Human Capital and the *Hukou* Constraint: Implications for China’s Growth

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It is widely appreciated that China’s household registration system (*hukou*) has exacerbated differences in incomes between urban and rural areas. The aim of this paper is to assess the implications of China’s *hukou* system for human capital accumulation. To do this we use a simulated model economy with two sectors and consider two counterfactual scenarios. The first is the impact of the relaxation of *hukou* restrictions on China’s growth path and human capital investment over the last decade. In practice the *hukou* system has been relaxed since China’s labour force currently consists of an estimated 150 migrants. We therefore consider the extent to which China’s growth path may have been stifled had these migration constraints been enforced. Second, as China’s faces rising labour costs, skill shortages and eroding comparative advantage in its labour intensive export industries, we consider the extent to which further reforms to *hukou* might assist the transition to a middle income country, with greater intensity of skilled labour in the workforce and of skill intensive exports in its external trade.

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1. Introduction

China is now officially a middle income country and forecasts suggest it might well reach per capital income levels similar to the USA in 30 years. Nevertheless maintaining growth through the middle income band may be difficult. Though many, like like Japan, South Korea, and Taiwan have succeeded other such as Indonesia, Malaysia and Thailand have slowed considerably following the Asian financial crisis. In particular the World Bank (2012) showed that most countries that were in this middle income band in 1960 were still middle income countries in 2008. Of these countries there are approximately 20 that are growing on a parallel path to the USA - neither converging nor diverging (Robertson and Ye, 2012).

This prospect of a middle income trap raises many questions regarding the impetus for reform in China – for example so that market legal and political institutions are flexible enough to prevent capture of economic rents and to cope with these potential changes. Of the numerous reforms that are needed, Household registration system (Hukou), is perhaps the most unique feature of the Chinese economy. Under this system permanent migration is controlled. In principle a rural person can obtain urban hukou by education, retiring from the military or by having farmland converted to urban use, (Whalley and Zhang 2007, Knight and Ding 2012,).

Rural hukou households may migrate temporarily though face limited options in the urban sector.

According to Cai, Park and Zhao, (2008) the hukou system changed after Deng Xiaoping’s tour of the South in 1992, when there was an economic growth boom resulting in increased demand for migrant labour. As a result migrants to urban areas could expect to be accommodated through employment certificates, rather than simply being expelled from a city. Nevertheless after other reforms caused unemployment in the late 1990s local governments began issuing their own employment regulations to protect urban jobs from migrant competition.

The situation thus remains unclear with stated intentions if reform from the central government, but entrenched urban interests apparently in competition with manufacturing firms facing rising labour costs. Thus despite further central government reforms in 2004, Cai et al (2008) argue that Hukou reforms have been slow and far from complete. For example according to Knight and Ding, Chinese authorities fear social instability increased urban settlement by migrants.
On the other hand, *Hukou* barriers – both formal and informal - are widely blamed for the rising inequality in China (Whalley and Zhang 2007). Knight and Song (2000) reported a ratio of GDP per worker between agriculture and non-agriculture of 5, which is the second highest in the world. Politically this is a concern because it undermines the catch phrase of “prosperity for some … then all”. Thus rising inequality - to world record levels associated with stalled middle income countries of Latin America and South Africa - indicates that the mixed state-led, market model of development may be under some stress.

**1.1 Impact of *hukou* on human capital**

Though the impact of *hukou* on inequality has been discussed widely in the literature little is known about its impact on factor accumulation and growth. In particular, literature on the impact of *hukou* on human capital accumulation is particularly scarce.

China’s investment in human capital has been mixed. Primary schooling was widespread in China by 1980, but higher education was neglected until the 1990s. Since 2000 there has been a significant catch-up effort with increased education targets in the government’s 5 year plans and also deregulation to allow some private education providers (Harris, Robertson and Xu 2010). This was due to a perceived shortage of skilled labour and rising inequality between skilled urban and unskilled urban workers.

Nevertheless there are reasons to suspect that *Hukou* barriers are also having an impact on human capital formation. Education can be acquired in rural sectors, and this is one means by which rural workers may gain urban registration (Cai et al 2008) Nevertheless the number of people who migrate this way is very small.

Total *hukou* migration in 2004 for example was approximately 17 million which consists of marriage, land conversion of fringe villages and through education. In comparison there were 98 million non-*hukou* migrants, i.e. people moving with what amount to temporary work visas. Moreover these “floating workers” cannot attain education in the urban areas, but would need to return to their home province for education and many other social services. Thus, on the face of it *hukou* restrictions would appear restrain investment in higher education.

Two question then arise are: (i) how has China’s growth been restrained by the *hukou* system in the past, and: (ii) what are the implications for China’s further growth, but particularly,
human capital formation, if *hukou* restrictions remain in place. These interactions between *Hukou* and human capital accumulation would appear important to gain an understanding of the future roadblocks facing China.

2. A Model

To analyse the interaction between *Hukou* and human capital formation – we use a simple two general equilibrium model. The economy has two sectors, agriculture which we denote $x$, and non-agriculture $m$ (manufacturing). A representative household allocates its labour time across economic activities, subject to the *hukou* constraint discussed below. It has an endowment of unskilled and skilled labour and chooses to invest some fraction of its overall labour time in human capital investment. It also owns capital and makes investment decisions.

2.1 Labour

There are three types of unskilled labour, designation politically (urban registered or not) and by sector (agriculture and manufacturing) and whether it is mobile or fixed. Specifically we have: (i) fixed agricultural labour (unregistered); (ii) mobile unskilled labour (unregistered) and (iii) mobile unskilled labour (registered for urban *hukou*). In common with the literature the unregistered mobile labour is also referred to as the “floating” migrant labour force. It is unregistered for urban residence, but may still work in manufacturing due to the availability of temporary work permits. Thus mobile unskilled labour may be employed in either sector, but only the registered labour can be used to create human capital. For all mobile unskilled labour (registered and permit labour) a common labour market means there is a common unskilled wage.

2.2 Firms

Production decisions are made by firms under constant returns to scale and perfect competition using three mobile factors of production, unskilled labour, $LU_i$, skilled labour, $LS_i$ and capital, $K_i$, taking factor prices as given. The labour stocks are also augmented by Harrod neutral productivity, $A_i$, which grows exogenously through time. Hence the effective stocks of labour are $A_i LS_i$ and $A_i LU_i$. 

3
We denote the return to capital as $r_t$ and the returns to skilled and mobile unskilled labour as $w_{LS,t}$ and $w_{LU,t}$ respectively. In addition fixed agricultural labour, $LF$, receives a wage $w_{F,t}$.

As noted above this is rural located labour that does not have urban *hukou* or a urban work permit. Hence the wage rate for this type of labour may differ from the mobile unskilled labour.

The agricultural firm's unit cost function is,

$$c_{x,t} = c_x \left( r_t, \hat{w}_{LS,t}, \hat{w}_{LU,t}, \hat{w}_{F,t} \right)$$

where $\hat{w}_{LS,t}$ and $\hat{w}_{LU,t}$, $\hat{w}_{F,t}$ are the wages per efficiency unit, $\hat{w}_{i,t} \equiv w_{i,t}/A_t$. The manufacturing firm's unit cost function is

$$c_{m,t} = c_m \left( r_t, \hat{w}_{LS,t}, \hat{w}_{LU,t} \right)$$

where $\hat{w}_{LS,t}$ and $\hat{w}_{LU,t}$ are the returns to skilled and unskilled labour per efficiency unit, $\hat{w}_{LS,t} \equiv w_{LS,t}/A_t$ and $\hat{w}_{LU,t} \equiv w_{LU,t}/A_t$. By Shephard's Lemma the unit factor demand functions are $\partial c_{i,t}/\partial w_{j,t}$, for $j \in \{K, LS, LU\}$ and $i \in \{x, m\}$.

### 2.3 Human and Physical Capital

Since only urban registered labour can acquire human capital, the registered population consists of urban registered unskilled labour plus skilled labour and any students in the education system. Specifically human capital accumulation is derived from a "Becker-Schultz-Mincer" type model of education decisions. Thus in order to become "skilled" workers must go to school for $\varphi$ years and consumed education resources – infrastructure.

Thus addition to forgoing their unskilled wage incomes, pay a price $p_m$. Since there are two goods only we simply assume that the price of education, and also investment is simply the manufacturing price.

Letting the urban registered labour force at time $t$ be $P_t$, then this will equal the sum of the stocks of urban registered skilled labour, $LS_t$, urban registered unskilled labour, $LU_t < LU_t$, and students, $H_t$. 


As shown in the appendix, in a steady-state the steady state ratio of investment in schooling is \( H_s / L S_t = b \zeta \). The steady state equilibrium condition for the skill premium is

\[
\hat{w}_{LS} - \hat{w}_{LU} = (p_m \varphi + \hat{w}_{LU})(\zeta / \Delta)
\]

where \( \Delta \equiv (1 + \hat{\gamma})/(1 + \rho) - (1 - d)(1 + \hat{\gamma}) \), \( \hat{\gamma} \) is the growth rate of productivity, \( \rho \) is the world interest rate, and \( d \) is the retirement rate of the working population.

This shows the relationship between the skill premium, \( \hat{w}_{LS}/\hat{w}_{LU} \), and the price of education investment relative to the opportunity cost of education, \( p_m/\hat{w}_{LU} \). For given unskilled wages, \( w_{LU} \), higher direct costs of education will imply a higher steady state skill premium.

For physical capital the investment the steady-state requires \( I_t / K_t = \delta = \gamma \), where \( I \) is investment spending, \( K \) is the economy-wide capital stock and \( \delta \) is the depreciation rate on capital. As shown in the appendix this implies

\[
r_t = (\rho + \delta) p_{m,t}
\]

The two conditions along with zero profits in each sector, factor market clearing for for each factor and the balanced trade define the equilibrium. Further details of the model are given in the appendix.

### 3. Experiment Design

Our aim is to consider the impact of \textit{Hukou} restriction on the China economy and particularly on human capital formation. We consider two basic experiments. First we consider a version of the model that reflects the Chinese economy around 1980, just after the major reforms began. Starting with most labour employed in agriculture with no urban hukou, we consider the impact of productivity growth in manufacturing that reproduces some stylized facts about Chinese structural change. We consider this productivity shock both with and without \textit{hukou} restrictions in order to see the impact of both (i) increasing urban \textit{hukou} registrations and an (ii) increasing temporary migration permits. Specifically we consider counterfactual equilibria that show how much capital and human capital accumulation would have been achieved in the absence of relaxing \textit{hukou} restrictions.
Our second exercise repeats the analysis but starting from a calibrated model that represents China’s contemporary structure and asks what the impact of how further hukou reforms will be on the Chinese economy under different growth scenarios, such a trade liberalization and a slowing world economy. Thus again we consider a series of exogenous changes (shocks) and evaluate these with and without hukou restrictions.

3.1 Stylized facts

We begin by considering some stylised facts regarding the structure of the Chinese economy. Table 1 shows the output and employment shares for China over its initial decades of economic growth. The pattern is very typical of successfully industrializing economies with the employment share of agriculture falling from just under 70% to 50%, and the output share of agriculture likewise from 30% to just 16% of economic activity.

As discussed above this transformation was associated with urban to rural migration. In the 2000 Census migrants comprised of 5.8% of China’s population, 19.6% of employment in China’s cities and 15% of the population aged 15-60 (Cai et al, 2008, Cai and Wang 2010). By 2009, however there were 150 million migrants, representing 19% of the labour force of 783 million (Cai and Wang 2010, China Statistical Yearbook 2011). As discussed above, most of this was non-hukou migration, who can work but not receive an education, health or other social benefits, in the urban centres.

3.2 Calibration and Shocks

We calibrate the model initially to an equilibrium where the distribution of output and employment as given in Table 1, for 1980. We consider two exogenous changes. The first is a productivity increase in manufacturing that is chosen so that manufacturing share of output rises to 84% of economy-wide output, representing the structural shift in output from Table 1 from 1980 to 2000.

Likewise in the initial state most of the labour is in agriculture. We assume specifically that there in the initial equilibrium manufacturing demand for unskilled labour is equal to the supply of registered urban unskilled labour.

Of the 70% of the population in agriculture we assume 60% is fixed while the remaining 10% is mobile. We also choose the initial factor shares such that in the initial equilibrium all
unskilled wages, fixed agriculture, and all mobile labour whether registered or not and in both sectors, receives the same wage rate.

Thus in our initial equilibrium 60% of the labour force are rural registered unable to migrate. another 10% can move but not acquire hukou status – which means they cannot become educated. In an initial equilibrium some fraction of this 10% of mobile unregistered workers may be working in manufacturing, so that total unregistered labour need not be equal to total agricultural employment. The initial allocation of labour across sectors and political designation, as well as by skill type, is given in column 1 of Table 2. It can be seen that in the initial equilibrium most (88%) of the mobile unregistered labour is in manufacturing.

To model the process of limited hukou reforms, whereby unregistered labour is given urban work permits but not urban-hukou status, we then consider an exogenous reduction in the number of fixed agricultural workers and a similar exogenous increase in the number of floating workers. Based on the preceding discussion this shift in work permit status applies to 20% of the total workforce, which is equal to 150 million workers. We consider the productivity change and the relaxation of the hukou constraint both simultaneously and individually to isolate the impact of the labour market permit regulations.

Finally it can be seen that the skilled labour is small, with the stock of skilled workers and students just 1.4% of the population. This is based on Barro and Lee’s (2001) estimate of the fraction of tertiary educated labour in 1980.

### 3.3 Neutrality of Hukou Registration.

Before proceeding with this experiment however we consider a preliminary result. Suppose we consider an initial steady state equilibrium where equation (3.) is satisfied for a given population, $P$, of registered workers. Suppose further that in this equilibrium some fraction, less than unity, of the registered labour force is unskilled and some are skilled so that there is an interior solution for the choice of human capital. Finally suppose that the labour market clearing consolidation holds for all mobile labour across urban and rural sectors - so that the wage rate received by the floating unregistered unskilled labour force, is the same as the registered unskilled workers. Then we have the following neutrality result
If the steady state equilibrium described above, assigning resident status to the floating unregistered unskilled labour force will have no impact on human capital stocks or education investment.

The reason for this is that assigning a different political status to workers in the same labour market has no net effect on the supply of unskilled labour in this labour market. Hence no impact on the unskilled wage rate. From (3.) it can be seen that there will be no change in the optimal choice of human capital stock, since there will be no change in the unskilled wage rate.

This preliminary result points to how changes in hukou impact on the supply of skilled labour. Specifically there needs be some effect of the regulation on the equilibrium wage rate. An increase in non-hukou migration, for example by issuing urban work permits to rural registered labour, can have an impact on human capital accumulation since it can affect the supply of unskilled in the mobile unskilled labour market. Thus the equilibrium condition (3.) suggests that allowing temporary migration, i.e. increasing the size of the floating labour force, can have an impact of human capital accumulation, even if those floating migrants themselves cannot acquire human capital.

On the contrary, if the current stock of skilled labour reflects an equilibrium such that some members of the population of registered workers choose to remain unskilled, the issuing of urban registration will not affect the total supply of human capital Intuitively even if some of the new urban registered workers decide to acquire education, the effect of this decision would be to reduce the skilled wage rate so that other workers choose not to become education. The point is that if education and human capital markets are not in a corner solution, then altering number of potential candidates for education does not affect the stock of skilled workers.

4. The Impact of Hukou – Initial Reforms

The results of the two experiments are given in Tables 2 and 3. Recall this experiment considers a productivity increase in manufacturing so that the manufacturing share out output increases to 84%. When we combine this with the freeing up of rural labour for migration, this requires a 23.3% increase in total factor productivity of the manufacturing sector. We then also consider, counterfactually, what the impact of this productivity growth might have
been if labour had not been free to migrate – that is if there had not been some relaxation of the hukou system.

First Column (ii) of Table 2 shows the labour reallocation that applies if there is no hukou reform. Naturally it is minimal. Recall 10% of the population is assumed to be rural mobile unskilled labour. It can be seen that less than half of this mobile population, approximately 5.2% of the total workforce, migrate to the city in this case.

Despite this migration, in the urban manufacturing sector the demand for unskilled labour falls slightly, whereas the stock of skilled labour plus students increases by 5.5 percentage points. Thus all of the agricultural mobile labour, plus some of the registered urban unskilled labour, is transformed into skilled labour in this experiment.

The economic impact associated with these changes is given in column (i) of Table 3. In this case it is convenient to report percentage changes, rather than absolute changes. It can be seen that the skilled labour stock increases by 40.6% and the physical capital stock nearly doubles (95%). These results reflect the fact that manufacturing is intensive in skilled labour and that the productivity improvement in manufacturing also serves to reduce the cost of investment in education and education.

Because of this accumulation, there is a large increase in the manufacturing output (104%), exports (109.6%) and a small expansion of agriculture of 4%. There is also a large increase in the wages of mobile unskilled labour which rise by 77% and arise in skilled labour wages of approximately 19.6%. Wages of rural fixed labour also increase but only by 5.5%

Next consider the impact on the economy if labour is allowed to migrate by reducing the fixed by supply of agricultural labour and increase the supply of unregistered mobile labour by an amount equivalent to twenty percent of the total population.

The net equilibrium labour allocation is given in column (iii) of Table 2. It can be seen that this 20 percentage points is absorbed in the manufacturing sector which absorbs almost all – 19.2 percentage points – of this 20 percentage point shift in the population. The total outflow if unskilled labour from the agricultural sector is 20.65 percentage points. The difference is represented by the uptake of education which increases by 1.4 percentage points effectively doubling. Thus the newly mobile unskilled workers put downward pressure on the unskilled wage rate and hence raise the skill premium. From (3.) this induces skill accumulation.
The economic consequences again are shown in Table 3. It can see that the skilled labour stock increases by 104% over the initial base equilibrium. Moreover the physical capital stock increases by 194%. These are large factor endowment responses for a 23% productivity shock in manufacturing, but this reflects the complementary impact of the inflow in capital because the inflows of labour offset the extent to which returns to capital diminish (Robertson 1999). Thus there is a very large expansion in manufacturing output and exports, which both expands by over 200%. Though there is a significant contraction in Agriculture, a Rydczynski effect, real GDP increases by nearly 90.7%. This is 1.66 times larger than the increase in GDP without hukou reforms. Thus it can be seen that the hukou system, by regulating migration, severely restrains human and physical capital accumulation.

Naturally there are also implications for income distribution. With migration the wage rate of the remaining fixed agricultural workers now rises by 16.9%, whereas in the previous case with no hukou reforms, it only increased by 5.5%. Hence the fixed rural workers gain much more as a result of the hukou reforms. The mobile unskilled workers also gain with unskilled mobile wages increasing by 65%, though this is only slightly less than the case when there is no hukou reform. Finally because of the expansion in the stock of skilled labour, in this case there is a much more moderate increase in skilled wage in the new equilibrium.

Thus it can be seen that the hukou reforms had a moderate egalitarian impact on labour market outcomes relative to what might have been the case in the absence of such reforms. In particular they mitigate the rise in mobile unskilled wages, generate a large increase in wages of fixed agricultural labour. It also reduces the skill premium over both types of unskilled labour, relative to the case without hukou reforms.

5. The Impact of further Hukou Reforms

6. Conclusion
Table 1: Employment and output shares

<table>
<thead>
<tr>
<th></th>
<th>1980</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP Share of Agriculture %</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>GDP Share of Non Agriculture %</td>
<td>70</td>
<td>84</td>
</tr>
<tr>
<td>Employment share of Agriculture %</td>
<td>69</td>
<td>50</td>
</tr>
<tr>
<td>Employment share of Non Agriculture %</td>
<td>31</td>
<td>50</td>
</tr>
</tbody>
</table>
### Table 2: Changes in Labour Allocation

<table>
<thead>
<tr>
<th></th>
<th>Initial allocation (% of pop)</th>
<th>Change in Employment (% of pop)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
<td>No Hukou Reform (ii)</td>
</tr>
<tr>
<td>Political</td>
<td></td>
<td>(i)</td>
</tr>
<tr>
<td>Unregistered</td>
<td>7.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Registered unskilled</td>
<td>2.87</td>
<td>-0.55</td>
</tr>
<tr>
<td>Registered skilled and students</td>
<td>0.14</td>
<td>0.55</td>
</tr>
<tr>
<td>Total</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sectoral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural Fixed</td>
<td>6.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Mobile Unskilled in Agriculture</td>
<td>0.12</td>
<td>-0.52</td>
</tr>
<tr>
<td>Mobile Unskilled in manufacturing</td>
<td>3.75</td>
<td>-0.03</td>
</tr>
<tr>
<td>Skilled Plus students in both sectors</td>
<td>0.14</td>
<td>0.55</td>
</tr>
<tr>
<td>Total</td>
<td>10.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Migration Flows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Unskilled Unregistered Mobile</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Demand for unskilled in manufacturing</td>
<td>3.75</td>
<td>-0.03</td>
</tr>
<tr>
<td>Total Registered labour in manufacturing</td>
<td>2.87</td>
<td>-0.55</td>
</tr>
<tr>
<td>Excess demand for urban unskilled labour</td>
<td>0.88</td>
<td>0.52</td>
</tr>
<tr>
<td>Demand for unskilled labour in agriculture</td>
<td>0.12</td>
<td>-0.52</td>
</tr>
<tr>
<td>Unregistered unskilled in agriculture</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Excess demand for rural unskilled labour</td>
<td>-0.88</td>
<td>-0.52</td>
</tr>
</tbody>
</table>
Table 3: Percentage Changes in Main Economic Variables

<table>
<thead>
<tr>
<th></th>
<th>No Hukou Reforms (i)</th>
<th>Hukou Reforms (ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Welfare</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Consumption</td>
<td>42.2</td>
<td>67.8</td>
</tr>
<tr>
<td>Real GDP Expenditure</td>
<td>52.5</td>
<td>89.2</td>
</tr>
<tr>
<td>Real GDP Factor cost</td>
<td>54.6</td>
<td>90.7</td>
</tr>
<tr>
<td>Real agricultural wage (rural fixed)</td>
<td>5.5</td>
<td>16.9</td>
</tr>
<tr>
<td>Real unskilled wages (mobile labour)</td>
<td>77.4</td>
<td>65.0</td>
</tr>
<tr>
<td>Real skilled wages</td>
<td>19.6</td>
<td>9.2</td>
</tr>
<tr>
<td>Real rent</td>
<td>-9.4</td>
<td>-18.8</td>
</tr>
<tr>
<td>Skill premium, $w/s_{w}$</td>
<td>-32.6</td>
<td>-33.8</td>
</tr>
<tr>
<td>Investment costs, $p_s/w_u$</td>
<td>-48.9</td>
<td>-50.8</td>
</tr>
<tr>
<td><strong>Endowments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS</td>
<td>40.6</td>
<td>104.5</td>
</tr>
<tr>
<td>K</td>
<td>95.3</td>
<td>194.7</td>
</tr>
<tr>
<td><strong>Trade</strong></td>
<td></td>
<td></td>
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<tr>
<td>Export Ag.</td>
<td>-19.2</td>
<td>-54.5</td>
</tr>
<tr>
<td>Export Man.</td>
<td>109.6</td>
<td>257.4</td>
</tr>
<tr>
<td>Total Exports</td>
<td>45.2</td>
<td>101.5</td>
</tr>
<tr>
<td>Imports of Agriculture</td>
<td>69.4</td>
<td>150.0</td>
</tr>
<tr>
<td>Imports Manufacturing</td>
<td>-6.0</td>
<td>-25.1</td>
</tr>
<tr>
<td><strong>Domestic Production</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture Output</td>
<td>2.2</td>
<td>-28.4</td>
</tr>
<tr>
<td>Man Output</td>
<td>104.3</td>
<td>218.3</td>
</tr>
<tr>
<td>Domestic Agriculture Supply</td>
<td>10.1</td>
<td>-19.2</td>
</tr>
<tr>
<td>Domestic Manufacture Supply</td>
<td>103.1</td>
<td>209.2</td>
</tr>
</tbody>
</table>
Appendix

As discussed in the text the economy has two sectors. These produce goods for the domestic market as well as exports to the rest-of-world (ROW) region. The ROW also supplies imports to Home and purchases Home’s exports. Each firm thus produces two destination specific goods one for the ROW market and one for the domestic market. Firms choose the production level of each destination specific good to maximize revenue. This implies a revenue function for firms located in Home, which we denote

\[ \phi^H_i(p_{i,t}, \bar{p}_t) g_{i,t} \]  

where \( \phi^H_i \) is the unit revenue function, \( p_{i,t} \) is the price in Home's domestic market, \( \bar{p}_t \) is the price in the ROW market, and \( g_{i,t} \) is the real output level of the firm. Note that since Home is assumed to be small relative to ROW, the prices received by Home for its exports to ROW, \( \bar{p}_x, \bar{p}_m \), are exogenous.

Likewise firms in ROW produce for each market and have the revenue functions

\[ \phi^W_i(p_{i,t}, \bar{p}_t) V_{i,t} \]  

where \( \hat{p}_{i,t} \equiv p_{i,t}(1 + \tau_t) \), \( \tau_t \) is the tariff rate on Home's imports, \( V_{i,t} \) is ROW’s endowment of real output of sector \( i \), and \( \phi^W_i \) is the unit revenue function for ROW firm \( i \). Note that prices in the Home market, \( p_{x,t} \) and \( p_{m,t} \), are endogenous and must clear Home’s goods market so that Home demand equals total supply from firms located in Home and ROW. As already noted the prices in the ROW market are exogenous and, by choice of units, we have \( \bar{p}_x = \bar{p}_m = 1 \).

By the envelope theorem the derivative of the revenue function with respect to the prices in each market gives the firm’s supply function to each market. Home’s supply of goods \( i \in \{x, m\} \) to consumers in the Home market, \( S_{i,t} \), is

\[ S_{x,t} = S_{m,t} = \frac{\partial \phi^H_i}{\partial p_{x,t}} g_{x,t} \]  

and

\[ S_{m,t} = \frac{\partial \phi^H_i}{\partial p_{m,t}} g_{m,t} \]

\[ S_{x,t} = \frac{\partial \phi^W_i}{\partial \bar{p}_x} V_{x,t} \]  

and

\[ S_{m,t} = \frac{\partial \phi^W_i}{\partial \bar{p}_m} V_{m,t} \]

\[ S_{x,t} = \frac{\partial \phi^W_i}{\partial \hat{p}_{x,t}} V_{x,t} \]  

and

\[ S_{m,t} = \frac{\partial \phi^W_i}{\partial \hat{p}_{m,t}} V_{m,t} \]

\[ 1 \]

\[ ROW \text{ supply to Home does not fix prices in Home as in the standard textbook model because goods are destination specific. Hence the ROW firms’ revenue functions will prevent an infinitely elastic supply response to prices in the Home market. The exogenous ROW market price vector implicitly defines the numéraire good as a bundle of } x \text{ and } m \text{ in the } ROW \text{ market.} \]
\[ S_{i,t} = \frac{\partial \phi^H}{\partial p_{i,t}} g_{i,t}, \quad i \in \{x,m\}. \]

Likewise, Home’s exports are its supply of goods to consumers in the ROW market,

\[ X_{i,t} = \frac{\partial \phi^H}{\partial p_{i,t}} g_{i,t}, \quad i \in \{x,m\}, \]

and ROW’s supply of goods to consumers in Home are Home’s imports

\[ M_{i,t} = \frac{\partial \phi^W}{\partial \hat{p}_{i,t}} V_{i,t}, \quad i \in \{x,m\}. \]

On the demand side, a representative consumer in Home maximizes utility by choosing consumption, export and import shares of each good, \( x \) and \( m \). Note that imported and domestically produced goods are identical, hence the optimal consumption choice can be represented by the expenditure function, \( e(p_{x,t}, p_{m,t})U_t \), where \( U_t \) is a volume index of real consumption. By Shephard’s Lemma the commodity demands for commodity \( i \in \{x,m\} \), are \( \partial e(p_{x,t}, p_{m,t})/\partial p_{i,t} U_t \). Finally we shall also assume balanced trade, or equivalently, that expenditure equals income, in each period.\(^2\)

**Physical Capital Investment**

We assume an installation cost function denoted by \( C(I_t, K_t) \), where \( I_t \) is real investment. The direct costs reflect purchases of Manufacturing output, so that \( p_{m,t} I_t \), is direct investment spending.\(^3\) Households then solve the Fisher problem of choosing a sequence of gross investments, \( I_t \) that maximize the net present value of the capital income, subject to the accumulation constraint, \( K_{t+1} - I_t = (1 - \delta)K_t \), where \( \delta \) is the rate of depreciation on capital. The Lagrangian is

\(^2\)This is for simplicity and rules out any current account dynamics. We shall relax this assumption later, though current account dynamics will not be an important part of the results.

\(^3\)Later we shall introduce a model with 11 sectors, and introduce an expenditure function for investment, that allows substitution between different inputs.
\[
L_K = \sum_{t=0}^{\infty} \left( \frac{1}{1+\rho} \right)^t \left[ r_t K_t - \delta_t C(I_t, K_t) - p_{m,t} I_t - \Pi_{K,t} (K_{t+1} - I_t - (1-\delta)K_t) \right]
\]  
(A3)

where \( \rho \) is the exogenous ROW interest rate and \( \Pi_{K,t} \) is the shadow price of a unit of physical capital. It is straightforward to show that the constraint in (A3) implies that on a steady state growth path \( \frac{K_{t+1}}{K_t} = 1 + \gamma \) and hence, \( \frac{I_t}{K_t} = \gamma + \delta \). Then we assume that the adjustment cost function takes the quadratic form

\[
C(I_t, K_t) = \frac{\beta_K (I_t - (\gamma + \delta)K_t)^2}{2K_t}
\]  
(A4)

where \( \beta_K \) is a parameter. The first order condition for investment, \( I_t \), is,

\[
\frac{I_t}{K_t} = \frac{\Pi_{K,t} - p_{m,t}}{\beta_K r_t} + \gamma + \delta.
\]  
(A5)

Equation (A5) is a "Tobin-Q" type demand for investment at each point in time. It shows that investment will exceed the steady state rate if the shadow value of a unit of capital exceeds the current cost of a unit of investment, \( p_{m,t} \). If investment rates differ from the steady state rate, then adjustment costs are positive and the net capital services available for production are \( \tilde{K}_t \equiv K_t - C(I_t, K_t) \).

**Human Capital Accumulation**

Human capital accumulation is derived from a "Becker-Schultz-Mincer" type model of education decisions. We assume that only urban registered labour can acquire human capital. Letting the urban registered labour force at time \( t \) be \( P_t \), then this will equal the sum of the stocks of urban registered skilled labour, \( LS_t \), urban registered unskilled labour, \( LU_t^R \), and students, \( H_t \).

\[
P_t = LS_t + LU_t^R + H_t.
\]  
(A6)

The net increase in the labour force is,

\[
P_{t+1} = (1 + b - d)P_t
\]  
(A7)
where \( b \) is the birth rate, \( d \) is the retirement rate.

The stock of skilled labour depends on past schooling decisions. There is an endogenous flow of students graduating each year and entering the skilled labour force. Denoting this flow of skilled entrants as \( E_t \), we have \( E_t = H_t / \zeta \) where \( \zeta \) is number of years in tertiary education.\(^4\) The updating equation for skilled labour is then;

\[
LS_{t+1} = LS_t + H_t / \zeta - d \cdot LS_t, \tag{A8}
\]

For future reference we note that the ratio \( LS_t / P_t \) will be constant on a steady state, and hence that \( LS_{t+1} / LS_t = 1 + b - d \). Then dividing (9) by \( LS_t \), gives a steady state stock of students relative to skilled labour of \( H_t / LS_t = b \zeta \).

The costs of acquiring education include the opportunity cost of forgone wages and direct education costs. Furthermore, as first emphasized by Mincer (1962), on-the-job training costs are also a significant cost of acquiring human capital.\(^5\) Hence we assume that firms face on-the-job training costs that depend on the current stocks of students and skilled labour, which we denote \( J(H_t, LS_t) \). Net labour income earned by a household is then the sum of net skilled labour income and unskilled wage income minus the direct costs of education. The net present value of this income stream, is

\[
\sum_{t=0}^{\infty} \left( \frac{1}{1 + \rho} \right)^t \left[ w_{LS,t} (LS_t - J(H_t, LS_t)) + w_{LU,t} LU_t - p_{m,t} \varphi A_t H_t \right] \tag{A9}
\]

where the expression \( p_{m,t} \varphi A_t H_t \) is the direct cost of a unit of education investment. Thus the direct education costs depend upon the effective number of students, and the price of manufactured goods for building education infrastructure, and \( \varphi \) is a parameter that converts numbers of students into units of education investment. Note also that education costs rise as

\(^4\)This is a simplification that allows us to keep the model tractable. One may think of any lags as being absorbed in higher training costs as discussed below. Specifically higher rates of graduation initially, imply higher on-the-job training costs and hence less effective labour available for production.

\(^5\)The importance of on-the-job training has been emphasized in the recent literature on computer technology and the "productivity paradox", (Helpman and Rangel 1999). See also Bishop (1991) and Barron et al (1999) for some related evidence.
labour productivity levels, $A_t$, grows, because new graduates must be of the same “quality” as the augmented skill level of the quality adjusted labour force.\(^6\)

We assume that on-the-job training costs take the quadratic form,

$$J(H_t, LS_t) = \frac{\beta_{LS} (H_t - b \zeta LS_t)^2}{2LS_t}. \quad (A10)$$

Hence (11) says that it is costly to raise, or lower, the stock of students from the steady state level $b \zeta LS_t$. These costs reflect an assumed lower productivity of new graduates and the skilled labour time used in formal training, such as internships, training programmes and informal learning in the workplace. These costs are realized as a reduction in the effective supply of skilled labour available for production when education flows deviate from the steady state path. Hence skilled labour services available at time $t$ are $\bar{L}S_t = LS_t - J(H_t, LS_t)$

The household’s objective is to maximize (A9) by choosing the flow of graduates, $E_t$, subject to (A10). This gives the Lagrangian

$$L_{LS} = \sum_{t=0}^{\infty} \left( \frac{1}{1+\rho} \right)^t \left[ w_{LS,t} LS_t - w_{LU,t} LU_t - p_{m,t} \varphi A_t H_t, \right.\]

$$\left. - \Pi_{LS,t} (LS_{t+1} - LS_t - H_t / \zeta + d LS_t) \right]$$

where $\Pi_{LS,t}$, can be interpreted as the price of a unit of skilled labour. The first order condition for the flow of graduates, $E_t$, recalling that $E_t = H_t / \zeta$, gives

$$\frac{H_t}{LS_t} = \frac{\Pi_{LS,t} / \zeta - w_{LU,t} - p_{m,t} \varphi A_t}{\beta_{LS} w_{LS,t}} + b \zeta, \quad (A12)$$

which can be interpreted as a demand for schooling function. Schooling investment will increase when the value of a unit of skilled labour, $\Pi_{LS,t}$ exceeds the sum of the current unskilled wage rate, $w_{LU,t}$ and the price of Manufacturing, $p_{m,t}$, that is needed for education infrastructure. Given the demand for schooling, and the current stock of skilled labour, the demand for unskilled labour is determined residually.

\(^6\)In the extended model below, these education costs also depend on primary factor input costs.
**Static Equilibrium**

We can now define a static equilibrium for this economy. Specifically we have:

*Definition 1.* Static Equilibrium. For given endowments, $K_t$, $LS_t$, $LU_t$, and shadow prices, $\Pi_{LS,t}$, $\Pi_{K,t}$, a static equilibrium is a set of commodity prices, $p_{x,t}$, $p_{m,t}$, factor returns, $r_t$, $w_{LS,t}$, $w_{LU,t}$, industry output levels, $g_{x,t}$, $g_{m,t}$, and a real expenditure level, $U_t$, that satisfies:

- **zero profits;**

  $$\phi^H_x(p_{x,t}, \bar{p}_x) = c_{x,t}$$

  $$\phi^H_m(p_{m,t}, \bar{p}_m) = c_{m,t}$$

- **goods market clearing:**

  $$S_{x,t} + M_{x,t} = \frac{\partial e(p_{x,t}, p_{m,t})}{\partial p_{x,t}} U_t$$

  $$S_{m,t} + M_{m,t} = \frac{\partial e(p_{x,t}, p_{m,t})}{\partial p_{m,t}} U_t + I_t + \Phi A_{LS,t} H_t$$

- **factor market clearing;**

  $$\frac{\partial c_{x,t}}{\partial r_t} g_{x,t} + \frac{\partial c_{m,t}}{\partial r_t} g_{m,t} = \tilde{K}_t$$

  $$\frac{\partial c_{x,t}}{\partial w_{LS,t}} g_{x,t} + \frac{\partial c_{m,t}}{\partial w_{LS,t}} g_{m,t} = \tilde{L}_S_t$$
\[ \frac{\partial c_{x,t}}{\partial w_{LU,t}} g_{x,t} + \frac{\partial c_{m,t}}{\partial w_{LU,t}} g_{m,t} = LU_t \]

\[ \frac{\partial c_{x,t}}{\partial w_{F,t}} g_{x,t} = LF_t \]

and the trade balance condition, that exports equals imports valued at pre-tariff prices;

\[ \bar{p}_{x,t} X_{x,t} + \bar{p}_{m,t} X_{m,t} = \hat{p}_{x,t} M_{x,t} + \hat{p}_{m,t} M_{m,t}. \]

This final condition also implies that factor income plus transfers equals expenditure. Implicitly all tariff revenue is returned to households via a lump sum transfer. Thus the static equilibrium is represented by these eight equations solving eight endogenous variables.

**Steady State Equilibrium**

To complete our description of the model we need the equations of motion for the shadow prices, $\Pi_K$, $\Pi_{LS}$, and the steady state. Differentiating with respect to $K_{t+1}$ gives the inter-temporal arbitrage condition for capital,

\[ (1 + \rho) \Pi_{K,t} = r_{t+1} (1 - C_2 (I_{t+1}, K_{t+1})) + (1 - \delta) \Pi_{K,t+1} \quad (A13) \]

where $C_2 (I_{t+1}, K_{t+1})$ refers to the marginal adjustment costs with respect to a change in the capital stock, $K_{t+1}$. Equation (14) equates the asset price of a unit of capital at time $t$ to the discounted marginal benefits at time $t+1$ and the resale value of a unit of capital, $(1-\delta)\Pi_{K,t+1}$.

A similar condition holds for skilled labour. From (??) we have

\[ (1 + \rho) \Pi_{LS,t} = w_{LS,t+1} (1 - J_2 (H_{t+1}, LS_{t+1})) - w_{LU,t+1} + (1-d)\Pi_{LS,t+1}, \quad (A14) \]

where $J_2 (H_{t+1}, LS_{t+1})$ is the derivative of the training cost function with respect to the second argument, $LS_{t+1}$. Equation (A14) is the arbitrage condition for a unit of skilled labour. It shows that on an equilibrium path the price of a unit of skilled labour must be equal to the
discounted future benefits of that asset. Specifically the marginal benefits are: the net wage premium, \( w_{LS,t+1} - w_{LU,t+1} \); the effect of a greater stock of skilled labour on reducing adjustment costs, \( w_{LS,t+1}J_2() \), and; the next period resale value of the asset, \( (1-d)\Pi_{LS,t+1} \).

Next we describe the steady state levels of the capital stocks \( LS_i \), and \( K_i \). First we define the effective total labour force as \( A_i P_i \). This effective stock grows exogenously at rate \( \gamma \). Hence assuming that labour productivity grows at rate \( \hat{\gamma} \), so that \( A_{i+1}/A_i = 1 + \hat{\gamma} \), and that the actual labour force grows at rate \( n \equiv b - d \), then \( 1 + \gamma \equiv (1+n)(1+\hat{\gamma}) \).

For a steady state to be feasible we must also assume that \( ROW \) endowments, \( V_{e,t} \) and \( V_{m,t} \), grow at rate \( \gamma \). Then a steady state equilibrium growth path will be a path where all real values: consumption; output, and capital, also grow at rate \( \gamma \). Along such a path the capital stock per effective worker, \( K_i/(A_i P_i) \), and skilled labour stock per capita, \( LS_i/P_i \), will be constant.

As discussed above, for physical capital this implies that \( I_i/K_i - \delta = \gamma \) on a steady state growth path. Hence from (A5) we have \( \Pi_{K,t} = p_{m,t} \), and from (A13), we obtain

\[
\rho_i = (\rho + \delta) p_{m,t}.
\] (A15)

With respect to skilled labour it was noted above that \( H_i/LS_i = b \zeta \) on a steady state. To derive the steady state equilibrium condition for the skill premium, we define the shadow prices per efficiency unit as \( \Pi_{LS} = \Pi_{LS,i}/A_i \). Then on a steady state we have \( \Pi_{LS,t} = \Pi_{LS,t+1}, \)

\( \hat{w}_{LS,t} = \hat{w}_{LS,t+1}, \) \( \hat{w}_{LU,t} = \hat{w}_{LU,t+1} \) and \( J_2() = 0 \) \( \forall t \). Using the steady state condition, \( H_i/LS_i = b \zeta \), and (15) gives

\[
\hat{w}_{LS} - \hat{w}_{LU} = (p_m \varphi + \hat{w}_{LU})(\zeta \Delta)
\] (A16)

As discussed in the main text.

We may now define a steady state equilibrium.
Definition 2. Steady State. Letting the capital stocks, $K_t$, and $LS_t$, be endogenous variables, then the economy is in a steady state if: (i) the conditions of a static equilibrium are satisfied and; (ii) if equations (16) and (17) are also satisfied.

Note that, since $A_t$ and $P_t$ are given, choosing the steady state values of $K_t$ and $LS_t$ also defines the steady state values of the physical capital stock per effective worker, $K_t/(A_t P_t)$, and skilled labour per worker, $LS_t/P_t$. 
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