Moreover, we denote the fixed and marginal input combinations of the
representative firm in the small country as $g$ and $\alpha$. The total costs of the
representative firms in the small country are:

$$C_{sj} = (g + \alpha q_{sj}) P_s, \quad g, \alpha > 0.$$  

In equilibrium, all factors, including land and labor, are fully utilized, so we have market clearance in all factors markets, that is

$$\lambda n l_{s} = L_s; (1-\lambda)n l_{sj} = L_s;$$  

$$L_s H_{sj} + \lambda n A_{sj} = R_r; L_s H_{sj} + (1-\lambda)n A_{sj} = R_s.$$  

Market clearing condition in the global market is that one country’s value of imports must be equal to the value of its total exports, which is

$$\left( (1-\lambda)n L_{s} B_{rij} + (1-\lambda)n \lambda n Z_{rij} \right) p_{sj} = \left( \lambda n L_{s} B_{sir} + \lambda n (1-\lambda) n Z_{sij} \right) p_{ir}$$  

In a Walrasian general equilibrium, the demand and supply of each good are determined by the prices of other goods as well as the good’s own price. The system is in equilibrium only when a set of prices equate the demand and supply of all goods (Walras, 1874). Solving the general equilibrium therefore involves finding that set of prices.

Solving the first-order maximum condition of the consumer’s and producer’s decision problems in both countries, we can obtain their quantities demanded of the final goods and those of factor inputs. These together with zero profit conditions ($\pi_n = p_n q_n - (f + \alpha q_n) P_r = 0$ and $\pi_{sj} = p_{sj} q_{sj} - (g + \alpha q_{sj}) P_s = 0$, which stem from (3) and (4)), factor market clearance (5) and (6), and utility maximization conditions of consumer, we obtain

$$p_{ri} = \frac{\alpha P_r}{\rho}, \quad p_{sj} = \frac{\alpha P_s}{\rho}$$  

and
From the international trade balance condition (7), the production function, the demand function of consumers and producers, and the function of product varieties, we obtain the following system of equations that defines the equilibrium\(^1\)

\[
\begin{align*}
P_r &= \left( \frac{\chi}{1-\phi-\chi} + 1-\gamma \right) \frac{L_r w_n}{\gamma R_r}, \\
P_s &= \left( \frac{\theta}{1-\mu-\theta} + 1-\gamma \right) \frac{L_s w_{sj}}{\gamma R_s}.
\end{align*}
\]

The equation set (8) includes 5 unknown variables and 4 equations. Defining \(P_r/P_s = P\), \(w_n/P_r = w_1\) and \(w_{sj}/P_r = w_2\), we can eliminate 1 unknown variable, and solve for \(P\), \(w_1\), \(w_2\) and \(\lambda\). All other endogenous variables can subsequently be solved. In our model, besides \(\lambda\) and \(n\), all prices are decided simultaneously, which guarantee clearance in all markets.

The real income (measured by utility) equations of the representative consumer from the two countries are

\[
(9)
\]

\(^1\) Detailed derivation of all equations in this section is in the Appendix A.
Substituting the values of $P$, $w_1$, $w_2$ and $\lambda$ to (9) and (10), we can obtain the real per capita income of consumers from two countries respectively.

2.2. The effect of population size in the large country on income differences

Since the purpose of our model is to study some of the driving forces behind income differences cross nations, we want to examine how changes of the exogenous variables in our model affect the equilibrium real income differences between the two countries. As the system of equations defining the equilibrium is complex, their algebraic solutions are unobtainable, and we have to resort to numerical simulations.

Let $L_s = 2800$, $R_s = R_i = 1600$, $f = g = 10$, $\alpha = 0.9$, $\gamma = 0.92$, $\rho = 0.72$, $\phi = \mu = 0.14$, $\chi = \theta = 0.08$, $t = \tau = 1.17$, $T = 1.65$, we vary only the population size of the large country $L_s$ and see how real income levels change in response in both countries. To better understand the mechanism of the effect of the large country’s population change, we examine the changes in the large country’s share of manufactured good varieties ($\lambda$), relative price of combined inputs, $(P_s/P_r)$, relative wage $(w_s/w_i)$ and relative land rent $(p_m/p_r)$ in the two countries. As a comparison, we also report real incomes levels in the close economy case (where
there is no trade between the two countries). The simulation results are presented in Table 1.

Table 1. Effects of changes in the population of the large country

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Closed Economy</th>
<th>Open Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_r$</td>
<td>$R_r / L_r$</td>
<td>$U_{ti}^{T^{+++}}$</td>
</tr>
<tr>
<td>2800</td>
<td>0.5714</td>
<td>2.7842</td>
</tr>
<tr>
<td>11900</td>
<td>0.1345</td>
<td>3.9244</td>
</tr>
<tr>
<td>23500</td>
<td>0.0681</td>
<td>4.6120</td>
</tr>
<tr>
<td>36100</td>
<td>0.0443</td>
<td>5.1064</td>
</tr>
<tr>
<td>51200</td>
<td>0.0313</td>
<td>5.5478</td>
</tr>
<tr>
<td><strong>62690</strong></td>
<td><strong>0.0255</strong></td>
<td><strong>5.8208</strong></td>
</tr>
<tr>
<td>71300</td>
<td>0.0224</td>
<td>6.0012</td>
</tr>
<tr>
<td>84500</td>
<td>0.0189</td>
<td>6.2480</td>
</tr>
<tr>
<td>93800</td>
<td>0.0171</td>
<td>6.4047</td>
</tr>
</tbody>
</table>

Two observations can be made from the simulation results. First, both countries have higher real income levels in the open economy case, indicating that trade is mutually beneficial. Second, there is a non-linear relationship between population size in the large country and income difference between the two countries. When the two countries have the same population size they have the same real income. As one country’s population increases the large country will become relatively richer. However, when population in the large country reaches a threshold ( $L_r = 62690$ in our simulation), the large country’s advantage disappears. If the population in the large country continues to increase, the real income of the large country will fall below that of the small country.

This non-linear relationship between population and income differences is due to the fact that an increase in population size in the large country has two different effects on the model economy. The first is income-enhancing to the large country: an increase in population increases the amount of labor resources, and supports a larger market which enables better utilization of increasing
returns to scale and a greater variety of manufactured goods produced. The second is income-limiting for the large country: the increase in population reduces per capita land, which reduces per capita real income in the large country directly (as land is a consumption item), and indirectly (due to decreasing returns to labor when land is fixed). Initially the income enhancing effect dominates, and the large country gains relatively more than the small country. However, when the population exceeds the threshold value, the income-limiting effect becomes more severe in the large country and the population advantage turns into a population burden.

2.3. The effects of other variables on income differences

Obviously (relative) population size is not the only factor determining cross-country income differences. While a large country has an advantage before its population reaches a critical threshold, there are other factors which strengthen or weaken this advantage. Thus a populous country may be rich (e.g., the US, Japan) or not (e.g., China, India) depending on the joint effects of many forces. In the following, we consider six factors affecting income differences cross countries, namely, international transaction costs \( T \), domestic transaction costs \( t \), technology \( f \), natural resources \( R_r \), the industry’s dependence on natural resources \( \chi \) and the degree of industrial linkage \( \phi \). Similar to our analysis of the population effect, we still resort to numerical simulations. Specifically, we start with a given set of parameter values and obtain real income levels in both countries; then we give different values to only the parameter in question, and obtain different real income levels. Based on the pattern of responses in real

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\(^1\) As population in the large country increases, both countries produce more goods, but the share of varieties produced in the large country increases.
income levels to the change of the parameter in question, we derive the following results:\(^2\)

\[ \frac{\partial U_i}{\partial T} < 0, \quad \frac{\partial U_j}{\partial T} < 0, \quad \frac{\partial (U_i - U_j)}{\partial t} > 0; \quad \frac{\partial U_i}{\partial t} > 0, \quad \frac{\partial U_j}{\partial t} > 0 \]

\[ \frac{\partial U_i}{\partial f} < 0, \quad \frac{\partial U_j}{\partial f} < 0, \quad \frac{\partial (U_i - U_j)}{\partial R_r} > 0; \quad \frac{\partial U_i}{\partial R_r} > 0, \quad \frac{\partial U_j}{\partial R_r} > 0 \]

\[ \frac{\partial U_i}{\partial \chi} < 0, \quad \frac{\partial U_j}{\partial \chi} < 0, \quad \frac{\partial (U_i - U_j)}{\partial \chi} < 0; \]

\[ \frac{\partial U_i}{\partial \phi} > 0, \quad \frac{\partial U_j}{\partial \phi} > 0, \quad \frac{\partial (U_i - U_j)}{\partial \phi} > 0; \]

\[ \frac{\partial U_i}{\partial \phi(\phi = \mu)} > 0, \quad \frac{\partial U_j}{\partial \phi(\phi = \mu)} > 0, \quad \frac{\partial (U_i - U_j)}{\partial \phi(\phi = \mu)} > 0. \]

From the above inequalities we draw five implications, which are empirically testable.

First, a fall in transaction costs in international trade promotes trade which benefits both countries \((\partial U_i/\partial T < 0, \partial U_j/\partial T < 0)\). However, the small country benefits more \((\partial (U_i - U_j)/\partial T > 0)\). This is because international trade substantially increases the market size for producers in both countries, especially the small country. In comparison, the market enlargement effect is less significant for the large country. Thus increased globalization as a result of falling transaction costs in international trade reduces the population advantage of the large country and cross-country income differences.

\(^2\) Due to space limitations, we do not report detailed simulation results in the paper. They can be obtained from the corresponding author.
Second, a fall in domestic transaction costs in the large country increases the large country’s real income \( \frac{\partial U_i}{\partial t} < 0 \), but has a small negative effect on the small country\(^3\), therefore the large country’s relative income increases. It should be noted here that transaction costs in our model can be interpreted to encompass not only transportation costs, but also other factoring influencing efficiency in market transaction, in particular, institutional factors such as rule of law, security property rights and contract enforcement. If a large poor country (e.g., China and India) reduces its domestic transaction costs through for example reforms that improve domestic institutions, it will capture most of the resulting benefits with little spillover, and consequently narrowing cross-country income differences.

Third, technology and natural resources are important determinants of real income. If the large country has a low level of technology (a large \( f \)) or a low level of per capita natural resources (small \( R_y/L_r \)), it will have a low level of real income. An improvement in technology or a discovery of more natural resources in the large country not only benefits the large country and increases its real income relative to the small country \( \partial(U_j - U_{sj})/\partial f < 0, \partial(U_j - U_{sj})/\partial R_y > 0 \), but also has a positive spillover effect through trade on the small country, i.e., \( \partial U_{sj}/\partial f < 0, \partial U_{sj}/\partial R_y > 0 \).

Fourth, a high level of dependence of production on natural resources (a large \( \chi \)) is not favorable to a country. When a country is in transition from a natural resource-intensive industrial structure to a labor-intensive or capital-

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\(^3\) A reduction in domestic transaction costs has two effects. First, it increase the total number of good varieties, which benefits both countries through international trade. Second, it may induce industries in another country to move to the country with reduced domestic transaction cost. As shown in Table B.2 in the Appendix B, as domestic transaction costs are reduced, the number of goods produced in another country \( ((1-\lambda)n) \) falls.
intensive industrial structure, the country is likely to experience a significant increase in per capita real income, and extends the benefits to other countries through trade. \( \chi \) indicates the large country’s degree of dependence on land or natural resource. \( \phi \) indicates the large country’s degree of dependence on capital (or intermediate inputs). If \( \phi \) remains unchanged, and \( \chi \) falls, it means that the large country is transitioning from an land-intensive agricultural economy to a labor-intensive handicraft economy. On the other hand, if \( \phi \) increases and \( 1-\phi-\chi \) remains unchanged \((1-\phi-\chi \equiv \text{cons})\), then \( \chi \) must move in opposite direction to \( \phi \). This means that the economic structure in the large country is moving from land-intensive agriculture to capital-intensive modern manufacturing. \( \partial(U_n-U_s)/\partial \chi < 0 \) and \( \partial(U_n-U_s)/\partial \phi (1-\phi-\chi \equiv \text{cons}) > 0 \) imply that if one country has transitioned from an agricultural economy to a handicraft economy or a modern manufacturing economy, whereas another country remains in an agricultural economy, then the former will enjoy a significantly higher per capital income.

Fifth, the degree of industrial linkage has a positive effect on both countries’ per capita real income, with the large country benefiting more from higher levels of industrial linkage. \( \phi \) has two meanings. Apart from the economic structure mentioned above, it can also indicate the linkages between firms and the degree of roundaboutness in production. In this paper, capital is intermediate input, which reflects the roundaboutness in production in the Böhm-Barwerkian sense. The degree of roundaboutness is related to the number of intermediate varieties. To some degree, \( \phi \) indicates the intensity of intermediate goods use. However, since an increase in \( \phi \) also increases the number of intermediate input varieties, thus it also reflects the extent to intermediate input use. The larger the number of intermediate input used, the longer the roundabout production process. Since the
large country produces more varieties of intermediate goods, when the degree of
linkages between firms increases, the large country will purchase more
intermediate inputs from its domestic market, thus saving international transaction
costs and lowering costs of production. This may widen the real income
differences between the large country and the small country
\[ \left( \frac{\partial (U_n - U_s)}{\partial \phi} \right) \left( \phi = \mu > 0 \right). \]

3. Empirical Analysis

Our theoretical model above has shown the existence of a large country
advantage (before the threshold population level has been reached), however
there are many other factors constraining the development of a large country. If
the constraining factors are significant, the large country advantage will be
offset and a large country is possibly poorer than a small country. Indeed there
are many large poor countries in the world, giving an impression that a larger
population is associated of poverty. However, first impression can often be
deceiving. In this section, we test the main conclusions of our theoretical model,
including the existence of the large country advantage.

3.1 Model setup and choice of variables

Although the subject of our paper concerns income growth, but our
theoretical model is one of spatial allocation, and we use comparative statics to
derive our conclusions. In the empirical analysis, we therefore try to exclude the
effect of time per se on the economic system. Based on the conclusions of our
theoretical model, we choose the following empirical model:

\[
\text{gdpdev}_{it} = \beta_1 \text{popshare}_{it} + \beta_2 \text{urban}_{it} + \beta_3 \text{export}_{it} + \beta_4 \text{road cost}_{it} + \beta_5 \text{energy}_{it} \\
+ \beta_6 \text{dust}_{it} + \beta_7 \text{tech}_{it} + \alpha_1 + \varepsilon_{it}.
\]
Where \( i \) denotes country or region, \( t \) denotes time, \( \alpha_i \) is unobservable country/region effects, \( \epsilon_{it} \) is random error.

The dependent variable in the model, \( gdpdev \), measures the deviation of a country’s average per capita real income from the world mean. Barro and Sala-i-Martin (1992) use the cross-country deviation of real per capital income to indicate cross-country income differences. In our analysis, \( gdpdev \) is calculated as the ratio of each country’s per capita real GDP (constant 1990 PPP $) and the world average per capita real GDP.

Independent variable \( popshare \) is a country’s population as a share of the world total. This variable measures population distribution, and is the key explanatory variable of our model. Since population is an important production input, and labor income in turn determines demand, a country’s GDP is likely to be positively correlated with its population. We will also use \( laborshare \) (which is a country’s total labor employed as a share of the world total labor employed), as an alternative indicator of population size.

Independent variable \( urban \) is the deviation of a country’s urban population share from the world average. The share of urban population is a common measure of urbanization and reflects also the degrees of industrialization. Since industries and services are labor-intensive industries which tend to concentrate in urban areas, a higher \( urban \) indicates that industrial products and services take a larger share in the total output, whereas agriculture takes a small share. Thus \( urban \) to some extent reflects the importance of non-agricultural activities in the economy structure.

Independent variable \( export \) is ratio of a country’s the share of exports in GDP to the world average. This is a measure of trade openness. The degree of trade openness is associated with country size. A large country tends to have a lower degree of trade openness because it has a large domestic economy and
residents can purchase more goods and services domestically. The US is considered to be a very open economy, however, its average trade openness over our sample periods is 11.02. The average trade openness for China is 27.37, however, the corresponding figure for Singapore is 198.08. Clearly, a small country tends to be more deeply immersed in international trade. Apart from population size, a country’s geographic location (distance to ocean, capacity of ports), international transportation and other transaction costs also affect a country’s trade openness.

Independent variable *roadcost* is the ratio of a country’s energy consumption per unit of GDP (PPP) by the road sector to the world average. It to some degree reflects cross-country differences in domestic transportation costs. Since a large portion of the transaction costs is unobservable, domestic transaction costs and the extent of market development is very hard to be measured. Of the measurable transportation costs, it is hard to be classified by type. We adopt energy use by the road transportation sector as a proxy of domestic transportation costs because it reflects millage travelled, which in turn is closely related vehicle depreciation and wage costs of drivers.

Independent variables *land* and *energy* measure cross country difference in per capita natural resources. *land* is the ratio of a country’s per capita land area to the world average. *energy* is the ratio of a country’s per capita production of energy equivalent to the world average. Since land in many countries includes deserts, jungles, high altitude mountains and plateaus, that are not suitable for human habitation or production, *land* is not an accurate measure of resources. Some scholars recommend the use of resource reserves per unit of land, but resource reserves are also hard to be measured accurately. Moreover, from the economic perspective, reserves do not reflect the difficulty and costs of resource extraction. Since resources will only be extracted up to the point where the margin benefit of extracting equals its marginal costs, resource output and value in each
country can better reflect differences in resource endowment. Therefore we use energy to measure cross country resource differences.

Independent variable \( \text{densitysq} \) and \( \text{dust} \) measure the degree of crowdedness due to land scarcity. \( \text{densitysq} \) is calculated by taking the ratio of a country’s population density (population per unit of land) to the world average, then squaring the ratio. Since population is positively correlated to GDP, if the coefficient of \( \text{densitysq} \) in our estimation turns out to be negative, it suggests a inverted U relationship between population and per capita GDP. \( \text{dust} \) is the ratio of a country’s per cubic meter total suspended particulates (TSP) to the world average. If the coefficient of \( \text{dust} \) is negative, it would suggest that environment degradation and overcrowding has a negative impact on economic development.

Independent variable \( \text{tech} \) is ratio of a country’s energy use per unit of GDP (constant 1990 PPP $) to the world average. As a rule countries with high levels energy efficiency also have advanced technologies albeit energy efficiency also reflects superiority of management practices.

### 3.2 Data sources and summary statistics

Our empirical analysis is based on a panel data set covering 91 countries over the period of 1994-2011. The main data source is the World Bank. Table 2 lists all variables, their definitions and summary statistics.
## Table 2. Variable specifications and summary statistics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Specifications</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>gdpdev</td>
<td>Each country’s per capita GDP / world average per capita GDP (1990 PPP $)</td>
<td>1.473344</td>
<td>1.178157</td>
<td>4.874605</td>
<td>0.0692495</td>
</tr>
<tr>
<td>popshare</td>
<td>Each country’s population / world total population</td>
<td>0.0093462</td>
<td>0.028019</td>
<td>0.211734</td>
<td>0.0000455</td>
</tr>
<tr>
<td>urban</td>
<td>Each country’s share of urban population / world average share of urban population</td>
<td>1.303454</td>
<td>0.4526141</td>
<td>2.256318</td>
<td>0.2905145</td>
</tr>
<tr>
<td>export</td>
<td>Each country’s share of exports in GDP / world average share of exports in GDP</td>
<td>2.024241</td>
<td>1.445766</td>
<td>10.4315</td>
<td>0.2783515</td>
</tr>
<tr>
<td>land</td>
<td>Each country’s average per capita land area / world average per capita land area</td>
<td>1.687775</td>
<td>3.042488</td>
<td>18.27533</td>
<td>0.0069891</td>
</tr>
<tr>
<td>energy</td>
<td>Each country’s per capita energy production / world average per capita energy production</td>
<td>45.72382</td>
<td>129.7664</td>
<td>1228.56</td>
<td>0</td>
</tr>
<tr>
<td>roadcost</td>
<td>Each country’s energy use per unit of GDP (PPP) in road sector / world average</td>
<td>1.154153</td>
<td>0.9679924</td>
<td>7.533225</td>
<td>0.0388403</td>
</tr>
<tr>
<td>densitysq</td>
<td>(Each country’s population per unit of land area / world average population per unit of land area)^2</td>
<td>418.8441</td>
<td>2666.335</td>
<td>20471.87</td>
<td>0.0029941</td>
</tr>
<tr>
<td>dust</td>
<td>(Each country’s TSP / m³) / (world average TSP / m³)</td>
<td>0.7861667</td>
<td>0.5096914</td>
<td>3.226444</td>
<td>0.1740067</td>
</tr>
<tr>
<td>tech</td>
<td>Each country’s energy use per unit of GDP (PPP) / world average energy use per unit of GDP (PPP)</td>
<td>1.212815</td>
<td>0.9226059</td>
<td>8.035316</td>
<td>0.242481</td>
</tr>
</tbody>
</table>

Note: “/” denotes “divided by” in this table.
3.3. Estimation method and results

Usually, a country’s income level in the current period depends on its income level in the last period. A poor country does not suddenly turn into a rich country or vice versa. Therefore we introduce lagged \( gdpdev \) to equation (11) and make it into a dynamic panel:

\[
(12) \quad gdpdev_{it} = \gamma gdpdev_{i,t-1} + \beta_1 \text{popshare}_{it} + \beta_2 \text{urban}_{it} + \beta_3 \text{export}_{it} + \beta_4 \text{roadcost}_{it} \\
\quad + \beta_5 \text{energy}_{it} + \beta_6 \text{dust}_{it} + \beta_7 \text{tech}_{it} + \alpha_i + \varepsilon_{it}
\]

A dynamic panel not only solves the problem of serial correlation but also addresses the problem of endogeneity between independent variables. Since the economic system in essence is a general equilibrium, the variables are interdependent, which gives rise to the endogeneity problem. In this case, the OLS estimator is biased and inconsistent. Our empirical model has this problem as well. In addition, the endogeneity problem arises when there is omitted variable due to unobtainable data or unmeasurable variables. Since we have only limited data from the World Bank, our model has the problem of omitted variables. These, together with possible measurement errors in the data, imply that all OLS estimates would be biased and inconsistent.

The data period in our analysis is 18 years. In the short run, \( \text{popshare} \) may be considered to be exogenous. However, over a longer term, population is affected by birth rate, mortality rate and migration rate, which in turn are affected by per capita GDP. Thus \( \text{popshare} \) and \( gdpdev \) are jointly determined. \( \text{urban} \) reflects changes in economic structure, and \( \text{export} \) reflects changes in trade openness. Both are influenced by per capita GDP. If per capita GDP in a country increases, its domestic demand and consumption structure will change in a way to facilitate the transition from an agricultural economy to an industrialized economy. An increase in GDP also implies larger production capacity and improvement in
transportation, therefore lowering transportation costs, and promoting domestic and international trade. Thus, \textit{gdpdev}, \textit{urban}, \textit{export} and \textit{roadcost} are interdependent as well. A country’s energy production is also affected by its level of economic development and industrialization. Countries with higher levels of per capita GDP, industrialization and urbanization have higher demand for energy, which stimulates energy production. Since energy production itself is energy intensive, higher energy production may also lead to higher CO$_2$ emission and higher total suspended particulates in the air. Thus, \textit{energy}, \textit{dust}, \textit{urban} and \textit{gdpdev} are interdependent. Finally, due to knowledge spillover effects, a country’s population size, urbanization and degree of industrialization may also affect the country’s energy efficiency and technology level. Thus, \textit{popshare}, \textit{urban}, and \textit{tech} may also be interdependent. All these complex endogeneity problems may be addressed by dynamic panel Generalized method of moments (GMM) estimation.

Either the one-step GMM estimator or the two-step GMM estimator can be used. Windmeijer (2005) shows that estimated asymptotic standard errors of the two-step GMM estimator may be downward biased in small samples due to the use of estimated parameters in constructing the weight matrix. He therefore recommends the use of a correction term generated by a Taylor expansion. However since this method leads to an asymptotically inefficient GMM estimator, one-step GMM estimator is more widely used (Bond, 2002). According to Blundell and Bond (2000), Blundell and Windmeijer (2002), one-step system GMM estimator is more precise than the standard first-step differenced GMM estimator. In this paper, we apply the one-step system GMM estimation (Arellano and Bover, 1995 and Blundell and Bond, 1998). As a robust check, we also report results from the two-step system GMM estimation. The estimation results of model (12) are presented in Table 3.
<table>
<thead>
<tr>
<th>Estimation method</th>
<th>Model 1</th>
<th></th>
<th></th>
<th>Model 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( gdpdev_{t,i} )</td>
<td>( 0.9579745 ) ***</td>
<td>( 0.9570233 ) ***</td>
<td>( 0.9580537 ) ***</td>
<td>( 0.9539156 ) ***</td>
<td>( 0.953327 ) ***</td>
</tr>
<tr>
<td>( \text{popshare} )</td>
<td>( 0.1404207 ) **</td>
<td>( 0.1385887 ) **</td>
<td>( 0.1127821 ) *</td>
<td>( 0.1117283 ) **</td>
<td></td>
</tr>
<tr>
<td>( \text{laborshare} )</td>
<td>( 0.127993 ) **</td>
<td>( 0.127993 ) **</td>
<td>( 0.1127821 ) *</td>
<td>( 0.1117283 ) **</td>
<td></td>
</tr>
<tr>
<td>( \text{urban} )</td>
<td>( 0.0501027 ) ***</td>
<td>( 0.054482 ) ***</td>
<td>( 0.0499097 ) ***</td>
<td>( 0.0699646 ) ***</td>
<td></td>
</tr>
<tr>
<td>( \text{export} )</td>
<td>( 0.0083687 ) ***</td>
<td>( 0.0083687 ) ***</td>
<td>( 0.0083439 ) ***</td>
<td>( 0.0147758 ) ***</td>
<td></td>
</tr>
<tr>
<td>( \text{land} )</td>
<td>( 0.0012101 )</td>
<td>( 0.0012101 )</td>
<td>( 0.0012388 )</td>
<td>( 0.0012388 )</td>
<td></td>
</tr>
<tr>
<td>( \text{energy} )</td>
<td>( 0.0000469 ) **</td>
<td>( 0.0000443 ) *</td>
<td>( 0.0000466 ) **</td>
<td>( 0.0000443 ) *</td>
<td></td>
</tr>
<tr>
<td>( \text{roadcost} )</td>
<td>( -0.022042 ) ***</td>
<td>( -0.0213119 ) ***</td>
<td>( -0.0220113 ) ***</td>
<td>( -0.0257409 ) ***</td>
<td></td>
</tr>
<tr>
<td>( \text{densitysq} )</td>
<td>( -3.75e-04 )</td>
<td>( -3.75e-06 )</td>
<td>( -3.75e-06 )</td>
<td>( -3.75e-06 )</td>
<td></td>
</tr>
<tr>
<td>( \text{dust} )</td>
<td>( -0.0219498 ) ***</td>
<td>( -0.0223564 ) **</td>
<td>( -0.0216473 ) ***</td>
<td>( -0.0223564 ) **</td>
<td></td>
</tr>
<tr>
<td>( \text{tech} )</td>
<td>( -0.0064044 ) **</td>
<td>( -0.0055863 ) *</td>
<td>( -0.0064115 ) **</td>
<td>( -0.0054152 ) *</td>
<td></td>
</tr>
<tr>
<td>( _cons )</td>
<td>( 0.0224925 ) (1.79) *</td>
<td>( 0.0133067 ) (0.91)</td>
<td>( 0.0225011 ) (1.79) *</td>
<td>( 0.0223769 ) (1.94) *</td>
<td></td>
</tr>
<tr>
<td>AR(1)</td>
<td>( -2.97 ) (0.003)</td>
<td>( -2.99 ) (0.003)</td>
<td>( -2.97 ) (0.003)</td>
<td>( -2.97 ) (0.003)</td>
<td></td>
</tr>
<tr>
<td>AR(2)</td>
<td>( -0.83 ) (0.405)</td>
<td>( -0.82 ) (0.411)</td>
<td>( -0.83 ) (0.405)</td>
<td>( -0.81 ) (0.416)</td>
<td></td>
</tr>
<tr>
<td>Hansen test of over-identification</td>
<td>69.18 (0.195)</td>
<td>69.18 (0.195)</td>
<td>69.02 (0.199)</td>
<td>67.20 (0.244)</td>
<td></td>
</tr>
<tr>
<td>Number of instruments</td>
<td>69</td>
<td>69</td>
<td>69</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Number of obs</td>
<td>1547</td>
<td>1547</td>
<td>1547</td>
<td>1547</td>
<td></td>
</tr>
<tr>
<td>Number of groups</td>
<td>91</td>
<td>91</td>
<td>91</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Obs per group</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Notes: \( t \) statistics corresponding each coefficient is displayed in parentheses below the coefficient of each variable, and *, ** and *** denote significance in the level of 10%, 5% and 1%, respectively. P-values consistent with AR(1), AR(2) and Hansen test of over-identification are placed in brackets.
Table 3 reports test statistics for residual serial correlation AR(1), AR(2) and over-identification and their corresponding p-values. It is clear that the null hypothesis of no first-order serial correlation is rejected at 1% level, whereas the null hypothesis of no AR(2) cannot be rejected. In all of our estimations, we use 69 instrumental variables to estimate 8 explanatory variables, giving rise to multiple over-identification moment conditions. The Hansen test statistics for all models has a p-value of greater than 10%, indicating the null hypothesis of valid instruments cannot be rejected. This implies that our choice of instrumental variables and their lag orders are appropriate.

From Table 3, we see that lagged income difference \((gdpdev_{i,t-1})\) has a positive and significant coefficient of 0.95. This indicates that much of cross-country income difference is determined by historical factors. Nature does not make jumps (Marshall, 1920), neither do human societies. There is clear path-dependence in economic development. Apart from the factors analyzed in this paper, a country’s development is influenced by many other factors including existing market potential, per capita capital stock, stock of knowledge and human capital accumulation, social institutions, and other “historical stock” (Acemoglu and Zilibotti, 1997). Since these factors do not change suddenly, a country’s per capita GDP can only grow on the basis of its previous level.

The variable of our most interest, a country’s population share \((popshare)\) has a positive and significant coefficient in all models. This supports our theoretical model’s conclusion that population size has a positive impact on a country’s per capita real income (before a population threshold level has been reached). Although this conclusion does not seem to match our casual observation, we consider the coefficient of 0.2 may in fact underestimate the extent of the large country advantage. This is because the large country advantage is likely to be a long term influence, however we have only 18 years of data. If we take China and India as large country examples, these two countries are currently
poor, but during the 1000 years before the modern era, they were among the richest in the world.

There are many reasons why the large country advantage may be offset. In our theoretical model, a number of factors interact to undermine the large country advantage, including trade openness, crowdedness due to over-population, underdeveloped domestic market and high transaction costs, high dependence on land and natural resources, low levels of technology, etc. The effects of these variables can be seen from Table 3.

Trade openness (export) has a positive effect on income. As mentioned before, in a closed economy, the income difference between the large country and the small country is very big. When international trade takes place, the large country advantage will spill over to the small country, leading to a narrowing of income differences. However, even with international trade, if the international transaction costs are high, the large country will still enjoy higher income. With the falling international transaction costs, trade volume will increase, and the degree of openness for the small country will rise faster. As a result, income differences narrow. In comparison, since a large country produces more product varieties and its residents can purchase more goods domestically, its benefit from international trade is relatively smaller. The estimation results support our theoretical prediction.

Domestic transaction costs (roadcost) have a significantly negative impact on a country’s income. Our theoretical model predicts that a fall in a country’s domestic transaction costs will increase the country’s per capita real income, but has a tiny negative impact on its trade partner. It should be noted that although fuel consumption by the road transportation sector is a good proxy of transportation costs, it does not cover all domestic transaction costs. The scope of transaction costs is large, including social customs, law and regulations, market development, corporate governance, property right systems etc. However these
factors are mostly un-measurable. Since we apply dynamic panel GMM estimation, the problems associated with omitted variables and measurement errors are addressed by lagged variables. The results in Table 3 support the conclusion that an improvement in domestic transaction efficiency enhances a country’s international competitiveness.

A country’s urban population as a share total population (urban) has significant positive effect on per capita GDP. The share of urban population reflects a country’s degree of industrialization. Usually a higher urban indicates a high proportion of non-agricultural activities in a country’s economy. Agriculture is a sector highly dependent on land. In countries with high proportions of agricultural population, the level of division of labor tends to be low. Farmers self-provide agricultural products and sell the surplus to the market. This low level of division of labor is not conducive to economic development. The transition from agricultural-based to industry-based economic structure in poor countries will narrow the income differences between these countries and the rich countries.

The estimated coefficient of energy use per unit of GDP (tech) is negative and significant. One the one hand, tech measures technological differences: countries with more advance technologies tend to consume less energy to produce a unit of GDP. On the other hand, tech to some extent describes the structure of the economy. If a country’s economy is dominated by energy-intensive industries such as electricity generation, mining and steel making, then it will have a high value of tech. The negative sign of the estimated coefficient suggests that higher technology levels and low energy intensity are associated with higher per capita real income.

A country’s per capita land area (land) has a positive coefficient but is not significant. Although land is an objective measure of per capital land area, it does not accurately capture the distribution of resources. Land of the same size may
differ in soil fertility and in resources. It is thus not entirely surprising to find land to be an insignificant explanatory variable for income differences.

A country’s energy production (energy) has a positive and significant effect on income differences, but the effect is small. Resource endowment contributes to per capita GDP, but it is possible to have the “resource curse”, resulting in a small net positive effect.

A country’s TSP measure in cities (dust) has a negative and significant effect on income differences. TSP measure may be related to industrial production and energy consumption. High levels of TSP may affect economic development through two channels: air pollution harms the health status of residents, and induce local enterprise to move elsewhere. Secondly, local governments and enterprises need to devote more resources to clean the environment, pushing up the costs faced by businesses. The negative coefficient of dust implies that excessive industry and population density creates over-crowded environment which has a negative impact on per capita GDP. This result is also supported by a negative and significant coefficient of densitiesq.

4. Conclusion

In this paper we have studied various factors affecting cross-country income differences within the framework of a spatial general equilibrium model. We have also empirically tested the conclusions of our theoretical model using data of 91 countries (regions) over the period of 1994-2011. The main conclusions are as follows.

First, cross-country income differences are determined by many different factors. A country’s population size and per capita natural resource endowment has an important impact on cross-country income differences. This conclusion is derived from our theoretical model and supported by our empirical test. We can also find much supporting evidence outside our sample period. China and India
are historically populous countries and were among the wealthiest in the world during the 1000 or so years before the modern era.

Second, falling international transaction cost and increasing trade openness tend to reduce cross-country income differences, whereas falling domestic transaction costs tend to increase them. Notably, some economists have identified significant club convergence. Mankiw et al (1992) find evidence of convergence at the rate predicted by the augmented Solow model. Kaitila (2004) shows that real per capita GDP in the EU15 countries converged during the periods 1963-1973 and 1981-2001. O’Rourke and Williamson (1994) demonstrate that trade liberalization since the end of 19th century ushered in an era of economic convergence. Ireland and Scandinavian countries have gradually caught up with the older developed countries such as Britain, France and Germany. The income gap has also narrowed between countries in Latin America and Oceania on the one hand and the older developed countries on the other (Yang, 2003). However the income levels of a number of African and South Asian countries still lag far behind developed countries, in some cases the income gap has even widened. One explanation for this growth pattern is that transaction costs within the EU have substantially fallen, and trade openness has also improved for North America, Latin America and Oceania. In contrast, South Asia, and African countries tend to be less integrated into the world economy, and their domestic markets are also under-developed. Our model suggests that when transaction costs within the EU fall, EU countries develop faster, increasing the income gap between them and countries outside of the EU. It should be also noted that while markets in many other countries enjoyed fast development after WWII, some African and South Asian countries had chosen the paths of central planning with authoritarian regimes. This led to political instability and high domestic transaction costs. As a result, their income levels have fallen further behind those of developed countries.
Third, a country’s per capita resource endowment and geographical location have important effects on its per capita income. Countries with high degrees of trade openness usually enjoy an advantage in maritime transport. This advantage has a positive impact on these countries’ income. When a country has a large per capita resource endowment, marginal productivity of labor tends to be large, which in turn raise per capita real income. In comparison, when per capita resource is small, people have to adopt intensive farming on limited land, consequently marginal product of labor is low. Hence, ceteris paribus, per capita income will be low.

Fourth, a shift of a country’s economic structure from land intensive production to capital intensive production usually raises per capita real income of this country. When per capita land resource is small, the shift in economic structure relaxes the country’s land constraint, enabling extraordinary growth. Kuznets (1973) argues a high rate of structural shifts is a main characteristic of modern economic growth. Our model supports this view. Historically, many populous countries indeed achieved fast economic growth following their structural shift from agricultural economies to industrial economies. China was a strong agricultural economy in pre-modern times. At the beginning of the 19th century, China’s population had reach 300 million, resulting in substantially smaller per capita arable land area. However, for various reasons, China did not achieve the structural shift from an agricultural economy to an industrial economy. Unsurprisingly, China remained a poor country.
References


Appendix. Derivation of General Equilibrium

The decision problem for the consumer in the large country is:

$$\max U_n = n^\rho \left[ \lambda \left( \frac{B_{nii}}{t} \right)^\rho + (1-\lambda) \left( \frac{B_{nij}}{T} \right)^\rho \right]^{\gamma/\rho} H_{nR}^{1-\gamma}$$

st. $$w_n = \lambda n p_{n} B_{nii} + (1-\lambda) n p_{n} B_{nij} + p_{r} H_{rR}$$

From the first-order conditions, we have:

(A.1)

$$B_{nii} = \frac{\gamma w_{n} t}{(1-\lambda) np_{n} T \left( \frac{p_{n} t}{p_{n} T} \right)^{\frac{1}{\gamma-\rho}} + \lambda np_{n}}$$

(A.2)

$$B_{nij} = \frac{\gamma w_{n} T}{(1-\lambda) np_{n} T \left( \frac{p_{n} t}{p_{n} T} \right)^{\frac{1}{\gamma-\rho}}}$$

The decision problem for the producer in the large country is:

$$\max \pi_n = p_n q_n - \left[ \lambda n p_{n} Z_{nii} + (1-\lambda) n p_{n} Z_{nij} + w_n l_n + p_{r} A_{nR} \right]$$

st. $$q_n = \left[ \int_0^{\lambda} \left( \frac{Z_{nii}}{t} \right)^{\rho} \int_0^{(1-\lambda) n} \left( \frac{Z_{nij}}{T} \right)^{\rho} \right]^{\gamma/\rho} l_n^{1-\gamma} A_{nR}^{\gamma}$$

The first order conditions yield:

(A.3)

$$np_{n} t \left( \frac{Z_{nii}}{t} \right)^{1-\rho} = \frac{\delta p_{n} q_n}{\lambda \left( \frac{Z_{nii}}{t} \right)^{\rho} + (1-\lambda) \left( \frac{Z_{nij}}{T} \right)^{\rho}}$$

and

(A.4)

$$l_n = \frac{(1-\phi-\chi) p_{n} q_n}{w_{n}}, A_{nR} = \frac{Z p_{n} q_n}{p_{r}}.$$
There are two equations in \((A.3)\). Solving them jointly gives:

\[
Z_{ni} = \frac{\phi p_nq_nt^\frac{1}{1-\rho}}{(1-\lambda)n\rho_{ij}T \left( \frac{p_{ij}}{p_{ij}T} \right)^{1-\rho} + \lambda n\rho_{ij}t} \quad Z_{nj} = \frac{\phi p_nq_nT}{(1-\lambda)n\rho_{ij}T \left( \frac{p_{ij}}{p_{ij}T} \right)^{1-\rho} + \lambda n\rho_{ij}t + (1-\lambda)n\rho_{ij}T}.
\]

From the labor market clearance condition in the large country, \(\lambda n_l = \frac{(1-\phi-\chi)\lambda n\rho_{ij}q_n}{w_{ni}} = L_n\), we obtain

\[
q_n = \frac{L_n w_{ni}}{(1-\phi-\chi)\lambda n\rho_{ij}}.
\]

The zero profit condition \(\pi_n = p_nq_n - (f + \alpha q_n)P_r = 0\) yields

\[
q_n = \frac{fp_r}{p_n - \alpha P_r}.
\]

From (A.6) and (A.7), we obtain

\[
p_n = \frac{\alpha L_n w_{ni}p_r}{L_n w_{ni} - (1-\phi-\chi)\lambda n fP_r}.
\]

Substituting (A.1) and (A.8) to the utility function gives:

\[
U_{ni} = n^{\lambda - \gamma} \left( \frac{L_n w_{ni} - (1-\phi-\chi)\lambda n fP_r}{\alpha L_n w_{ni} P_r} \right)^{\gamma} \left( \frac{p_n}{p_{ij}T} \right)^{\rho/\rho} + \lambda \left( \frac{1-\gamma}{P_{ir}} \right)^{1-\gamma} w_{ni}.
\]

Let \(\frac{\partial U_{ni}}{\partial n} = 0\), we can solve for the optimal number of varieties of the manufactured good:

\[
n = \frac{(1-\rho)L_n w_{ni}}{(1-\phi-\chi)\lambda fP_r}.
\]
From (A.10), (A.8) and (A.7), we solve for the price and quantity produced in the large country of the manufactured good $i$:

(A.11) \[ p_n = \frac{\alpha P}{\rho}, \quad q_n = \frac{\rho f}{(1-\rho)\alpha}. \]

From the land market clearance condition in the large country 
\[ L_rH_{nr} + \lambda n A_{nr} = R_r, \]
we solve for the land rental in the large country:

(A.12) \[ p_{rR} = \left( \frac{\chi}{1-\phi-\chi} + 1-\gamma \right) \frac{L_w n_R}{\gamma R_r}. \]

Substituting (A.4), (A.5), (A.10), (A.11), (A.12) into the production function, we can obtain the following equation:

(A.13) \[
\left( \frac{w_n}{P_r} \right)^{1-\frac{\phi}{\rho}} = \left( \frac{1-\rho}{\lambda f} \right)^{\frac{\phi}{\rho}} \left( 1-\frac{\lambda}{\rho} \right)^{\frac{1}{1-\rho}} + \lambda \left( \frac{\alpha}{\rho} \right)^{1-\frac{\phi}{\rho}} \frac{(1-\phi-\chi)^{\frac{1}{1-\rho}} (\chi R_r)^{\gamma} L_r^{\frac{\phi}{\rho}-\phi-\chi}}{(\chi + (1-\gamma)(1-\phi-\chi))^{\gamma}}.
\]

Following a similar procedure for the small country, we can obtain

(A.14) \[ n = \frac{(1-\rho)L_s w_{sj}}{(1-\mu-\theta)(1-\lambda)g P_s}, \quad p_{sj} = \frac{\alpha P}{\rho}, \quad q_{sj} = \frac{\rho g}{(1-\rho)\alpha}, \]

\[ p_{sR} = \left( \frac{\theta}{1-\mu-\theta} + 1-\gamma \right) \frac{L_s w_{sj}}{\gamma R_s} \]

and

(A.15) \[
\left( \frac{w_{sj}}{P_s} \right)^{\frac{1-\mu}{\rho}} = \left( \frac{\mu}{\tau} \right)^{\frac{\rho}{\mu}} \left[ \left( \frac{P_s \tau}{PT} \right)^{\frac{\rho}{1-\rho}} + 1-\lambda \right] \left( \frac{\alpha}{\rho} \right)^{1-\frac{\mu}{\rho}} \frac{(1-\mu-\theta)^{\frac{1-\mu}{\rho}} \lambda (\theta R_s)^{\gamma} L_s^{\frac{\mu}{\rho}}}{(\theta + (1-\gamma)(1-\mu-\theta))^{\gamma}}.
\]

From (A.10) and (A.14), we have:

(A.16) \[ \frac{L_s w_{ni}}{(1-\phi-\chi)\lambda f P_r} = \frac{L_s w_{sj}}{(1-\mu-\theta)(1-\lambda)g P_s}. \]
The trade balance condition, 

\[ ((1-\lambda)nL_B - \lambda n Z_{nBj})p_{nj} \]

implies:

\[ \frac{\lambda L_w w_{ij}}{1-\mu-\theta} \left( (1-\lambda) \left( \frac{P T}{P_T} \right)^{1-\rho} + \lambda \right)^{-1} = \left( \frac{1-\mu}{1-\phi-\chi} \right) \left( \frac{1}{1-\phi-\chi} \right)^{-1}. \]

(A.17)

(A.13), (A.15), (A.16) and (A.17) form a system of equations with 5 unknowns \( P_r, P_s, w_i, w_j \) and \( \lambda \). Let \( P \equiv P_r/P_r, w_i \equiv w_i/P_r \) and \( w_j \equiv w_j/P_r \), we can solve the system of equations and obtain the utility level (real income) for the representative consumer in the large country:

(A.18)

\[
U_n = \frac{1-\phi}{L_r} \left( \frac{1-\rho}{\lambda f} \right)^{1-\gamma} \left( \frac{\rho}{\alpha t} \right)^{\gamma} \left( 1-\lambda \right) \left( \frac{t}{PT} \right)^{1-\varphi} + \lambda \left( \frac{L_w w_i}{1-\phi-\chi} \right)^{\gamma} \left( \frac{(1-\gamma)R_i}{\chi + (1-\phi-\chi)(1-\gamma)} \right)^{-1-\gamma}
\]

Similarly, we can obtain the utility level (real income) for the representative consumer in the small country.

(A.19)

\[
U_s = \frac{1-\mu}{L_r} \left( \frac{\rho}{\alpha t} \right)^{\gamma} \left( \frac{\rho}{\alpha t} \right)^{1-\gamma} \left( 1-\lambda \right) \left( \frac{t}{PT} \right)^{1-\varphi} + \lambda \left( \frac{L_w w_i}{(1-\mu-\theta)P} \right)^{\gamma} \left( \frac{(1-\gamma)R_i}{\theta + (1-\mu-\theta)(1-\gamma)} \right)^{-1-\gamma}.
\]