The Depressing of China's Economy: The effect of Rural---Urban Educational inequality and Absence of Land Market

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The Depressing of China’s Economy: The effect of Rural—Urban Educational inequality and Absence of Land Market

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the Graduate School of
Clemson University

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of the Requirements for the Degree
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Huayong Zhou
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Abstract

The first chapter demonstrates that workers were over-placed in traditional agricultural sector in China’s economy after 1978. I investigate two factors which hindered the labor mobility from agricultural and non-agricultural sector: (1) human capital difference between rural and urban workers brought by China’s urban oriented public educational policy; (2) absence of land property rights and a well functioning land market. I incorporate those two frictions into a two-sector dynamic macro model to evaluate how large they impeded the labor mobility between two sectors and how large they suppressed the overall per-capita GDP of Chinese economy.

The second chapter discussed the effect of sectoral interconnections on the output fall in transitional economies, especially Former Soviet Union. In a planned economy, consumption were heavily distorted and resources (labor, capital etc.) were heavily misallocated. During the economic transition, when state orders were abandoned and price were suddenly liberalized, demand restructured according to consumer’s preference, but firms couldn’t adjust production so quickly because of the sluggishness of labor mobility between sectors. As result, GDP fell. More importantly, demand shock propagated through the network connections between sectors, which made the output fall in each sector much more seriously than the situation without interconnections. Also due to the interconnections between sectors, increasing of price in some sectors passed to other sectors, so we can observe large scale of price increase in the transitional economies.
Dedication

This dissertation is dedicated to my family for their endless love.
Acknowledgments

I would like to thank my advisor Kevin Tsui and Michal Jerzmanowski for their generous helps, without their guidings and comments I may never be able to finish my dissertation. I also thank professor Tom Lam for his constructive suggestions and solutions provided for some specific problems. I benefited a lot from the discussions with professor Sergey Mityakov and those who attended Macro workshop, I’m grateful to their feedbacks to my presentations.
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Chapter 1

The Depressing of China’s Economy:
The effect of Rural—Urban Educational inequality and Absence of Land Market

Abstract

This paper argues that too many workers were placed in traditional agricultural sector in China’s economy after 1978. I investigate two factors which hindered the labor mobility from agricultural and non-agricultural sector: (1) human capital difference between rural and urban workers brought by China’s urban oriented public educational policy; (2) absence of land property rights and a well functioning land market. I incorporate those two frictions into a two-sector dynamic macro model. I calibrate the model and show that it provides a good fit for the evolution of GDP per capita and employment share in agriculture in the Chinese economy. I use the model to conduct counterfactual experiments in order to evaluate the hypothetical performance of the Chinese economy under different policy scenarios. If rural people received the same quality of public education as urban people did, GDP per-capita during this period would increase by about 30%, and employment share in agricultural sector would decrease by 4-8 percentage points; if there was a well functioning land market, so that farmers were able to cash in their land rent by either selling or subleasing land, GDP per-capita would increase 12.8% for this period and labor share in agricultural sector would decrease by 4.63 percentage point on average.
1.1 Introduction

China’s economy started to catch up from 1978 when it abandoned the state planning economic policy. Many things have been changed since then, for example, China’s economy became more market oriented although government intervention is still strong comparing those developed countries; labor mobility between areas and sectors was officially completely liberalized; private firms were allowed to emerge as legal entity and have become the main power of China’s economic engine. However, the legacy of central planning is still playing as a role in distorting the economy, for example, state owned enterprises are still favored by government’s policy on bank loans and fiscal subsidies; *hukou* system (It is a record of identification in household registration system in China, there are two classifications: urban and rural *hukou*)\(^1\) is still impeding the urbanization process by hindering immigration of rural people to urban areas; public education system is still favoring urban residents, public media occasionally reports the tendency that smaller portion of college students is came from China’s rural area. Despite those serious market distortions and resource misallocations, China’s economy was growing fast and has already become the second largest economy in the world. Such huge economic achievement may obstruct both researchers and policy makers to discover such economic problems that seriously retard economic development. Recently, one astonishing fact that caught the attention of Chinese policy maker recently is the quality of rural labor forces, in 1978, 70\% of workers were placed in agricultural sector but only produced 28\% of final output, until 2012, there were still 33.6\% percent of labors were placed in agricultural sector and only produced 10\% of final output. Although labors were continually moving out of primary sector after 1978, comparing to developed countries there are still too much workers were placed in this sector. In the appendix, I calculate the marginal product of labor and capital for both sectors, it appears that both marginal product of capital and labor were lower in agricultural sector from 1978 to 2012, it implies certain kind of over placement of labor in agricultural sector. As Vollrath pointed out, the misplacement of labor in agricultural sector heavily depressed the over all TFP level, international evidence suggests that it can explain 90\%—100\% of variation of aggregate TFP.

\(^1\)People with rural *hukou* are not able to enjoy the public welfare provided in urban area by government even if they moved to urban area.
level (Vollrath, 2009). There is a detailed discussion of the labor market distortion measured by the gap of marginal product of labor between agricultural sector and non-agricultural sector in the appendix, aside of the over-placement of labors in primary sector is the China’s urbanization process, in 1978, official data shows that 84.2% people were officially registered by hukou system as rural residents, in 2010, this number is still 65.8%. More importantly, as pointed out by Chinese policy makers that rural workers typically are poorly educated comparing to their urban counterparts, and they are very hardly to get official permission to immigrate to city and enjoy the benefits provided in urban areas, such as public health care insurance, children’s education, public housing subsidies and etc. Moreover, China’s public education system restricted rural residents and their descendants to receive poor quality of formal education (before high school) in rural areas, to enter better high school or college, rural students must compete with their urban counterparts to take an entrance exam, it is not hard to imagine that how low the chance for the rural students would be to get higher level of education.

Combing the fact that such huge amount of people live in rural area and the fact that their low chance to get high level of education, it is not hard to imagine that how large the wastes of human resources created by the urban directed public educational policy. It is quite interesting for me to think about that how large the wastes of human resources measured by the human capital; whether it is quantitatively important for the whole economy measured by the loss of GDP per-capita; and whether it hindered the shifting out of labors from agricultural sector? All these questions motive this paper to calibrate Chinese economy under a traditional two-sectoral model paradigm and try to answer them with counterfactual simulation. This paper mainly discussed two factors which contributed to the over-placement of labor in agricultural sector: low human capital level of rural workers due to the urban oriented public educational policy and the absence of land market. In use of J-F (Jorgenson and Frumeni) approach, I measured the average human capital level of rural and urban workers by CHNS household survey data, which gives the information on the distribution of educational attainment, age and gender for various years. It shows that the gap of human capital between urban workers and rural workers was widening from 1989 to 2011, which made rural workers earn lower than the average wage in non-agricultural sector, it made the non-agricultural sector less attractive.
for rural workers. Moreover, without a well-functioning land market, farmers can neither sell nor sublease land to cash in the income stream of land rent if they leave agricultural sector, which increase the opportunity cost of moving out and decrease the incentive to leave to non-agricultural sector. The further empirical evidence shows that urban oriented public educational policy largely affect rural people’s educational attainment negatively, if they received the same quality of education as urban people did, rural workers’ human capital would have increased 26.2%, as result, the gap of human capital narrowed down. Counterfactual simulation shows that GDP per-capita would have increased about 30% between 1985 to 2012 and employment share in agricultural sector would have decreased by 4-8 percentage points; if there was a well functioning land market, GDP per-capita would have increased 12.8% for this period and labor share in agricultural sector would have decrease by 4.63 percentage point on average.

This paper is organized as follows. Section I is a brief introduction. section II summarizes some related literatures. Section III presents the two sector model and describes how to solve this model. In section IV, in order to calibrate model, I implements J-F approach to calculate the average human capital of rural and urban workers. Section V describes the how the model is calibrated and demonstrates the quantitative results. Counterfactual experiment is presented in section VI. Section VII concludes and makes some policy implications. Finally I put standard growth accounting for both agricultural sector and non-agricultural sector in Chinese economy into the appendix.

1.2 Related literature

Resource misallocation is pervasive in the whole economy and has caught a lot of attentions in recent years, most of related researches focused on the capital market distortion. Song, Storesletten and Zilibotti discussed financial frictions in capital market (Song, Storesletten & Zilibotti, 2011), they modeled state firms without financial constraint to borrow and private firms have limited access to bank loans in Chinese economy, and predicted high saving rate and high overseas lending coincided in the economy. A similar work of Brandt and Zhu talked about the over-placement of
capital in state owned sectors (Brandt & Zhu, 2010), they concluded that without the capital market distortion, the annual growth rate of GDP per-worker would have increased 1.58 percentage points between 1978 and 2007. Hsieh and Klenow discussed labor and capital misallocation across plants in China’s manufacturing sector (Hsieh & Klenow, 2009), which depressed China’s overall TFP level by 30-50% comparing to the situation that resource can be allocated between plants as efficiently as USA economy. Brandt, Tomble and Zhu did the similar work as Hsieh and Klenow by investigating the distortions in capital and labor markets across different provinces; and within provinces misallocation between state owned firms and private owned firms (Brandt, Tomble & Zhu, 2013). This paper relates to the market distortion literature on China’s economy. Unlike Hsieh and Klenow (2009); Brandt, Tomble and Zhu (2012), this paper used a dynamic model and focus only on the labor misallocation in agricultural and non-agricultural sector. Unlike Song, Storesletten and Zilibotti (2011), they highlighted the financial friction in the whole economy, nevertheless this paper focus on labor market distortion and the GDP loss created by the public educational policy. The methodology of this paper is similar to that used by Hayashi and Prescott (2008), their paper exclusively focused in the pre-war Japan and quantify the importance of the barrier of sectoral labor mobility (Hayashi & Prescott, 2008). This paper shares the same method and dataset with Cao and Birchenall, however, it differs from them in researching the different problem; their paper interested in accounting the TFP growth in China’s agricultural sector and further quantify the contribution of liberalizing the sectoral labor mobility after 1978 (Cao & Birchenall, 2013).

1.3 Model

Assuming there are two sectors: agricultural sector and non-agricultural sector. Each sector is producing according to the following production function:

$$Y_{at} = A_{at} K^{\gamma}_{at} H^{\eta}_{at}$$  \hspace{1cm} (1.1)

$$Y_{mt} = A_{mt} K^{\alpha}_{mt} H^{1-\alpha}_{mt}$$  \hspace{1cm} (1.2)
Where $H_{at}$ and $H_{mt}$ is the human capital of agricultural and non-agricultural sector workers respectively. Since there are a lot of rural workers working in the non-agricultural sector, the labor force in the non-agricultural sector is the summation of the labor force in urban area and the rural workers which move to non-agricultural sector. So we have $H_{at} = h_t(E_{at} - X_{at})$, where $h_t$ is the human capital of each rural workers', $E_{at}$ is the total amount of labor force in rural area and $X_{at}$ is the amount of rural worker immigrate from agricultural sector to non-agricultural sector. Therefore, $H_{mt} = h_tX_{at} + \bar{h}_tE_{mt}$, here $\bar{h}_t$ is the human capital of each labor force in urban area and $E_{mt}$ is the total urban labor force among the whole urban population. It is important here to point out that the labor mobility between two sectors is assumed one way from agricultural sector to non-agricultural sector, this assumption corresponds to the fact in China’s economic transition on one hand, and consistent to the numerical solution of this model that the paper will present below on the other hand.

Since all rural labor can only accept education in rural schools by China’s hukou system, and there is huge difference of educational quality between rural area and urban areas, so those immigrating workers normally have lower educational achievements than their urban counterparts, and in this paper, I further assume that no one is going to improve his/her educational level once he/she left school; also rural people’s child are getting very poor educations in rural schools. Since all education are provided publicly, In the model I take it as exogenous and will not incorporate the personal choice of investment in education and human capital into consideration, therefore model assumes that educational achievement and human capital are given for each worker. I further assume that each individual lives for infinite periods.

So the production function for both sectors becomes:

$$Y_{at} = A_{at}K_{at}^{\gamma}(h_t(E_{at} - X_{at}))^\eta \quad (1.3)$$

$$Y_{mt} = A_{mt}K_{mt}^{\alpha}(h_tX_{at} + \bar{h}_tE_{mt})^{1-\alpha} \quad (1.4)$$

Because in recent years, China experienced rapid urbanization process, and it was not totally en-

---

2They were not real immigrants from rural area to urban area, they are still counted as rural people by hukou system, they can not get any benefits as other urban residents do; their children can not get education in urban area. Those workers are called as “floating workers”
dogenous determined by the immigration of rural labor force, instead it is largely determined by the aggressive urbanization plan of provincial level government. It’s worth to clarify here that the labor force from rural and urban areas defined in the model is different from China’s official statistics on rural and urban employment; the former one counts the number of workers who are from rural or urban household, the latter definition distinguish workers by the location of working place. These two different definitions yield a very different number of rural and urban labor force. So in the model we take the urbanization process as exogenously determined, which means $E_{at}$ and $E_{mt}$ evolves exogenously.

A stand-in household maximize its utility function:

$$\max_{\{K_t, X_{at}, c_{at}, c_{mt}\}} \sum_{t=0}^{\infty} \beta^t u(c_{at}, c_{mt})N_t$$

Subject to:

$$N_t(p_{at}c_{at} + c_{mt}) + K_{t+1} - (1 - \delta)K_t = w_{at}(E_{at} - X_{at}) + w_{xt}X_{at} + w_{mt}E_{mt} + r_tK_t - Tax_t - Nex_t \quad (1.5)$$

Equation (5) is the budget constraint, $w_{at}$ is the wage of agricultural workers, $w_{mt}$ is the wage of non-agricultural workers, $w_{xt}$ is the wage of immigration workers, they have different wage rate from a typical urban workers because they have different human capital although both of them are working in the same sector; moreover, they may also have different wage from the workers who are working in the agricultural sector given the fact that they are working in different sector although they have the same human capital. $p_{at}$ is the relative price of agricultural goods in terms of non-agricultural goods; and $K_t = K_{at} + K_{mt}$, where $K_t$ is the total capital stock, $K_{at}$ and $K_{mt}$ are capital stocks in agricultural and non-agricultural sectors. Here, we include the lump-sum tax and net export into this equation, none of them appeared to be negligible in Chinese economy, lump-sum tax is included for one reason that it is the financial source of government expenditure which is a big part from 1978; and for another reason that is for the consideration of model extension for including market distortion, since in standard model budget constraint should be consistent with the resource constraint, including market distortion will inevitably result in inconsistency between budget constraint and resource constraint, introducing tax is one way to solve this problem without
creating theoretical difficulties because as shown below that budget constraint is a redundant once we have resource constraint conditions; Incorporating net export is for calibration purpose because China became the biggest exporter in recent years, since it can be seen as a net lending to the rest of the world.

There is a couple of remarks on the setup of this model. Firstly, the gap of human capital between rural area and urban area is mainly created by the urban biased education policy, certainly, children from low income family tend to have lower educational achievements, this is mainly due to lower parents’ input into children’s education, but in China, all education are provided by government, government’s low educational expenditure in rural areas is largely responsible for such gap. So in this paper, it is meaningful to discuss the consequence (costs) of such biased policy. Secondly, the educational gap brought certain human capital gap between rural and urban labor forces such that the labor mobility from agricultural sector to non-agricultural sector is relatively low, by introducing the human capital gap into traditional two sector economic model, the huge difference of marginal product of labor between two sectors doesn’t necessarily imply misplacement of labor force.

There are distortions in labor market which restrict the labor mobility from agricultural sector to non-agricultural sector, such as the rural workers’ disutilities of being away from family, poor quality of housing and the danger of being robbed when they were working at some place which is far from home (Zhao, 1999a; Hertel & Zhai, 2006). Also Shi et al. (2002) found huge labor income gap between rural and urban household and only 52% of which can be explained by the differences in personal characteristics, the 48% of labor income gap is left to be unexplained. Owing to this in equation (5), certain wage wedge may appear between agricultural workers and immigrating workers. However, this kind of labor market distortion is hard to quantify and few empirical works has been done in calculating the institutional costs of moving from agricultural sector to non-agricultural sector. Anyway, in the baseline calibration, I will not take this kind of labor market distortion into account.

---

3By including the net export into household’s budget constraint, model treats it as net lending. Technically, international lending is gross national income minus domestic expenditure, however this actually equals net export.

4Instead, efficient labor market implies the equalization of marginal product of human capital between agricultural and non-agricultural sector.

5Labor market distortion can possibly be estimated from data by regressing Mincer equation for rural workers those who stayed in agricultural sector and those who moved to non-agricultural sector, and treat the labor market distortion as...
consideration; it will be discussed in the alternative calibration and counterfactual experiment.

Household’s first order condition yields:

\[
\frac{\partial u}{\partial c_{at}} - \lambda_{t} p_{at} = 0. \tag{1.6}
\]

\[
\frac{\partial u}{\partial c_{mt}} - \lambda_{t} = 0. \tag{1.7}
\]

\[
\begin{align*}
X_{at} &= 0 & \text{if } w_{at} > w_{xt}, \\
X_{at} &= E_{at} & \text{if } w_{at} < w_{xt}, \\
X_{at} &\in (0, E_{at}) & \text{if } w_{at} = w_{xt}.
\end{align*}
\tag{1.8}
\]

And Euler equation:

\[
\lambda_{t-1} = \rho \lambda_{t} (1 - \delta + r_{t}). \tag{1.9}
\]

The transversality condition is:

\[
\lim_{t \to \infty} \rho^{t} \lambda_{t} K_{t+1} = 0. \tag{1.10}
\]

Equation (8) is the immigration condition, which means that if rural workers can earn higher wage in agricultural sector no one will move out to non-agricultural sector; if wage in non-agricultural sector is higher, all rural workers will move out; if they can earn the same wage in either sector, a fraction of them will move out. In general equilibrium model, wage in each sector is determined by how workers are going to be placed between both sectors, with more workers are placed in one sector, wage decreases because marginal product of labor decreases. So in equation (8), which case will happen depend on the setup of the model, however, the second case that all rural workers move to non-agricultural sector can be excluded theoretically by Inada condition of the production function in agricultural sector. Specifically, if all rural workers move out, no worker is placed in agricultural sector, with any positive capital stock in this sector, MPL approaches to infinity which results wage in agricultural sector greater than wage in non-agricultural sector, it yields a contradiction to the the wage gap which can not be explained by personal characteristics.
assumption that $w_{at} < w_{ut}$; if no capital is placed in agricultural sector (which can prevent the MPL in agricultural sector from approaching to infinity), which means agricultural sector doesn’t exists, therefore no agricultural good will produced, then utility will approach to negative infinity, obviously, this is not optimal. The first case may happen when the solution of model yields a higher wage in agricultural sector, however, this model can be solved by the following way: firstly, solve this model by assuming the third case in equation (8) holds, if the solution of $X_{at}$ is in the range, then the solution is fund; if the solution of $X_{at} \leq 0$ for some $t$, then use the condition that $X_{at} = 0$ and for those $t$ to solve this model $^6$. In the rest of the paper, I only specify the third case in equation (8) for the variants of this equation (i.e, equation (8’), equation (8’’), etc.); and for any variant of equation (8), no corner solution of $X_{at}$ is fund when solving this system numerically in the following of this paper$^7$.

In China’s economy, production in agricultural sector is mainly in the form of self production by farmers, land as an input in this sector earn rents which goes to agricultural workers as part of their income.$^8$ Normally, rent from land doesn’t affect worker’s incentive to move out since if there is a competitive land market, farmers can either sell or lease land to maintain their income streams. In this situation, farmers will move to non-agricultural production if their labor income (wage) from off-farming production is higher than their labor income (wage) from farming. But in China, farmers have no property rights for land, they are forbidden to sell it, once farmers leave land, they have to return it to collective village and it will be assigned to other farmers. Although they are officially permitted to lease under some specific circumstances, the failure of developing a rental market made the subcontracting behavior very rarely happened (Kojima, 1988 & Lin, 1988). Yang theoretically investigated the effect of such institutional arrangements on discouraging farmers’ incentive to move out of farming production (Yang, 1997); Zhao used rural household survey data from Sichuang.

$^6$When $X_{at} < 0$, the model should be changed to allow the urban workers move to agricultural sector.

$^7$Equation (8) is a benchmark equation that determines the labor mobility. Since wages are not equal in reality, various factors made them unequal, such as those specified by equation (8’) and (8’’) which also can be derived from F.O.C by the same way as equation (8) with introducing those things into the household budget constraint. In calibration, the benchmark equation (8) is never used, instead equation (8’) and (8’’) are used.

$^8$The production function (3) doesn’t specify land as a production factor, because it barely changes it’s amount in production, by the specification of (3) the share of land in agricultural sector is $1 - \gamma - \eta$. In the household budget constraint, I didn’t incorporate the income from land as a source of fund to agricultural workers.
province empirically exam the such effect, she found that the size of landholding has significant negative effect on the decision of rural—urban migration (Zhao, 1999b).

Based on the above discussion, income from land appears as a particular income and it combines with agricultural workers’ labor income to determine their migrating decision, if they stay in agricultural sector, they claim rents from land, if they leave, they lose rents. Therefore equation (8) becomes:

\[ w_{at} + R_t = w_{xt}. \]  

(8’)

\( R_t \) is the income of rents from land for each agricultural worker. Representative firms in both sectors maximizing profits:

\[
p_{at} MPK_{at} = p_{at} A_{at} s_{kt}^{\gamma - 1} K_t^{\gamma - 1} \left[ h_t (E_{at} - X_{at}) \right]^{\eta} = r_t + \phi 
\]

(1.11)

\[
MPK_{mt} = \alpha A_{mt} (1 - s_{kt})^{\alpha - 1} K_t^{\alpha - 1} \left( h_t X_{at} + \bar{h}_t E_{mt} \right)^{1 - \alpha} = r_t + \phi 
\]

(1.12)

\[
p_{at} MPL_{at} = p_{at} A_{at} s_{kt}^{\gamma} K_t^{\gamma} \left[ h_t (E_{at} - X_{at}) \right]^{\eta - 1} = w_{at} 
\]

(1.13)

\[
MPL_{xt} = (1 - \alpha) A_{mt} (1 - s_{kt})^{\alpha} K_t^{\alpha} \left( h_t X_{at} + \bar{h}_t E_{mt} \right)^{\eta} = w_{xt} 
\]

(1.14)

\[
MPL_{mt} = (1 - \alpha) A_{mt} (1 - s_{kt})^{\alpha} K_t^{\alpha} \left( h_t X_{at} + \bar{h}_t E_{mt} \right)^{\eta} = w_{mt} 
\]

(1.15)

\( s_{kt} \) is the share of capital in the agricultural sector. \( \phi \) is the wastes of capital in financial intermediaries, it measures the capital dissipation by moving it from households to firms.\(^9\) Since it appeared to be significant in China, ignoring this costs may potentially results in a huge discrepancy between the real data and calibration.

Finally, as the standard two sectoral model assumes that capital formation is only from the non-

---

\(^9\)So far, this model doesn’t include any other forms of labor market distortions, such as the disutilities of leaving family as discussed previously. These workers are typically called as “nongmingong” by Chinese official statistical publications, they normally leave their children for months each year and seek temporary job opportunities in big cities and go back at the end of each year. This is mainly due to the institutional reasons that they are unable to get their children be educated in cities. According to official report from NBS (National Bureau of Statistics of China), in the year of 2013, the total number of “nongmingong” was more than 260 million; among which, more than 160 million were far away from home.

\(^{10}\)Hayashi and Prescott (2008) interpret this cost as the percentage rate per machine for intermediation service. Song, Storesletten and Zilibotti (2011) interpret this as an iceberg cost, such as operational costs, red tap, etc. Since in both Hayashi and Prescott model and Song, Storesletten and Zilibotti model, it was treated as social wastes, I favor the latter interpretation.
agricultural sector; also this model assumes that government only consumes non-agricultural goods. As for the foreign trade, agricultural products are set as non-tradable goods, therefore this model ignores the foreign trade in agricultural sector. According to China’s official statistics, China became a net importer of agricultural products from 1995, most part of imports of the primary products were served as raw materials of manufacturing rather than final end use; and the food imports were trivial comparing to the domestic final products.\textsuperscript{11} Net export in non-agricultural sector is relatively large, which composed about 10% of total value added in non-agricultural sector. So the resource constraints in both sectors satisfy:

\begin{align}
N_t C_{at} &= Y_{at} \\
N_t C_{mt} + K_{t+1} - (1 - \delta) K_t &= Y_{mt} - \phi K_t - G_t - N e x_t = (1 - \psi_t) Y_{mt} - \phi K_t.
\end{align}

\(\phi K_t\) is the financial wastes incurred by the financial intermediations. \(\psi\) is the ratio of government expenditure and net export to the value added in the non-agricultural sector. It is worth noting that resource constraints implies household’s budget constraint, so equation (5) is not necessary for solving this model.

\subsection*{1.3.1 Model Solving}

Rewrite the production function of both sectors as:

\begin{align}
Y_{at} &= A_{at} h_t^{1/\eta} K_{at}^{\eta} \left( E_{at} - X_{at} \right) \eta^\eta. \\
Y_{mt} &= A_{mt} h_t^{1-\alpha} K_{mt}^{\alpha} \left( X_{at} + \frac{h_t}{h_t} E_{mt} \right)^{1-\alpha}.
\end{align}

\textsuperscript{11}China’s Statistical Yearbook gives the information on the foreign trade of primary sector, the import of food composed a very small fraction of total import, comparing to the domestic value added in the primary sector, its proportion was about 4% in 1995, 1.2% in 2000, 2.4% in 2005 and 3% in 2010. Actually, China had even larger amount of food export than food import for the whole period after 1978. As a net exporter of food, ignoring the food trade from other countries as consumption is reasonably sound in this model.
Define $\tilde{A}_{at} = A_{at} h_{t}^{\eta}$, and $\tilde{A}_{mt} = A_{mt} h_{t}^{1-\alpha}$. And define two trends of this model with $X_{Yt}$ and $X_{pt}$, such that $k_t = K_t X_{Yt}$, $y_{mt} = Y_{mt} X_{Yt}$, $\tilde{p}_t y_{at} = \frac{P_{at} Y_{at}}{X_{Yt}}$ and $\tilde{p}_t = \frac{P_{at}}{X_{mt}}$. This implies that:

$$X_{Yt} = \tilde{A}_{mt}^{\frac{1}{\gamma}} E_{mt}$$

$$X_{pt} = \left( \frac{\tilde{A}_{mt}^{\frac{1}{\gamma}} E_{mt}^{\frac{1}{\gamma}}}{\tilde{A}_{at} E_{at}^{\frac{1}{\gamma}}} \right)^{1-\gamma}$$

Denote $\frac{h_t}{h_{t-1}} = \zeta_t$, we have:

$$y_{mt} = (1 - s_{kt})^\alpha k_t^\alpha (x_{mt} + \zeta_t)^{1-\alpha}$$  \hspace{1cm} (1.18)

$$y_{at} = s_{kt}^\gamma k_t^\gamma (1 - x_{at})^\eta$$ \hspace{1cm} (1.19)

Where $x_{at} = \frac{Y_{at}}{E_{at}}$ and $x_{mt} = \frac{Y_{mt}}{E_{mt}}$. By the condition of equalization of marginal revenue of capital in both sector, namely equation (11) and (12), we have:

$$\eta \tilde{p}_t s_{kt}^\gamma k_t^\gamma (1 - x_{at})^\eta = \alpha (1 - s_{kt})^\alpha k_t^\alpha (x_{mt} + \zeta_t)^{1-\alpha}$$ \hspace{1cm} (1.20)

Rents from land is the residual claim, its share should be $1 - \gamma - \eta$ of the total value added in agricultural sector if the production function in this sector is assumed as Cobb-Douglas; the labor share is $\eta$. So the total share of land rent and labor income is $\eta + 1 - \gamma - \eta = 1 - \gamma$, for each worker, $1 - \gamma$ fraction of average production per worker in agricultural sector is the total opportunity costs of moving to non-agricultural sector. Therefore the immigration condition (8') becomes:

$$(1 - \gamma) \tilde{p}_t s_{kt}^\gamma k_t^\gamma (1 - x_{at})^{\eta-1} = (1 - \alpha)(1 - s_{kt})^\alpha k_t^\alpha x_{mt}(x_{mt} + \zeta_t)^{1-\alpha}$$ \hspace{1cm} (1.21)

Interest rate $r_t = \alpha (1 - s_{kt})^\alpha k_t^{\alpha-1} (x_{mt} + \zeta_t)^{1-\alpha} - \phi$. Define $\lambda_t = \frac{4X_{at}}{N_t}$, as result Euler equation (9) becomes:

$$\lambda_{t-1} = \rho \tilde{\lambda}_t \frac{N_t}{N_{t-1}} \frac{X_{Yt-1}}{X_{Yt}} (1 - \delta + r_t)$$ \hspace{1cm} (1.22)
As Hayashi and Prescott (2008) suggested that by setting utility function $u(c_{at}, c_{mt}) = \mu \log(c_{at} - d) + (1 - \mu) \log(c_{mt})$, this model not only can capture Engle’s law but also, more importantly, making those dynamic equations be stationary. With such utility function, from equation (6) and (7), $c_{at} = \frac{\mu}{\lambda} P_{at} + d$ and $c_{mt} = \frac{1 - \mu}{\lambda}$. By the resource constraint equations (16) and (17) we have:

$$\frac{\mu}{\lambda} X_{pt} + \frac{d N_t}{X_{yt}} = y_{at} = \frac{k_t}{k_t^0} (1 - x_{at})^\eta \quad (1.23)$$

$$\frac{1 - \mu}{\lambda} + \frac{k_{t+1}}{X_{yt}} Y_{t+1} - (1 - \delta - \phi) k_t = y_{mt} = (1 - \psi_t)(1 - s_{kt})^\alpha k_t^\alpha (x_{mt} + \zeta_t)^{1-\alpha} \quad (1.24)$$

By definition of $x_{at}$ and $x_{mt}$, we have:

$$x_{at}E_{at} = x_{mt}E_{mt}. \quad (1.25)$$

The major problem emerges from equation (25) is that once this model introduce the trend of $\frac{E_{at}}{E_{mt}}$, the system equations will become extremely complicated to capture the steady state, i.e, if $\frac{E_{at}}{E_{mt}}$ steadily decrease to zero, which means a 100% urbanization, all workers eventually live in urban area, but the whole system will end up with no steady state; if alternatively, $\frac{E_{at}}{E_{mt}}$ is assumed as asymptotically decreasing to a non-zero constant level as many urbanization literatures empirically found out (such as Davis and Henderson (2003), Chang and Brada (2006)), but we don’t know how the urbanization process exactly behaves; and the exact non-linear function form is unclear. So in this paper, I took this ratio as a constant and use an appropriate value in calibration.

It is worth noting here that although China’s rural and urban labor force was changing after 1978, and there was a continuous increasing of urbanization and huge amount of rural people migrated to urban areas to work; their residential status are not urban, those workers from rural area are still officially classified as rural people, their children were still educated in rural school, only few of them can became officially registered urban residents. After more than 30 years of economic reform, China’s urban residents grew 3.45% each year and rural population grew 0.28% each year, which implies that some rural people actually could reside in urban areas and got urban hukou, however, this process is highly restricted before 2000. Very limited quota was placed for each big city (0.02%
of those all nonlocal residents were qualified to get official urban *hukou* —including people from both rural areas and other cities who were running business or has already bought dwelling house and at meantime those people must had a permeant job in that city). Undoubtedly, those restrictions precluded most of rural immigrants from applying urban *hukou*. I interpret the huge growth rate of urban population as a consequence of the aggressive urbanization process of Chinese local government such as West Region Development Plan, specifically, Chinese local government transformed huge amount of agricultural land as urban or suburban use through expelling farmers from their land in order to increase government revenue and GDP growth, as result those farmers became non-agricultural residents but with none, or very few if there was, improvement in the quality of labor force. Public education system indeed became better in the newly emerging urban areas, modern teaching buildings emerged but with the same teachers, so the improvements in public education were limited; more importantly, public education in the old urban areas also improved, So I expected there was very little effect on the human capital (especially educational attainments) of rural labor forces by the such urbanization process.

More importantly, by the end of 1990 there was still 80% of Chinese population were officially classified as rural residents (during 1949 to 1978, this ratio stably remained at 84%), at the end of 2010, this ratio became 66%; the average ratio of rural population between 1978 and 2010 is 75%. The huge wave of rural immigrants firstly appeared in 1989, and those rural workers actually got education in rural schools, if there were some of them actually could officially registered as urban residents after a couple of years later and educated their newborn children in urban schools (this kind of immigration would potentially affect the quantity of labor force in urban and rural areas, but when they migrated out from rural area, they have already finished education, and it is expected to be remained unchanged in future), it would effectively resulted in a decline of rural labor force with lower educational attainments, therefore a significantly decline of $\frac{E_u}{E_{int}}$; but this effect has to be waited at least 20 years later when those newborns enter into labor market. So I argue that between 1978 and 2012, rural labor force took 80% of total labor force; also this argument gains supports from CHNS survey data, in table 5 and tale 6 we can see that the transition of major labor force from both rural area and urban area from 1989 to 2011 is mainly due to the aging of those workers.
In the model, I assume that during 1978—2012 80% of Chinese labor force were discriminated by China’s urban directed public educational policy, that is \( \frac{E_{at}}{E_{mt}} = 4 \).

Finally, transversality condition becomes:

\[
\lim_{t \to \infty} \rho t \tilde{A}_t N_t \frac{X_{Yt+1}}{X_{Yt}} k_{t+1} = 0
\]

Once we know the path of \( k_t \) and \( \tilde{\lambda}_t \), \( \tilde{p}_t \), we can solve \( s_{kt} \), \( x_{at} \) and \( x_{mt} \) from equation (20), (21), (23) and (25); (22) and (24) determine the dynamics of \( k_t \) and \( \tilde{\lambda}_t \). However, (23) and (25) are non-stationary equations, they evolves with time, So we need to introduce another variable \( q_t \equiv \frac{N_t X_{pt}}{X_{Yt}} \).

So equation (23) becomes:

\[
\frac{\mu}{\tilde{\lambda}_t \tilde{p}_t} + dq_t = \gamma^k (1 - x_{at})^\eta \quad \text{and} \quad \frac{q_{t+1}}{q_t} = \frac{N_{t+1} X_{pt+1}}{N_t X_{pt}} \frac{X_{Yt}}{X_{Yt+1}} = \beta. \quad (23.a, b)
\]

### 1.3.2 Steady State

In the whole system, both \( h_t \) and \( \bar{h}_t \) are assumed exogenously evolved with time. In both sector it is normalized to 1, and accredit its change over time to the TFP growth. In non-agricultural sector, assume \( \zeta_t \), the ratio of urban worker’s average human capital to rural worker’s average human capital, evolves with time and it is going to reach a constant level.\(^{\text{12}}\)

Since \( \zeta_t \) is assumed as exogenously evolved over time, and there is no new further information on it after 2012, here I assume \( \zeta_t = \zeta_{2012} = \zeta \) for \( t \geq 2012 \).

Taking the labor force \( E_{at} \) and \( E_{mt} \) grows at the same rate as the population growth rate, that is

\[
\frac{E_{at+1}}{E_{at}} = \frac{E_{mt+1}}{E_{mt}} = \frac{N_{t+1}}{N_t} = 1 + n; \quad \text{technology grows for agricultural and non-agricultural sector at the rate of} \quad g_a \quad \text{and} \quad g_m. \quad \text{So} \quad \frac{X_{pt+1}}{X_{pt}} = \frac{(1 + g)_{at+1} E_{at+1}^{1-\gamma}}{\tilde{A}_a E_{at}^{1-\gamma}} = \frac{(1 + g_m)_{pt+1} E_{mt+1}^{1-\gamma}}{\tilde{A}_m E_{mt}^{1-\gamma}} = (1 + g_{at})^{1-\gamma} \eta, \quad \text{and} \quad \frac{X_{Yt+1}}{X_{Yt}} = (1 + g_{at})^{1-\gamma} \eta. \quad \text{By equation (23.b),} \quad \beta = (1 + g_m)_{pt+1} (1 + g_m)^{1-\gamma} \eta. \quad \text{\beta} < 1 \quad \text{implies that} \quad \lim_{t \to \infty} q_t = 0, \quad \text{thus the}
\]

\(^{\text{12}}\)This is a valid assumption, there is no reason that it will keep increasing until to reach infinity. Since the difference in human capital is due to the difference in the distribution of education, age and gender. Either rural people will catch up or not, the human capital gap will eventually bound by some values. Perhaps, although \( \zeta_t \) is bounded, it is not asymptotically approaching a constant level, instead it keeps varying over time, then there is no steady state and the model can not be solved.
steady state for equation (23.a) is

\[ \frac{\mu}{\lambda p} = s_k^\gamma k^\gamma (1 - x_a)^\eta. \]

Also the steady state for equations (20)-(25) yields:

\[ \gamma \tilde{p}s_k^{1-1}k^{1-1}(1 - x_a)^\eta = \alpha(1 - s_k)\alpha^{-1}k^{\alpha-1}(x_m + \zeta)^{1-\alpha}. \]

\[ (1 - \gamma)\tilde{p}s_k^{1-1}k^{1-1}(1 - x_a)^{1-1} = (1 - \alpha)(1 - s_k)\alpha^{-1}k^{\alpha}(x_m + \zeta)^{-\alpha}. \]

\[ \tilde{\lambda} = \rho \tilde{\lambda}(1 + g_m)^{-1}(1 - \delta + r). \]

\[ r = \alpha(1 - s_k)\alpha^{-1}k^{\alpha-1}(x_m + \zeta)^{1-\alpha} - \phi. \]

\[ \frac{\mu}{\lambda p} = s_k^\gamma k^\gamma (1 - x_a)^\eta. \]

\[ \frac{1 - \mu}{\tilde{\lambda}} + k(1 + g_m)^{-1}(1 + n) - (1 - \delta - \phi)k = (1 - \psi)(1 - s_k)\alpha^{-1}k^{\alpha}(x_m + \zeta)^{1-\alpha}. \]

\[ \frac{x_a}{x_m} = \frac{E_m0}{E_a0}. \]

Steady states of those variables can be used to solve the dynamical equations by assuming a sufficient large time T such that at which \( \lambda_t, s_k, k_t, x_{at}, x_{mt} \) and \( p_t \) achieve their steady state levels.

### 1.4 Human Capital

The main task of this section is calculating the level of human capital for rural and urban workers. Unlike physical capital which has a market purchasing price, there is no market price for human capital. Like the income streams of rent from physical capital, wage can be considered as rent of human capital. In a competitive market, the purchasing price of physical capital should equal to the present value of its life-time income. Based on same idea, one can calculate human capital by the present value of life-time wage income of a specific worker. The most widely used method to do this is J-F (Jorgenson and Fraumeni) approach proposed by Jorgenson and Fraumeni (Jorgenson and Fraumeni, 1989). In this section, I restrict my attention on the working people aged 15 to 74.
since only those people are production factors in the production function.\textsuperscript{13} I use a variant version of J-F approach which is similar to Gu and Wong’s method used to measure Canada’s working age population, aged 15 to 74 (Gu and Wong, 2010); and it is similar to Li, Liang, Fraumeni, Liu and Wang’s method to measure China’s human capital (Li, Liang, Fraumeni, Liu and Wang, 2010).\textsuperscript{14}

This approach distinguishes workers by age, educational level and gender, different type of workers are suppose to have different human capital.\textsuperscript{15} The human capital for a worker with gender \textit{s}, educational level \textit{e} and age \textit{a} is defined by his/her present value of life-time income \(h_{s,e,a}\), and it satisfies the following recursive equation:

\[
h_{s,e,a} = w_{s,e,a} + sr_{s,a,a+1}h_{s,e,a+1}(1 + g)/(1 + r).
\]

In this equation, \(w_{s,e,a}\) is the average wage earned by the worker of gender \textit{s} (female of male), educational achievement \textit{e} at age \textit{a},\textsuperscript{16} \(sr_{s,a,a+1}\) is the probability of this worker survive from age \textit{a} to age \textit{a} + 1, \(h_{s,e,a+1}\) is the life-time income of the same worker at age \textit{a} + 1. Note that when this worker lives one more period, \(h_{s,e,a+1}\) actually is his/her life-time income in the next year, actually it is imputed by the worker who has the same gender and educational level but at age \textit{a} + 1 in current year. Normally, there is a growing trend of wages for all workers with time, so this model introduce a general trend of growth rate of productivity, that is \textit{g}. \textit{r} is the rate to discount the life-time income of the next year. Since I only focus on the working people, education achievement is assumed unchanged for each worker.\textsuperscript{17} To calculate one worker’s human capital (for example, a

\textsuperscript{13}In Jorgenson and Fraumeni’s paper, they measure the human capital for the whole population of United States, including students, unemployed workers and kids who are not old enough to go to school.

\textsuperscript{14}In the paper of Li etc., they also calculated human capital for students and non-schooling kids, since my interests only restrict on working people, students and non-schooling kids are absent in my calculations.

\textsuperscript{15}Like physical capital, human capital can be interpreted as price of specific worker, in production function, human capital are perfectly substitute for each other. Rather than traditional production function in which workers are assumed to be perfectly substitute for each other and simply adding all workers together to get the total workers. In this paper, workers are considered as a capital, adding all workers’ human capital make more sense.

\textsuperscript{16}In Jorgenson and Fraumeni’s paper, they proposed using average wage, this means that the same type of workers has the same amount of human capital regardless how human capital will be used. It shares the same property of physical capital, no matter by which way it is going to be used, firms purchase the same type of physical capital with the same price. However, Li ect. calculated China’s human capital for rural and urban workers in use of different wages and growth rates, it gave different price of human capital for the same type of worker.

\textsuperscript{17}Without this assumption, this equation need to introduce the probability that individuals pursue further studies which can be measured by the school enrollment rate.
college graduated 25 years old male worker), it starts with the age 75, at which \( h_{s,c,a+1} = 0 \); then use backward recursion to calculate the human capital at age 74, which is imputed by the average wage income of of the workers who have the same educational background and same gender; The lifetime income of 73 years old people is calculated by adding the imputed wage income at age 73 and the present value of lifetime income at age of 74 adjusted for increases in real income. Continue this procedure to get the present value of lifetime income at age 25.

The difficulty in applying this approach to China is the lacking of comprehensive wage dataset, the key to implementing this method is estimating wage income with Mincer equation. The reason I don’t use sample mean wages for different types of worker from Survey data is because for some types of worker, the survey data identify them as working people, but there is no wage information; more importantly, the sample size for some specific type of worker is too small. This paper use CHNS (China health and Nutrition Survey) dataset to regress Mincer equation. There are 9 waves (1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011) of survey conducted in 9 provinces for both rural and urban households. The survey has very detailed information on each household member’s age, educational background, gender, working information and labor income for each year. For those people who are working as a farmer under the household responsibility system (HRS), the survey investigate their yearly household income from various agricultural activities such as income from farming, raising livestock/poultry, fishing and handicrafts; then distribute the household income to each family member according to the time spent on working. For those people who are working in non-agricultural sector, the survey report their yearly wage incomes. The summary statistics is described in table 1.

Based on each people’s background and labor income, I can identify each worker’s educational

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18Because of the same problem, Young (2003), Cao and Birchenall (2013) also use Mincer equation to estimate the wage income when computing the human capitals. Li etc. also adopted Mincer equation to estimate wages to calculate human capitals in China.
19For example, in CHNS dataset, there are less than 10 observations for some specific workers, i.e high school graduated, 16 years old male worker from rural area.
20This dataset covers Heilongjiang, Liaoning, Shandong, Jiangsu, Henan, Hunan, Hubei, Guangxi and Guizhou province, in 2011 survey, 3 more provinces—Beijing, Shanghai and Chongqing were included. These provinces demonstrates enough variations in economic conditions, i.e, developed regions like Beijing, Shanghai, Jiangsu and Shandong, medium developed regions like Heilongjian, Liaoning, Henan, Hunan and Chongqing, and the least developed regions like Guangxi and Guizhou.
attainments, age and gender to get various types of labor input, in which the highest educational attainment of each observation is categorized by 6 groups: no schooling, primary school (6 years), lower middle school (9 years), upper middle school (12 years), professional school (equivalent to 11-12 years, but non-formal education, it trains people some professional skills such as computer skill, car repairing or cooking, etc.), and college (with more than 3 years of formal college education); Age is divided into 60 groups (15—74), gender is divided into 2 groups (male and female). So, there are $6 \times 60 \times 2 = 720$ types of workers. Once labor income of each type of workers is imputed, I’m able to get its human capital by the recursive equation described before, and total human capital for the whole labor force in rural and urban areas can be calculated by the summation of human capitals of all workers:

$$H_l = \sum_s \sum_e \sum_a h_{s,e,a} L_{s,e,a,l} = L_l \sum_s \sum_e \sum_a h_{s,e,a} d_{s,e,a,l}, \ l = \text{Urban or Rural.}$$

$L_{s,e,a,l}$ is the number of each type of worker in location $l$, which can be written as the multiplication of the total number of workers $L_l$ and the fraction of each type of workers $d_{s,e,a,l}$. The basic assumption here is average human capital in different area is only determined by the difference of demographic patterns, for the same type of workers in different area, they have the same human capital.\textsuperscript{21}

### 1.4.1 Log Wage Profile

I calculate experience as age $-$ 6 $-$ years of education and regress the log labor income with educational attainments, experience, experience square and gender. In the regression, I restrict my sample with full time working people with age between 15 and 74, and include time fixed effects of each survey year. Pooling regression with time fixed effects makes those coefficients estimated being the long term return of education, experience and gender. This is very important for the following counterfactual experiment in which rural people’s educational attainments are going to be changed,\textsuperscript{21}

\textsuperscript{21}Also we introduce no labor market distortions which may potentially cause the difference of human capital for the same type of worker in different areas.
since if more people get higher level of educations, the return of education is suppose to decrease, it will make the counterfactual human capital gain of rural workers being overestimated if I use the year by year regression to impute the wages.

Table 2 demonstrates the regression results. Column 2 is the result when controlling the province fixed effects, comparing with column 1 which doesn’t include such fixed effects, the result doesn’t change too much. Then I run Mincer equation separately for rural and urban workers, results in column 3 and 4 shows a different return to education and experience. Primary school appears to be unimportant for rural workers, but it significantly affect urban workers; higher level educations bring larger return for rural workers than urban workers (for example, upper middle school, professional school and college). On the job training also seems to be more important for rural workers but aging decrease their wage much quicker, the labor income peaks after 30 years of on the job training for rural workers and 32.5 years for urban workers. Overall, urban workers earn more than rural workers (the intercept term in the estimation for urban workers is much higher than that for rural workers), which may implies possible labor market distortions related to the Household Registration System, or urban labors may have better access to the job opportunities than rural workers.

1.4.2 Human capital

In addition to the log wage profile which can be used to impute labor income for each type of worker in each sample year, I also need the information of the quantity of various types of labors in both rural and urban areas. Without comprehensive dataset of China’s demographic information on rural and urban households\textsuperscript{22}, I rely on the CHNS survey data again. Tables 4 and 5 demonstrate a brief information on the distribution of education, age and sex for both rural and urban labor force, urban labor force has huge advances in education, more fraction of urban workers have higher level of educational achievements. The age and gender structure doesn’t show much difference for rural and

\textsuperscript{22}China Yearbook Rural Household Survey provides distribution of education, age and gender separately only for working people in rural households from 1978—2012. UHS (Urban Household Survey) data contains such information of urban household, but it is not publicly available.
urban workers, except that urban workers were relatively younger than rural workers.\textsuperscript{23}

Before calculating human capital, 3 more parameters are needed—growth rate of real wage $g$, discount rate $r$ and survival rate for people at different ages. Real growth rate of wage can be estimated from growth rate of GDP per-capita since production function implies that the former one is proportional to the latter one, which gives a value of 8.3% estimated from CSY; The discount rate is set as 5.43%, which is the average lending rate in China.\textsuperscript{24} As for the survival rate, it can be retrieved from China’s official statistics on the death rate for different age groups. There are only 5 waves of death rate data published by NBSC, 1990, 2000 and 2010 whole population census data, 1995 and 2005 1% population sample survey data. However, the death rate data were only grouped by age and gender, there was no further information for people with different educational or regional backgrounds. When calculating human capital for all 9 sample years, I take the death rate data to calculate the survival rate for people at different age, and use 1990 census data for sample year 1989 and 1991, 1995 survey data for sample year 1993 and 1997, 2000 census data for sample year 2000, 2005 survey data for sample year 2004 and 2006, 2010 census data for sample year 2009 and 2011.

Figure 1(a) plots the average per-capita level of human capital for urban and rural workers in the year of 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. It measures the real present value of lifetime income of an average rural or urban worker in 2009 price. Figure 1(b) demonstrates the gap of human capital between an average urban worker and rural worker, which is measured by the ratio of human capital. There is an obvious trend that the gap was enlarging for those years, this is consistent with the widening gap of labor income between urban and rural households revealed by the data provided by CSY (China Statistical Yearbook).\textsuperscript{25}

\textsuperscript{23}Table 4 and table 5 only give a brief information, when calculating human capital for rural and urban workers, detailed information on the distribution of all 720 types of workers is needed.
\textsuperscript{24}This approach is suggested by Li et al. (2010)
\textsuperscript{25}According to CSY, in 2011, the average income from both wage and household operations for a rural people was 8903.22RMB, and it was 17621.65RMB for an urban people, it gave a ratio of 1.98; in 2000, it was 2953.78RMB for rural people and 4726.74RMB for urban people, the ratio was 1.60. Both are higher than the human capital ratio of 1.64 for 2011 and 1.29 for 2000 calculated by J-F approach. However, J-F approach in this paper doesn’t incorporate any potential market distortions which may enlarge the human capital gap.
Since there are only 9 observations of $\zeta_t$ after 1978, to get the values for all years, I use linear function to interpolate values between 2 consecutive observations, i.e., use the middle point value of 1989 and 1991 to estimate the value of 1990, etc., for the year before 1989, I extrapolate those values in use of the value of 1989, and for the year after 2011, I extrapolate them in use the value of 2011.

Figure 1.1: Human capital for rural and urban workers.
1.5 Quantitative analysis

Like most of economic models, this one has no analytical solution. Combining with the steady state, equation (20)—(25) can be solved numerically. Strictly speaking since the subsistence level of agricultural consumption $d$ is non-zero, this economic system will only asymptotically approach the steady state (with the value of $\beta < 1$, it can be guaranteed by our choice of parameters). This system is a typical difference equation system with boundary conditions governed by initial capital stock and steady state, given the complication of the systematic equations, I use shooting algorithm to solve this system. With a initial guess of $\lambda_0$, this system gives the solution of $k_t$—the detrended level of capital stock and $\lambda_t$ of period one and thereafter, one can adjust the initial guess of $\lambda_0$ to make $\lambda_t$ asymptotically approach the steady state of this system.

As discussed above, the human capital in agricultural sector is normalized to unity, so with the initial guess of $\lambda_0$, we can solve $s_{k0}, x_{a0}, x_{m0}$ and $p_0$ by equations (20), (21), (23) and (25); then use equation (24) to solve $k_1$. Finally, we can solve $\lambda_1$ by equations (20), (21), (22), (23), (25) and the value of $k_1$, repeating this process to solve $\lambda_t$ and $k_t$ for a sufficiently large time period $T$, if the path of $\lambda_t$ from $0$ to $T$ is significantly lower than the steady state level, increase $\lambda_0$; if it is significantly higher than the steady state level, then decrease $\lambda_0$. With a proper initial value of $\lambda_0$, both the pathes of $\lambda_t$ and $k_t$ asymptotically approach their steady state levels.

The value of related parameters are chosen as table 3 described. The following part will discuss the details of the choice of those parameters.

- For a stand-in household, we set the time discount parameter $\rho$ as 0.96, this is a commonly used value. The asymptotic share of agricultural goods $\mu$ is set as 0.15, this value is suggested by Prescott and Hayashi (Prescott & Hayashi, 2008), they calculated this value from Japan’s Engle coefficient, this value is also fit the empirical evidence of most of developed countries. The minimum subsistence level of agricultural goods is solved by the model to fit the distribution of employment in agricultural sector and non-agricultural sector in the first period.
• This model assumes that agricultural sector is producing with a decreasing return to scale, since one of the factor—land is nearly fixed, this production function in agricultural sector was discussed by Hanssen and Prescott (Hanssen & Prescott, 2002). Cost share of labor and capital, namely, \(\eta\) and \(\gamma\) are calculated from China’s 1992 and 1997 IO table published by GTAP. 1992 IO table suggested values for cost share of labor and capital as 0.594 and 0.124 respectively; 1997 IO table suggested values of 0.593 and 0.119 respectively. Although there is only two samples, those values are really stable, moreover, those values are close to Japan’s agricultural cost shares before WWII (Prescott & Hayashi, 2008). Taking the average of the values from 1992 and 1997 IO table, which yields 0.594 for \(\eta\) and 0.121 for \(\gamma\); so the cost share of land in agricultural sector is 0.285.

These values are quite different from that suggested by Chow (Chow, 1993), Cao and Birchenall (Cao & Birchenall, 2013). They ran OLS regression on the historical data of Chinese economy, the coefficients of their regression suggested 0.25 for \(\gamma\) and 0.38 for \(\eta\). I will not take those values in the calibration since OLS regression on the time-series data may fail to capture the endogeneity problem; more importantly, Unlike Cao and Birchenall, I fail to replicate his results in use of the data given by Chow.

In non-agricultural sector, cost share of capital and labor adopt the value calculated from IO table from various years by Young (Young, 2003), that is \(\alpha = 0.54\).

• The average growth rate of population from 1978 to 2012 is about 1% each year, in the quantitative analysis, the growth rate of labor force, for both rural and urban labor force, is set as the same value as population growth rate. Depreciation rate of physical capital is set as 10% each year according to Bai, Hsieh and Qian (Bai, Hsieh & Qian, 2006).

According to a very influential paper by Bai, Hsieh and Qian, the return to capital in China from 1978 to 2004 is roughly 20% (Bai, Hsieh & Qian, 2006); and China’s one year average deposit interest rate is about 4.56% from 1991 to 2012. Combining both facts, one can conclude that the financial costs incurred by the intermediates is about 15.44%. However, it undoubtedly over-estimates the financial costs due to the fact that some of the entrepreneurs
finance their projects through self-finance, in this case financial wastes are nearly negligible. According to Song, Storesletten and Zilibotti, the State Owned Enterprise finance their projects with 7.55% intermediary cost (Song, Storesletten & Zilibotti, 2011); they might over-estimate the financial intermediary cost since they use deposit interest rate in checking account as the interest rate received by depositor. According to the spread between one year deposit rate and lending rate published by People’s Bank of China, it is 3.5% on average between 1990 and 2010.

I also use another way suggested by Prescott and Hayashi (2008) to double check the value of \( \phi \), according to equation (12), \( r_t = MPK_{mt} - \phi = \alpha \frac{Y_{mt}}{K_{mt}} - \phi \). By Euler equation (9) \( \frac{\delta K_t}{\rho K_t} = r_t + 1 - \delta \), then we have \( \frac{c_{mt}}{p_{mt-1}} = \alpha \frac{Y_{mt}}{K_{mt}} - \phi + 1 - \delta \). Choose \( \phi \) to make the average value on both sides of the equation equal, it gives 3.34% for the value of \( \phi \), which is close to the average spread between one year deposit rate and lending rate. In calibration, I use 3.34% for this parameter.

- In this paper, I adopted standard growth accounting method to calculate \( \tilde{A}_{at} \) and its growth rate in agricultural sector; for non-agricultural sector I calculate \( \tilde{A}_{mt} \) and its growth rate in use of production function (4’); interpolation and extrapolation of \( \frac{K_t}{L_t} \); urban labor force data \( E_{mt} \); rural immigrating labor force data \( X_{mt} \) which is estimated from employment data in both sectors and rural labor force data. The average growth rate of \( \tilde{A}_{at} \) in agricultural sector is 4.32%; and the average growth rate of \( \tilde{A}_{mt} \) is 3.35% in non-agricultural sector.

With the parameters are fully specified, I’m able to assess the validity of this model by checking whether it captures the main facts of China’s economy; and whether the model track the real data well. Owing to the fact that Chinese government intentionally depressed the price of agricultural goods before 1978, and the economic reform started in 1978 didn’t liberalize prices for most of agricultural goods, instead price was liberalized gradually until 1993 after which market force became dominated economic power. Compulsory quota on the agricultural production was still placed on farmers, more importantly it can largely affect the shifting of labor force from agricultural sector, since farmers were not really free to allocate their time on different sectors and were forced to
engage in on-farm production to achieve the target level.

By including compulsory quota on agricultural production and price control into model may increase the explanatory power and fit the real data more accurately. However, it will complicate this model and such topic is beyond the scope of this paper. Actually in 1985, most of the prices were liberalized, only very few amount of materials were still allocated by government plan (Lin, Cai & Li, 1994); and compulsory quota on agricultural production was also officially aborted. Considering this situation, to test the validity of our model, I calibrate this model by taking 1985 as starting point. Also, I intend to include labor market distortion into this model since lots of empirical researches on the income inequality between rural and urban households documented the importance of barrier on the movements of labor from rural to urban area.\footnote{Such as those I mentioned before, such as that pointed by Zhao (1999a), Hertel and Zhai (2006) and Shi et, al. (2002), Fleisher and Yang (2004), and Cai et, al. (2001).} If so, the immigration condition (8’) becomes:

\[ w_{at} + R_t = w_{xt}(1 - \tau_t). \] (8’)

\(1 - \tau_t\) measures the wage gap that created by social factors other than workers’ personal characteristics (such as education and experience) and land rent between workers those who shift out of agricultural sector and those who stay in agricultural sector. In this setup, I interpret \(\tau_t w_{xt}\) as average costs of job movement (such as transportation costs, disutility of being away from home, discrimination from urban people, institutional barriers, and etc.) other than land rent for each rural worker involved in off-farm production. The value of \(\tau_t\) is hard to quantify, Zhai, Hertel and Wang (2006) suggested a value of 81%, which is based on the residual wage difference between urban and rural workers after counting in their personal characteristics calculated by Zhao et,al. (2002). This might overestimate the cost of labor movement from agricultural sector to non-agricultural sector for 2 reasons: first of all, it actually measured the wage gap between urban workers and on-farm rural workers, this perhaps correctly revealed the costs of movement of a worker from rural area to urban area, however, some of rural workers had off-farm job in local non-agricultural sector located in rural area; secondly, the income from land, which can actually affect rural worker’s incentive to move to non-agricultural sector as I discussed before, was not included as part of income for rural
worker in the analysis of Zhao et al. In use of CHNS data, with a simple econometric analysis, roughly I have $\tau_t = 0.5$.\(^{27}\)

Figure 3—6 plots the simulating result and data starting from 1985. Baseline calibration (dot line) shows the model solution without labor market distortion; alternative calibration (dashed line) plots the model solution with labor market distortion; solid line plots the real data. From 1985 to 2006, per-capita level of capital stock, GDP and the share of value added in agricultural are closely tracked by the alternative calibrations. However, after 2006 data shows a higher capital stock and GDP per-capita than model predicts, I interpret this discrepancy as a possible innovation of financial intermediates that decreased the financial wastes or the investment subsidies after 2006 which may increase both the capital accumulation and GDP per-capita.\(^{28}\) In both baseline calibration and alternative calibration, employment share in agricultural sector has a lower predicted value than real data. Model predicts a faster shifting of labor force from agricultural sector to non-agricultural sector, it starts with 62.5% in 1985, baseline and alternative calibration predicts a value of 21.1% and 28.5% in 2012 respectively, but the data published by CSY is 33.6%. However, official data of the employment share may over-estimate the labor force worked in agricultural sector according to Brandt et al. (Brandt et al., 2008), they pointed out that the workers in agricultural sector spent a significant amount of time in working as non-agricultural activities and they estimated the time distribution of agricultural workers according to Chinese household survey data (Brandt & Zhu, 2010). Their revised data lies somewhere between the baseline calibration and alternative calibration in recent years; it deviates model largely in initial years because of the selection of subsistence level in model is to fit the official data of employment share in 1985, however, the choosing of this parameter only affects initial periods.\(^{29}\)

\(^{27}\)In a simple econometric analysis, I selected rural workers as sample. I used their earning income as dependent variable, which implicitly contains the land rent income for rural workers; then regress log income on their personal characteristics (education, experience, gender, experience square, marital status) and a working dummy equals 1 if that observation is working in agricultural sector and equals 0 when otherwise. The coefficient of the working dummy is -0.7, which means that when controlling personal background, if one rural worker changes his/her working sector the wage increase $e^{0.7} - 1 = 1.01$, therefore $\tau = 0.5$.

\(^{28}\)Actually starting from 2008, Chinese government encouraged investment in new energy industry (including solar, wind and etc.) through aggressive government subsidies.

\(^{29}\)The employment data revised by Brandt et al. may overestimate the shifting out of labor from agricultural sector, since they use survey data only from ten provinces (Shanxi, Jilin, Jiangsu, Zhejiang, Anhui, Henan, Hunan, Guangdong, Sichuan (and Chongqing), and Gansu) which had relatively more active rural industries.
Figure 1.2: Capital stock per-capita, model and data: 1985—2012.

(Level in 1985 is normalized to 100.)

Figure 1.3: GDP per-capita (in logs with a base of 2), model and data: 1985—2012.

(GDP per-capita in 1985 is normalized to 1, and vertical axis actually plots the normalized GDP per-capita level in logs with a base of 2, in this case, difference of 1 means 100% difference in levels.)
I also can assess the importance of human capital gap between rural and urban labor forces in explaining the labor force placement in both sectors. Figure 7 demonstrates another result under the assumption of homogenous labor in both sectors, comparing to the alternative calibration with heterogenous labor force, it predicts a slightly lower, nearly indistinguishable, employment share in agricultural sector. Clearly, including human capital difference between rural and urban labor force in model has limited power to explain why such huge amount of labor force were placed in agricultural sector in China’s economy, instead labor market distortion, namely, the costs of moving to non-agricultural sector from agricultural sector turns out to be essential (see the baseline
calibration in figure 5). However, adding human capital in this model helps to distinguish the various sources of labor misplacement and to quantify the GDP loss of China’s urban oriented public educational policy by counterfactuals.

Figure 1.6: Calibration with homogenous labor in both sectors, model and data: 1985—2012.

1.6 Counterfactual experiment

In this paper, I take this model as a valid one to depict China’s economy after 1985, and in this section, this paper will discuss some counterfactual experiments on China’s economy based on this specification.

1.6.1 Equal educational opportunity

Chinese government provides unequal public education for rural and urban residents, Willmann and Schucher deeply investigated the facts and the reason behind the inequality in educational opportunity between rural and urban residents. They attributed the educational inequality to the government’s political will and fiscal decentralization policy. As a consequence of fiscal decentralization, local government took responsibility of financing elementary school and junior high school education. Local government in rural area normally have much less tax income than their urban
counterparts, as result, there is much lower level of educational investment in public school in rural area. Although central government also provides supports on education to local government, schools in rural areas receive much less supports from central government than urban schools did. Wu (2011) empirically found that under Household Registration System (HRS), people who holds rural hukou tend to have lower educational attainments and lower chance of school transition.

In this section, I will use data to quantify the gap of educational attainments between rural and urban residents, which is measured by the probability of getting certain levels of education as highest educational achievement; then reevaluate the gap by removing the educational discrimination between rural and urban areas; and apply this result to the CHNS data set to calculate the rural workers’ educational achievements and compute their human capital levels under the condition of equal provision of public education; finally recalibrate this model in use of rural worker’s imaginary human capital levels to evaluate how much gains of GDP and how many more rural workers would shift out from agricultural sector.

1.6.1.1 Data

The log wage profile is constructed in use of CHNS data set, it would be a very good choice to study the educational inequality for consistency of the data. CHNS dataset is feasible to do this once we can separate children and parents in each household to study the children’s educational attainments given the parents’, because many theories suggested that parents’ education and income largely affect children’s educational attainments (see i.e Glomm and Ravikumar; 1992). However, CHNS data set is not reliable for this purpose since it specified family member as those who either live together or who share income together. This specification excludes the children those who moved out, especially for urban households, kids moved out when grow up and start to work, this situation is normal in urban households particularly for those kids with high educational achievements; children in rural households tend to share income with their parents when they start to earn their livings. In the data set, this tendency is clear, survey data showed that many urban households have

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30See similar discussions can be found by Li’s (2009) field investigation in schools located in Yunan province
no child or has child with low educational attainments; instead rural households normally have their children as part of family member. It tend to underestimate the gap of educational achievements between rural and urban residents since the definition of household member in this data set bias toward incorporating well educated people in rural household.

Alternatively, data from CHIP (Chinese Household Income Project) investigated all children’s information in each household. There are 6 waves of survey, only in the survey of 2007 and 2008 has detailed information for all child, previous waves didn’t contain such information. 2007 and 2008 survey inquired the same group of people. In this section, I only use 2007 survey data, first of all, I excluded those urban households in which the household head carry rural hukou (normally, in those households, their children are highly likely got education in rural area), then I separate children from parents and excluding those children who are still in school, in table 6, there shows the summary statistics.

1.6.1.2 Method and result

To evaluate the probability of educational attainment, I apply ordered probit model. Since the major concern in this section is evaluating the educational gap between rural and urban residents, I identify the location of each household with rural or urban, and assume that urban people with urban hukou sent their children to urban school and rural people sent their children to rural schools. The coefficient of this location dummy is not good enough to estimate the government’s discriminate educational policy because the gap is originated from the government’s educational expenditure which largely depends on the economic condition of different areas, for example, some rural areas in one province may be richer than urban areas in another province, therefore educational expenditure may be higher; the ideal solution should be the government expenditures on education. However, on the one hand, because of the availability of data, this piece of information is missing; on the other hand the gap of educational achievement between rural and urban area is pervasive in China

31Since I have excluded those households which live in urban area but the head of household is holding rural hukou. According to China's educational policy, rural people normally can not have their children educated in urban schools. Therefore, in this sample, there will be no self selection problem because children’s educational attainment can not affect their parents' hukou status which is used as proxy of location of children’s school.
and eventually the goal is evaluating the educational gap between rural and urban people rather than evaluating how public expenditure on education affect people’s educational attainments, I treat this method as an acceptable and valid solution.

Also many theories suggest that children’s educational achievements highly rely on the number of their siblings, parents’ educational background and investment in children’s education; empirically family income also highly affect children’s educational level. The information on family income and educational investments in children are missing, although there is tendency that rural parents’ income are lower and they invested less in children’s education than urban parents do, omitting these information may produce some bias problems in the econometric model; Some models of educational production (e.g Becker et. al, 1990; Glomm and Ravikumar; 1992) only highlighted the importance of parents’ educational level and number of kid’s siblings, they inducted educational investment and parents’ income as an outcome of parents’ educational level; also empirical works related to educational production also ignored parents’ income information when it is not available (See Wu’s empirical investigation (2011) of the effect of hukou on people’s educational attainments).

So, in econometric analysis, I don’t think missing those information is essentially important. Considering the Chinese tradition of favoring son more than girl, I include the gender information of each observation in model.

Owing to the fact that the history of China before 1978 were particularly special, rural and urban people were segregated, officially no movement between these two areas were allowed except for very rare situations, and very few rural children had opportunities of receiving higher level of education because of the government tended to keep rural people staying at their lands. The educational system after 1978 was very different when college entrance exam was officially resumed. Furthermore the Cultural Revolution between 1966—1976 created a total chaos for the whole society, students were not seriously educated in both rural and urban areas and university entrance examination were aborted, which means that those cohorts born before 1960s were not seriously educated and had little chance to enter university. Certainly, the educational discrimination toward rural people before 1978 played a role in affecting rural people’s educational attainments, however,
it had very different influences on both rural and urban people who were born after 1978. To accurately evaluate the urban—rural educational discrimination, it is better to identify that for different cohorts, and revise the educational distribution for labor force by related cohort information. Since the household registration system (hukou) was introduced in 1955, which successfully served the political purpose of rural—urban segregation; also the dataset has limited number of samples on the cohorts who were born before 1949 (only 19 observations), I will only focus on the cohorts born after 1950.\textsuperscript{32} In the following analysis, I classify those observations into 5 cohorts according to their birth year: 1950—1959, 1960—1969, 1970—1979, 1980—1989 and ≥ 1990.

Table 7 display the results of Ordered Probit estimation for different cohorts, it demonstrates that urban location of school can significantly affect people’s educational attainment, Urban people are much more likely to success in education. Parents’ educational background is also very important to children’s educational achievements; at meantime, more siblings means less likely to get higher level of education. It’s worth noting that estimation with including province fixed effect doesn’t bring many changes to the results, for the purpose of convenience, I use the estimation without fixed effect to evaluate the probability that an average rural and urban person get different level of educational attainment. In the whole sample, on average, 3.6% rural parents are illiterate; 34.8% rural parents only had primary school education; 44.4% had lower middle school education; 14.1% had upper middle school education; 2.1% had experience of professional schooling; only 1% had college education. On average, each child had 1.79 siblings; and the percentage of male was 53.2% in Chinese rural area. In the urban area, the situation is quite different, say, 3.2% parents are illiterate; 10.8% parents had primary school education; 27.9% had lower middle school education; 23.1% had upper middle school education; 13.3% of them had experience of professional schooling; 21.7% had some experiences in college education. On average, urban kids had 1.18 siblings; 53.8% kids were male.

Combining the estimation from Ordered Probit model, one can calculate the probability of an average person’s educational attainments for different level and correct probability of educational attain-

\textsuperscript{32}Actually, there is no need to discuss the effect of educational difference for the cohort born before 1950, since this cohort were less likely affected, even some of them finished education before this country was born in 1949.
ment for rural residents. Because I’m interest in how much the difference in quantity of educations between rural and urban areas is due to the public educational policy, in this section I can calculate a corrected probability of educational attainment by removing the urban rural discrimination—setting the urban dummy variable as 1 for rural workers in Ordered Probit model and hold their family background unchanged. It’s worth noting that correcting the probability of educational attainment for rural residents in use of this way can not be very accurate since the Ordered Probit model used in this paper is only a reduced form regression, but it’s better than directly applying the probability of urban residents’ educational attainments to rural residents since it attributes all the difference of educational attainments between rural and urban residents to public educational policy, as discussed above, this is not correct, since family characteristics highly influence children’s quantity of education.

1.6.1.3 Correcting educational attainments

The problem left is correcting the probability of educational attainments for all 9 years survey data from CHNS. After that, I can implement the human capital equation to recalculate the human capital of rural labor force. The task of this section is arguing a proper way to correcting educational attainments in use of the information from ordered probit model.

First of all, once set the dummy variable urban as 1 for all rural residents, the probability calculated from Ordered Probit model will change, certain people have higher probability to get higher level of educational attainment. So, one can calculate a transition probability which measures the probability that an average rural resident transit from getting educational level \(i\) to getting educational level \(j\) after correction according to the correction procedure described above. Let’s denote is as \(P_{ij}\). By this definition:

\[
P_{ij} = P(EDU_c = j | EDU = i) = \frac{P(EDU_c = j, EDU = i)}{P(EDU = i)}.
\]

Where \(EDU_c\) denotes the educational achievement after correction. \(P_{ij}\) can be successfully retrieved from the estimating result of the Ordered Probit model. Table 8 shows the transitional probability
matrix for all 5 cohorts, there is no chance that rural people will get lower level of educations after correction, this coincides our intuition that if there will be better public educational provided in rural areas, everyone tend to be better educated; most of people who are illiterate or have primary schooling experience will jump to the next higher level; the most amazing result shows in the transitional probability matrix is that all those people who stopped at upper-middle high school or professional school are supposed to enter into college if they can get the same quality of education as their urban counterparts did.

Secondly, we are going to use this transitional probability matrix to revise the distribution of education for each male and female workers aged 15—74 in CHNS survey data. It is problematic to use this transitional matrix to revise the whole labor force, it only can apply part of them since some workers might not be in any cohort I specified above, e.g., for those who are too old that they born before the birth of the country, there is no reason to consider them have been affected by the inequality of public educational provision between rural and urban areas.

In each year, for workers with a specific gender and age, I can identify which cohort they belongs to, for example, in 1989 those who aged 30 to 39 belongs to the cohort 1950—1959; those who aged 20 to 29 belongs to the cohort 1960—1969, etc. Certainly, we use different cohort information to revise different group of people. It’s worth noting that I am not going to revise the educational attainments for the people under 20, since I may encounter some difficulties on a practical issue, imaging that if part of those people will jump to a higher educational level after revising by the method mentioned above, most of them would be still in school rather than in the labor market, for example, for a 18 years old rural worker, typically, he\she is at most high school graduate or finished professional school, If he\she would have college after revising his\her educational attainments, he\she is not in labor market until at least three years later when he\she graduate from college. So, technically, part of those workers will disappear after revised; moreover, owing to the fact that this group only compose a very small fraction of the whole labor force, ignoring to revise such people will not create huge error. Table 9 shows the distribution of education for rural labor force after revising by such method. I’m not surprised by the result that for some years rural area had more college
graduates than urban had, because comparing to urban students rural students have more incentive to enter college, according to the educational return presented in table 2, one can clearly see that college will bring higher return for rural worker than for urban workers, so, if rural students can get the same quality of education as urban students, they were more likely to enter college.

1.6.1.4 Counterfactual simulation

Now I use the same method as specified before to calculate the human capital of rural workers after their educational background has been corrected, on average it is 23.1% higher than before; which means the gap of human capital between urban and rural workers narrows down, with new values of $\zeta_t$ for all 9 observations (to extend values for other years between 1985 and 2012, use the same way before to extrapolate and interpolate). Since all rural workers’ human capital increase largely, their productivity increase correspondingly, according to the setup of the model, TFP in agricultural sector ($A_{\mu_t} h_t^n$) increase 13.14% ($1.231^n - 1$); TFP in non-agricultural sector ($A_m h_t^{1-\alpha}$) increase 10.03% ($1.231^{1-\alpha} - 1$). Figure 8 below displays the counterfactual GDP per-capita between years 1985—2012. Unsurprisingly, after lifting rural people’s educational level, GDP per-capita increase roughly 20-30%, with an average value of 30%. Figure 9 plots the share of employment in agricultural sector, comparing to the model, it decrease about 4-8% for those years, and the average value is 6.1%.
The solid line plots the real GDP per-capita series; long dashed line plots the predicted GDP per-capita level by model with labor market distortion; dashed line plots the counterfactual GDP per-capita level if rural people were provided by the government with the same educational quality with urban people.

It is a very significant economic gain (about 20-30%) after removing the urban—rural educational inequality. More or less, for policy implications this should be interpreted as an upper bound of GDP per-capita increase. Since when quantifying the educational gap between urban and rural

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people, I actually attributed all the causes of rural urban educational differences other than family backgrounds into the government’s urban biased educational policies. Other things undoubtedly played as a role in producing gaps in educational level for rural and urban people, such as the differences in the infrastructures between urban and rural areas, i.e., public transportation, public libraries, bookstores, etc. However, without further information, it is very difficulty to disentangle the effects of urban infrastructures and public policy. In this data set, there are some information on the community level, such as the time spent on commuting from the community to the nearest school. This information approximately revealed the differences in infrastructure; however, adding this information into the statistical model doesn’t decrease the coefficient of location dummy (location of school) much.

1.6.2 Land market reform

In use of this model, I also can evaluate the effect of land market reform. As discussed before, Chinese farmers didn’t have the property rights of land, if they shift to off-farm production, land should be returned. Hence land rent become the opportunity costs of moving from agricultural sector to non-agricultural sector. If there is a complete land market in which farmers can either selling or subleasing land, the incentive to stay in land will decrease. Then equation 8” becomes:

\[ w_{at} = w_{xt}(1 - \tau_i). \]  

(8”’)

Also, \( \tau_i \) is set to be 0.5. Figure 10 and 11 displays the per-capita level of GDP and employment share in agricultural sector. Comparing to the model, If there is a complete land market, GDP per-capita will increase 10-14%, on average it increases 12.8%; employment share in agricultural sector decreases 2-6%, on average, it decreases 4.63%.
Figure 1.9: GDP per-capita, model, data and counterfactual result: 1985—2012.

The solid line plots the real GDP per-capita series; long dashed line plots the predicted GDP per-capita level by model with labor market distortion; dashed line plots the counterfactual GDP per-capita level if there is a complete land market.

Figure 1.10: Employment share of agricultural sector, model, data and counterfactual result: 1985—2012.

The solid line, long dashed dot line and dashed line display the real data, solution by model with labor market distortion and the counterfactual employment share in agricultural sector if there is a complete land market.

It’s also possible to conduct the counterfactual experiment by removing institutional costs of moving out of agricultural sector. However, it is not particularly interesting to me since it contains so much information that can not be interpreted into an useful policy implications.
1.7 Conclusion and implication

This paper used two sector model to explain the over-placement of labor in agricultural sector under the effect of human capital difference between rural and urban labor force; labor market distortion that directly tied to the institutional costs of moving from agricultural sector to non-agricultural sector; and the absent of property rights and land leasing market.

To calculate the human capital for rural and urban labor forces, I implemented J-F (Jorgenson and Fraumeni) method by estimating the present value of lifetime income for various types of workers. Without data on the average wage for different type of worker, I used Mincer equation to impute the average wage. With the information on the demographic pattern for rural and urban working forces, I calculated the human capital level for rural and urban working people.

By calibrating the model under the baseline scenario which contains human capital difference between rural and urban labor forces and the land market malfunctioning, model predicts a much quicker shifting of labor from agricultural sector to non-agricultural sector; and much higher GDP per-capita level than real data. After including the labor market distortion measured by the costs of moving from agricultural sector to non-agricultural sector in alternative calibration, model gives a better fits to the real data on the GDP per-capita level, agricultural employment share, and the share of value added in agricultural sector. By comparing the baseline calibration and alternative calibration, I found that institutional costs of moving out of agricultural sector played as an essential barrier that impeded the migration of labors from agricultural sector to non-agricultural sector. To assess the importance of human capital difference, I compare the alternative calibration to the model with the assumption of homogenous labors in both rural and urban areas, the findings shows that human capital gap had limited role in impeding labors immigration between agricultural sector and non-agricultural sector.

Considering that China’s official data on employment in both sectors are inaccurate, I compare agricultural employment share data revised by Brandt et, al., except for the initial years, the revised data lies between baseline calibration and alternative calibration. However, I take the alternative
calibration of model as valid by arguing that data given by Brandt et, al. tend to under-estimate the employment share in agricultural sector. And did counterfactual experiments based on the model with the alternative specification to investigate the GDP gains under the situation of equal provision of public education for rural and urban residents and land market reform. To do the counterfactual simulation for provision of public education, I implemented Ordered Probit model on CHIP dataset to investigate the probability of educational success on different educational levels, then revised the educational distribution for rural workers according to the corresponding cohort information under the assumption that if rural residents were provided the same quality of public education as urban residents. As result, rural workers’ human capital will increase 23.1% which lifts the GDP per-capita level about 30% during 1985—2012; and the employment share in agricultural sector decrease about 4-8% for those years. If farmers had property rights on lands, or there was a complete leasing land market, the incentive to move out from agricultural sector will increase. Counterfactual simulation demonstrated that there would be a 12.8% increase in GDP per-capita level and 4.63% of decrease in the share of agricultural employment.

The counterfactual experiments showed a huge gain of GDP per-capita level if Chinese government provided the same quality of public education to rural people as that to urban people. For policy implications, what I didn’t take into consideration is that the provision of public education is not free, it increases government expenditure. However, the ratio of educational expenditure never exceeded 3% of GDP before 2005, in 2010 it increased to 3.1% and until 2012 it reached to 4.1%. Comparing to the world average, about 5%, obviously China spent too little on education. Until 2012, about 80% of primary school students were in rural and suburban schools, and 54% of them were in the rural area. In 2003, about 67% primary school students were in rural area, in addition to those in suburban area, it reaches to about 84.5%. According to the estimation of Yang (2007), the educational expenditure in primary education for rural students is 87% of the national average. Combining the ratio of rural students in primary school in 2003, I am able to make a simple estimation that to make the educational expenditure on rural students equal to that on urban students, roughly the government expenditure in education need to increase $\frac{2}{3}$, from 3% of GDP to 5% of GDP. Certainly, the rural—urban educational inequality relied more on the educational capital
stock rather than on the educational investment; however, if public investment in education was not biased to urban people after 1978, there shouldn’t be so large gap in educational achievement that can be observed. The policy implication for land market reform would also be very constructive, although the costs of such institutional innovation is unclear, the welfare gain is very significant based on above discussions.
1.8 References


Li, Zhang (2009), “Disparity between Rural and Urban Education in China.” Institute for Education


1.9 Appendix A: Tables

Table 1.1: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<th>Max</th>
<th>N</th>
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</table>

*gender*= 1, means sample is male, =2 otherwise;
wave is the survey year;
urban=1, if sample lives in urban area;
logindinc is the log labor income that is inflated to the year of 2009.
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<th>OLS: Urban</th>
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$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

* All specifications include time fixed effect.
Table 1.3: Calibration details

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<td>Prescott &amp; Hayashi calculated from Japan’s Engle coefficient.</td>
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<td>$\gamma$</td>
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<td>Calculated from IO table.</td>
</tr>
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<td>Young’s calculation from China’s IO table.</td>
</tr>
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<td>$\bar{h}$</td>
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<td>Minimum subsistence level for agricultural goods</td>
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<td>By standard growth accounting.</td>
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|      | N    | 6203 | 5820 | 5294 | 5090 | 5462 | 4198 | 4073 | 4223 | 4867 |
Table 1.5: Urban labor force distribution

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Table 1.6: Summary statistics, data source: CHIP 2007

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<th>Max.</th>
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* Number of observations=14877, eduattainment is each observation’s highest educational attainment, there are 6 categories: illiterate, primary school, lower middle school, upper middle school, professional school and college; parents’ educational attainment are 6 groups of dummy variables: parentnone, parentprimary, parentlowermiddle, parentuppermiddle, parentprofessional and parentcollege, those variables are constructed as choosing the highest educational level between mother’s and father’s; siblings is the number of siblings for each observation; urban is a dummy indicating the area of residency; if an observation is male, the dummy male=1, 0 when otherwise.
Table 1.7: Ordered Probit estimation by group.

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*t statistics in parentheses*

*p < 0.05, **p < 0.01, ***p < 0.001*
Table 1.8: Transitional Probability Matrix.

(a) 1950—1959 cohort:

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(b) 1960—1969 cohort:

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(c) 1970—1979 cohort:

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(d) 1980—1989 cohort:

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(e) ≥1990 cohort:

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Table 1.9: Rural and urban workers’ educational attainments distribution after correction.

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<table>
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<th>Urban workers</th>
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<td>0.1372</td>
<td>0.1866</td>
<td>0.1917</td>
<td>0.2721</td>
</tr>
</tbody>
</table>

In this table, urban workers’ educational attainments is the same as the survey data since by assumption after removing the urban rural educational discrimination only rural people will receive better public education, there is no change for urban public education.
1.10 Appendix B: Growth accounting

Doing growth accounting for both agricultural and non-agricultural sector is standard, data needed to accomplish this purpose include final output, capital stock and labor input in both sectors, production functions are assumed as discussed before. Final output (for both real nominal) in agricultural and non-agricultural sector are from CSY (China Statistical Yearbook). For different periods, different base year is chosen, for example, for periods during 1978—2012, I use 1978 as the base year; for periods during 1985—2012, I use 1985 as the base year.

1.10.1 Capital stock

National Bureau of Statistics (NBS) doesn’t provide capital stock data either on aggregate level or on sectoral level. So to retrieve the capital stock, I apply perpetual inventory method on investment data for both sectors, there are three types of investment data provided by NBS: investment in fixed capital, gross fixed capital formation and the investment data from national accounts. Investment from national accounts includes changes of inventory, which should not be considered as part of physical capital for productive purpose; Bai, Heish and Qian (2006) discussed the shortcoming of investment in fixed capital that it only account those investment larger than 500 thousand RMB and considered the purchasing of land as part of investment. Followed Young (2003) Bai, Heish and Qian (2006), I also use gross fixed capital formation as the sequence of investment to construct capital stock for both sectors.

The problem is CSY only provided gross fixed capital formation (GFCF) on aggregate level. NBS only provided sectoral level investment in fixed capital after 2001, and investment in fixed capital by different ownerships: state owned enterprise, private owned firms, foreign firms and households in which only state owned firms and private owned firms have detailed information on investment in different sectors. Hsueh and Li (1995) collected gross fixed capital formation data for primary, secondary and tertiary sector between 1978 and 1995 in use of information on investment in fixed capital by different ownerships, they assigned foreign firms the same ratio of investment in different
sectors as state owned firms and households the ratio of private firms to construct the investment in fixed capital by all 3 sectors; then apply the sectoral distribution of investment in fixed capital to disseminate GFCF to 3 sectors. I expand the data to 2000 and use the official data of investment in fixed capital by different sectors after 2001, then repeat the procedure used by Hsueh and Li to get the GFCF for different sectors. However, all GFCF data are nominal terms, I still need price index of capital to deflate GFCF, official deflator of investment are available since 1991, as suggested by Hu and Khan (1997), price index of building materials from 1986 to 2000 can be used to deflate investment, Chow’s investment deflator (Chow, 1993) from 1978 to 1985 can be used to calculate the real investment. Physical capital depreciation rate is set to 10% according to Bai, Heish and Qian (2006). Initial capital stock in 1978 is calculated from the ratio of investment in 1978 to the summation of average investment growth rate for the subsequent five years and the depreciation rate. With GFCF sequence and initial capital stock in hand, by applying perpetual inventory method: $K_t = (1 - \delta)K_{t-1} + I_{t-1}$. Capital stock for both agricultural and non-agricultural sector is retrieved.

1.10.2 Labor

China’s official statistics on employment in different sectors are really messy, for example, In 1997 there was an official adjustment for employment data, more people were included with a broader definition of employment. But only employment data after 1990 were adjusted, no adjustment was made for the data before 1990; and In 1998, those employees who were not on the post but officially are still on the roster (this situation was pervasive especially in the state owned enterprises) were excluded. But again, data before 1998 were not adjusted accordingly. For the 1st problem, data before 1978 can be revised by the same way as NBS revised employment data after 1990 according to population census survey in 1990. Holz (2006) revised China’s employment data between 1978 and 1990 in use of 1982 population census information. For the 2nd problem, in the CSY of recent years, unlike provincial level employment data, national level employment data after 1998 didn’t create a huge discontinuity. As discussed by Holz, if any adjustment need to be made for this issue, probably only for the years between 1994 and 1997 during which this situation was widespread and
many workers in SOEs were laid off. However, there is no feasible way to adjust employment data to deal with the second problem, I use national level employment data for agricultural sector and non-agricultural sector revised by Holz for the period between 1978 and 1990.

1.10.3 Method and result

The method is standard, by production function:

\[ \ln TF P_{at} = \ln Y_{at} - \gamma \ln K_{at} - \eta \ln L_{at}, \]
\[ \ln TF P_{mt} = \ln Y_{mt} - \alpha \ln K_{mt} - (1 - \alpha) \ln L_{mt}. \]

Figure 17 plots the TFP growth rate for both sectors during 1978—2012. The average TFP growth rate in agricultural sector during 1978—2012 is 4.32%, in non-agricultural sector is 3.35%.

Figure 1.11: TFP growth rate for both sectors: 1978—2012.

For the years during 1985—2012, the method and data is the same, the only difference is year 1985 is chosen as the base year. In use of these data, we can also discuss the labor market and capital market distortion that can be briefly measured by gap of the marginal product of factors between
two sectors. One thing very important to notice is that agricultural goods and non-agricultural goods are traded with equal price, so To make a meaningful comparison of MPK and MPL for two different goods, we compare the marginal revenue of capital and labor, respectively, $p_tMPK_t$ and $p_tMPL_t$. Without any information on the relative price of agricultural goods, using current price output data and production function can capture the relative price change. Figure 18 plots the marginal product of capital in terms of current price output in both sectors; and the ratio of marginal revenue of capital in agricultural sector to that in non-agricultural sector. As one can see that the gap of marginal revenue of capital in non-agricultural sector is persistently higher than that in agricultural sector; and it was widening before 1990, then it slightly declined thereafter, in recent years it remains relatively stable.

Now, let’s turn to the labor market distortion. In use of the same method as that in capital market, marginal revenue of labor in both sectors is defined as $p_{at}MPL_{at}$ and $p_{mt}MPL_{mt}$. In addition to the specification of production functions for both sectors, we can calculate the marginal revenue of labor for both sectors in use of current price final outputs. As been pointed out by many researchers that in agricultural sectors, workers get the average return rather than marginal return, instead in non-agricultural sector workers get marginal return, after taking this into consideration, I calculate the average product of labor in agricultural to measure the alternative labor market distortion. Figure 19 plots both calculations, both lines indicate values less than 1, it clearly implies an obvious misplacement of labor force between two sectors.

The results imply that both too many capitals and too many labors were placed in agricultural sector. It is counterintuitive that both capital and labor are excessive. This became the major motive of this paper to investigate the human capital difference between rural and urban workers.
Figure 1.12: Marginal product of capital in agricultural and non-agricultural sectors and measurement of capital market distortions: 1978—2012.

(a) MPK in terms of current price in agricultural and non-agricultural sectors: 1978—2012.


Capital market distortion is measured as the ratio of marginal revenue of capital in agricultural sector to that in non-agricultural sector calculated as figure 18 shows.
Figure 1.13: Labor market distortion: 1978—2012.

The solid line marked by diamond demonstrates the ratio of marginal revenue of labor in agricultural sector to that in non-agricultural sector; instead the dash line marked by square shows the ratio of average product of labor in agricultural sector to the marginal revenue of labor in non-agricultural sector.
Chapter 2

Demand restructure in Transitional Economies: A Network Approach on the Severity and Pervasiveness of Output Fall

Abstract

This paper discussed the effect of sectoral interconnections on the output fall in transitional economies, especially Former Soviet Union. Based on the model developed by Hulten (1978), Gabaix (2011) and Acemoglu et. al. (2012), various economic sectors connect to each other through input-output relationship. In a planned economy, giving the assumption that central planner has different preference from consumer’s, model shows that no economic mechanism exists to satisfy central planner, firms and consumers simultaneously. I assumed that only central planner and state owned firms were satisfied with certain sacrifice of consumers’s welfare in this paper, as result resources (labor, capital etc.) were heavily misallocated. During the economic transition, when state orders were abandoned and price were suddenly liberalized, consumer demand restructured according to preference, but firms couldn’t adjust production so quickly because of the sluggishness of labor mobility between sectors. As result, GDP fell. More importantly, demand shock propagated through the network connections between sectors, which made the output fall in each sector much more seriously than the situation without interconnections. Also due to the interconnections between sectors, increasing of price in some sectors passed to other sectors, so we can observe large scale of price increase in the
transitional economies. Calibration of FSU economy shows that sudden price liberalization brought down the GDP level about 19.9%, of which 13.6% is due to the interconnections between sectors.
2.1 Introduction

There are more than 20 years till the crash-down of Former Soviet Union (FSU), retrospectively, this is a huge political progress since some republics aborted the one-party political system and formally adopted the democratic political system. But, the “big bang” reform brought to all the republics a miserable economic disaster. According to World bank’s estimation, there were on average 6.5 years of consecutive output decline and 50.5% cumulative output decline for CIS countries (Commonwealth of Independent States of the former Soviet Union). As we also know that China launched its reform in 1978, however, the whole scenario of reform is completely different from that of FSU, instead of political progress, China has experienced fast economic growth—7% annual growth rate in GDP. Table 1 lists the economic performance of FSU and China after 15 years since economic transition.
Table 2.1: Economic Performance between FSU and China: 15 years after transition.

<table>
<thead>
<tr>
<th>Years</th>
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<th>Output Change (%)</th>
<th>China (1978=100)</th>
<th>Output Change (%)</th>
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<tr>
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<tr>
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<td>−14.49</td>
<td>118.00</td>
<td>6.00</td>
</tr>
<tr>
<td>4</td>
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<td>−9.82</td>
<td>126.88</td>
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<tr>
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<td>8.40</td>
<td>291.35</td>
<td>9.68</td>
</tr>
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</table>

In the first column, the numbers mean the years after transition; we normalize 1989 GDP of FSU as 100 and 1978 GDP of China as 100. The output change is the percentage change of output relative to last year. Data source: Angus Maddison.

First of all, unlike the economic performance of China, FSU has an instant output drop, in the first year of transition (1990), output declined roughly 2.42% relative to 1989. Secondly, the output drop was severe, the second year of transition (1991), output decline accelerated, say, comparing to 1990 GDP dropped 6.32%, this number might be not quite accuracy, other sources estimated the output drop in 1991 was about 12.9% (Aslund, 1995). In the third year of transition (1992), output dropped even more. Finally, the duration and depth of recession was very long lasting and serious, nearly after 9 years of consecutive recession, GDP began to recover continuously, and in the 9th year of transition, GDP dropped to 55.65% of 1989’s level. However, China experienced rapid and continuous economic growth.

This phenomenon was unexpected, since the foreign economic advisors to the Russian government
only expected a slight and short period of economic downturn during the economic reform. Such serious situation was really a surprise. Furthermore, FSU, especially Russia, was implemented a market-oriented reform, it included the reforms on price liberalization, macroeconomic stabilization, trade liberalization and privatization which were taken into force rapidly, like a “big bang”; However, China’s reform was a form of “gradualism”, with dual-track price system in the early years of transition, partial liberalization on State Owned Enterprises (SOEs), partial liberalization on foreign trade and nearly no privatization. Generally speaking, both FSU and China were reforming their economic systems from plan to market, the difference is that FSU introduced market into its economy within a short period; instead China did the same thing with a very slow pace. FSU’s economic recession and China’s economic miracle posed a question to economists: why the instant implementation of market institution didn’t yield instant economic success, instead there came an instant output drop? But China’s gradual implementation of market institution could avoid such economic downturn. Also, this paper focuses on understanding the pervasive output drop across sectors during the initial years of economic transition and the vast scale of price increase even without monetary overhang or increase in the quantity of money.

Certainly, there were many factors contributed the output fall in transitional economies, such as sectoral level negative shocks; dismantling of trade connections between various republics of FSU; hyperinflation and etc. However, in this paper I only pointed out one potential cause of output fall bright about by the sudden price liberalization. Since central planner allocated resources according to his/her preference which is different from consumer’s, as result labor force were distortedly placed between sectors. With a “big bang” style of economic reform, by aborting the state orders of production on firms and liberalizing prices, central planner gave the way to consumers, thus final demand restructured according to consumers’ preference but labor force in each sector couldn’t restructured accordingly in a short time. This is the main reason of output fall with the sudden liberalization of price; if labor could move between sectors without any friction, although some sectors shrank some sectors would expand, GDP level would remain unchanged. Interconnection between sectors matters in propagating demand shocks to other sectors and can result large scale of output drop; positive demand shock in certain sectors pushed up the price of those products, as an inter-
mediate goods for other sectors, it pushed up the prices in other sectors. Although price increase during economic transition in FSU economy was largely due to the monetary overhang which is not included in the model presented in this paper, this findings predicts that even without monetary overhang, price increase in each sector is inevitable with a sudden price liberalization. Furthermore, negative shocks made some sectors suffering by profit loss, and government imposed pressures on those employers to maintain employment in exchange of subsidies, it increased government’s financial burden which might lead to further inflation in the whole economy.

In use of GTAP database (Global Trade Analysis Project), I’m able to retrieve FSU I/O table and the pattern of domestic final expenditure for 16 sectors in 1989; to quantify the restructuring of domestic final expenditures, I targets the end point of the preference shifting in use of the pattern of FSU in 1997. The calibration shows that if labor can not move between sectors fully, sudden price liberalization bring down the economy by 19.9%, of which 2.7% is due to the interconnections between sectors; and the price level increase by 35.1% due to the sudden price liberalization. Moreover, comparing to the economy with out interconnections, the simulation shows that more sectors experience real output fall and price increase.

In China, during the initial years of transition, “gradualism” approach prevented the GDP fall by remaining the state orders and price control; even if there was demand restructuring, as the Monte Carlo simulation shows below, China would experienced less output fall than FSU economy. More importantly, institutional restrictions on labor mobility from agricultural sector to non-agricultural sector were officially aborted, which made labor mobility were much more flexible than that in FSU economy. Furthermore, technological progress in agricultural sector contributed a lot to economic growth, and due to the fact that agricultural sector played as a major supplier in Chinese economy (in China’s I/O table, it can be seen that many sectors were heavily relied on agricultural sector), agricultural technological progress could propagate to other sectors by decreasing the costs of input. However, the model in this paper has limited power in understanding whether the “dual track” system contributed to China’s economic growth during the initial periods of transition.

This paper is organized as following: section 2 will go over some theories or explanations to the in-
stant drop of FSU’s GDP, and comments those theories; section 3 will introduce an economic model to illustrate how sudden price liberalization brings down GDP level; section 4 will present numerical simulation to justify my main conclusions; section 5 presents conclusions and implications; all proofs are showed in section 6; section 7 lists references.

2.2 Old explanations and related literatures

Enormous theories were created to understand the instant output fall during the beginning years of transitional economies. Perhaps the most famous theory is developed by Murphy, Shleifer and Vishny in 1992. They pointed out that in 1991 there were substantial diversion of subsidized inputs away from state firms towards private firms. This diversion of inputs was inefficient and output level will fall if state firms value those inputs more than private firms (Murphy, Shleifer and Vishny, 1992). Another paper similar to this one was written by Shleifer and Vishny in 1991 also pointed out the supply diversion (Shleifer and Vishny, 1991), moreover Shleifer and Vishny paper pointed out another important reasons of output fall, i.e. the input hoarding under the high expectation of retail price increase by producers, they explained that producers were intentionally hoarding the inputs to reduce their output when there was a high expectation of retail price increase because they wanted to save their production for future to sold at a higher price. Those theories suggested that full liberalization is necessary to eliminate this inefficient supply diversion and output would recover.

When we look at the price liberalization process in FSU carefully, we can find that in Jan. 1991 production prices were significantly liberalized, flexible “contractual” prices accounted for 40% of the total volume in light industry; 50% in machine building industry and 25% in raw materials industry; more than this, in April 1991, government revised retail prices, in increased by about 70% (Aslund, 1995). Actually, Murphy, Shleifer and Vishny wrote this paper before April 1991, it got published in Journal in 1992; before April 1991 price liberalization was partial, they made a fair guess of the reason of output fall. But in 1992, after the disunion of FSU, most of the republics launched full price liberalization (Blanchard, 1997), for example, in Jan. 1992, Russian Federation undertook the basic transition to free market. 80% of producers goods and 90% of consumers goods
were freed (Aslund, 1995). However, after price liberalization, output drop continued and became more severe.

Oliver Blanchard highlighted the vertical supply chain coordination failure during the transitional period (Blanchard, 1997). In his paper, he supposed that the production process contains many steps, each step was in different firms, and the whole production process was coordinated by central planning system. After the central planning system was broken down, supply chain become more likely to fail for the goods those need more steps to produce. This paper pointed out a very important issue in this topic—the interconnections between firms, considering the fact that production was sparsely distributed between republics (Kaminski, 1996; Djankow, 2001), the disunion of FSU indeed broke the interconnections of firms largely. Furthermore, Li pointed out the dismantling of central planning and centralized organization of production resulted in monopolistic power of state owned firms (Li, 1999). As the standard economic theory predicts monopolistic pricing bring down the output level. However, it is really hard to say whether the monopolistic was pervasive during the period of economic transition. In fact, Monopolies and oligopolies actually accounted for a very small share of national employment and production (Brown, Ickes and Ryterman, 1993). Although free entry was definitely limited by the existing state owned enterprises, the production in FSU was not usually conducted by single one or two firms, Gosnab tended to think like this but actually there were many alternative producers for the same or very similar goods (Aslund, 1995). Also monopolistic pricing behavior was heavily restricted in Russian, in 1991, the government regulated the prices of products from monopoly enterprises (many monopoly enterprises were falsely identified by the biased data from Gosnab (Aslund, 1995)), the markup was restricted usually to 25%.

There are also many other theories which focused on exogenous shocks, such as troubles in the oil industry, coal strike in 1990 and trade disconnection between COMECON (Council for Mutual Economic Assistance). These theories are also problematic since exogenous shocks are not pervasive (Shleifer and Vishny, 1991); from 1991, trade with EE countries declined but the foreign trade only accounted for a small share of total trade (here foreign trade refers to the trade with other countries other than the republics of FSU, intra-republic trade was not counted in this category). Figure 1
plots the ratio of foreign trade to the total trade, it tells us that only the most important three countries in the union, namely, Belarus, Russia and Ukraine had more than 10% of foreign trade in the total trade. Even Russia had less than 40% of this ratio, for other 12 republics this ratio was below 10%, for the whole union, this ratio was about 25 percent, about 75% of the trade was occurred between those 15 republics. In figure 2, we can see the time series trend of intra-republic trade and foreign trade flows. In Jan. 1991, COMECON broke down and FSU’s foreign trade started to decline at that time, this is coincide with the large output drop started from 1991, it looks like a plausible explanation of output drop; however, since 1992, foreign trade stopped to decline, output fall remained at a very high rate. It was not consistent with the explanation that the crash down of foreign trade caused output fall.

Figure 2.1: Ratio of foreign trade to total trade in republics of FSU in 1989. Data source: World bank
Those factors pointed out by various theories undoubtedly played a role in the large output fall, but perhaps not so essential to the depth and the timing of economic downturn. Important thing is that they pointed out the importance of interconnection between firms in the production process, this lead us to consider the role of interconnections between industries during the transitional period. So this paper will focus on the interconnections between industries and model the propagation of the shocks occurred during the period of economic transition. This helps us to understand the big downturn of the economic performance.

### 2.3 Economic model

This model focus on the interconnections between industries on the production side, and the instant output fall was mainly due to the discrepancies of the target of production between central planner and people.

**Assumption 1**: central planners utility function \( U_p = \sum_{i=1}^{n} \theta_i \ln C_i \). \( C_i \) is the final product of good i.
but the representative agent in the whole economy may have different preferences. \( U = \sum_{i=1}^{n} \theta_i lnC_i \).

We further assume that \( \sum_{i=1}^{n} \theta_i = \sum_{i=1}^{n} \hat{\theta}_i = 1 \).

**Assumption 2**: sector \( i \) produces with the production function:

\[
Y_i = \lambda_i \exp(b_i lnL_i) + \sum_{k=1}^{n} (1 - b_i)\phi_{ik} lnX_{ik}; \text{ for } \forall i = 1, 2, 3, \cdots, n \tag{2.1}
\]

\[
0 < b_i \leq 1 \tag{2.2}
\]

\[
\sum_{k=1}^{n} \phi_{ik} = 1 \tag{2.3}
\]

Here \( \lambda_i \) is TFP; \( L_i \) is labor input; \( X_{ik} \) is the intermediate goods \( k \) needed to produce good \( i \). This production function is a typical assumption of constant return to scale. Its easy to show that the cost share of labor in input is \( b_i \), and the cost share of factor \( k \) in input is \( \phi_{ik} \).

**Assumption 3**: resource constraint:

\[
Y_i = C_i + \sum_{k=1}^{n} X_{ki}; \text{ for } \forall i = 1, 2, 3, \cdots, n \tag{2.4}
\]

\[
L = \sum_{i=1}^{n} L_i \tag{2.5}
\]

**Assumption 4**: wage in each sector is the same. The model assumes equal wage for convenience, it doesn’t necessarily means that labor is mobile between sectors and industries. Actually, in a commanding economy like FSU and China in pre-reform periods, labor is distributed according to central planning, the cost of changing working position for each workers was so high that labor mobility was highly limited.

This model is adopted by Gabaix and Acemoglu to understand the large variation of GDP in market economy (Gabaix, 2011; Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi, 2012); and the large economic downturns caused by economic shocks (Acemoglu, Ozdaglar and Tahbaz-Salehi, 2013).
Central planner solve the optimization problem as:

\[
max : \mathcal{L} = \sum_{i=1}^{n} \theta_i \ln C_i + \sum_{i=1}^{n} p_i \left( Y_i - C_i - \sum_{k=1}^{n} X_{ki} \right) + q \left( L - \sum_{i=1}^{n} L_i \right)
\]

here \( p_i, q \) are the shadow prices of good \( i \) and wage rate. The first order condition gives:

\[
\frac{\partial \mathcal{L}}{\partial C_i} = \frac{\theta_i}{C_i} - p_i = 0 \quad (2.6)
\]

\[
\frac{\partial \mathcal{L}}{\partial X_{ik}} = \frac{p_i Y_i (1 - b_i) \phi_{ik}}{X_{ik}} - p_k = 0; \forall k = 1, 2, 3, \ldots, n. \quad (2.7)
\]

\[
\frac{\partial \mathcal{L}}{\partial L_i} = \frac{p_i Y_i b_i}{L_i} - q = 0 \quad (2.8)
\]

are hold for \( \forall i \in \{1, 2, 3 \ldots n\} \).

from equation (6), we get \( p_i C_i = \theta_i \), and define \( p_i Y_i = s_i \). From (7), we have \( s_i (1 - b_i) \phi_{ik} = p_k X_{ik} \);

from (4), we get \( p_i Y_i = p_i C_i + \sum_{k=1}^{n} p_i X_{ki} \), that is \( s_i = \theta_i + \sum_{k=1}^{n} s_k (1 - b_k) \phi_{ki} \). Therefore:

\[
\begin{bmatrix}
    s_1 \\
    s_2 \\
    \vdots \\
    s_n
\end{bmatrix} =
\begin{bmatrix}
    \theta_1 \\
    \theta_2 \\
    \vdots \\
    \theta_n
\end{bmatrix} +
\begin{bmatrix}
    (1 - b_1) \phi_{11} & (1 - b_2) \phi_{12} & \cdots & (1 - b_n) \phi_{1n} \\
    (1 - b_1) \phi_{21} & (1 - b_2) \phi_{22} & \cdots & (1 - b_n) \phi_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    (1 - b_1) \phi_{n1} & (1 - b_2) \phi_{n2} & \cdots & (1 - b_n) \phi_{nn}
\end{bmatrix}
\begin{bmatrix}
    s_1 \\
    s_2 \\
    \vdots \\
    s_n
\end{bmatrix}
\]

(2.9)
We can write it as $\vec{s} = \vec{\theta} + W \vec{s}$. Furthermore, from the equation $s_i = \theta_i + \sum_{k=1}^{n} s_k(1 - b_k)\phi_{ki}$, we get:

\[
\sum_{i=1}^{n} s_i = \sum_{i=1}^{n} \theta_i + \sum_{i=1}^{n} \sum_{k=1}^{n} s_k(1 - b_k)\phi_{ki}
\]

\[
\Rightarrow \sum_{i=1}^{n} s_i = \sum_{i=1}^{n} \theta_i + \sum_{i=1}^{n} s_k(1 - b_k)\sum_{i=1}^{n} \phi_{ki}
\]

\[
\Rightarrow \sum_{i=1}^{n} s_i = \sum_{i=1}^{n} \theta_i + \sum_{k=1}^{n} s_k(1 - b_k)
\]

\[
\Rightarrow \sum_{i=1}^{n} s_i = \sum_{i=1}^{n} \theta_i + \sum_{i=1}^{n} s_i(1 - b_i)
\]

\[
\Rightarrow \sum_{i=1}^{n} b_i s_i = \sum_{i=1}^{n} \theta_i
\]

Combining with equation (8), therefore we get:

\[
qL = q \sum_{i=1}^{n} L_i = \sum_{i=1}^{n} b_i s_i = \sum_{i=1}^{n} \theta_i = 1 = \sum_{i=1}^{n} p_i C_i.
\] (2.10)

Equation (10) points out the relation between final product and gross product, also we can see that in this system, total GDP (final product) is normalized to 1.

**Proposition 1**: equations (1)-(8) are sufficient to solve this system uniquely. i.e the vectors $\vec{C} = (C_1, C_2, \cdots, C_n)$, $\vec{Y} = (Y_1, Y_2, \cdots, Y_n)$, $\vec{X}_i = (X_{i1}, X_{i2}, \cdots, X_{in})$ for $\forall i = 1, 2, 3, \cdots, n$; and the price vector $\vec{p} = (p_1, p_2, \cdots, p_n)$ and the wage rate $q$ are all uniquely determined endogenously by the preference vector $\vec{\theta} = (\theta_1, \theta_2, \cdots, \theta_n)$.

Proposition 1 suggests that central planner’s preference decides the resource allocation in the whole economy uniquely. Typically, in the socialist countries, such as FSU and China, the decision makers made a series of economic plans on the production of various goods. Proposition 1 implies that those production plans are uniquely determined by central planner’s utility. We also can show that for different utility functions, the production plans, namely $(C_1, C_2, \cdots, C_n)$, $(Y_1, Y_2, \cdots, Y_n)$, $(X_{i1}, X_{i2}, \cdots, X_{in})$ for $\forall i = 1, 2, 3, \cdots, n$ are different.
**Corollary 1:** If the central planner’s utility function is different, the production plans—\((C_1, C_2, \cdots, C_n), (Y_1, Y_2, \cdots, Y_n), (X_{i1}, X_{i2}, \cdots, X_{in})\) for \(\forall i = 1, 2, 3, \cdots, n\) are different.

Proposition 1 and corollary 1 implies that the mapping from preference vector \(\vec{\theta}\) to production plans vectors \(\vec{Y}, \vec{C}\) and \(\vec{X}_i\) for \(\forall i \in \{1, 2, \cdots, n\}\) is one to one. Once we have this important conclusion, we can translate any central planner’s production plan into a corresponding central planner’s utility maximization problem under certain constraints. Furthermore the shadow prices we derived in proposition 1 are the price mechanism to direct the resource allocation.

We know that in a free economy price system can allocate resource according to peoples willingness. In this economy central planner has a different utility function from a representative agent (who is in charge of production and consumption). Central planners plan can not be achieved by market force, implementing certain market regulations is necessary. Typically, government restricted all productions in the state owned firms which can be easily controlled by government and set compulsory production targets on each of them. Since the representative agent’s preference is different from the central planner’s, the market demand of representative agent for final products—\((C_{d1}, C_{d2}, \cdots, C_{dn})\) is different from the supply of them by each firm, which is determined by then central planner’s preference (by corollary 1).

Central planer can force the managers in SOEs to carry out the compulsory plans and buy all products with a regulated prices; then distributed part of those goods to other firms as intermediate production materials and the rest to the retailers for consumers’ needs. In FSU, Gosnab was well functioning to execute this mission; in China, State Planning Commission conducted this mission. Prices are also needed to be controlled by government since the shadow prices derived above are not able to clear the market given the difference between firm’s supply and the demands of representative agent for which some goods are over produced, some are under produced, market force will drive some prices up and others down if there is no price regulations. The whole country can keep its financial balance by paying wages to all the workers, and selling those products to workers. The expenditures equal to the revenues, namely, \(\sum_{i=1}^{n} p_iC_i = qL\), from equation (10) we know that this is guaranteed if all goods can be bought by representative agents under the shadow prices.
**Proposition 2**: Once central planner can effectively control the production at the desired level and the price of each good at the level of shadow price, the shadow price vector is the only price choice to maximize each firm’s profit. The consumers will buy all the goods provided at the controlled price level (without achieving the maximum level of utility, alternatively achieving the second best, under the assumption that representative consumers preference is different from the central planners).

Proposition 2 guarantees a planed economy can circulate its economic resource smoothly with a certain social welfare costs. In a planed economy, representative agent’s utility is not maximized, instead central planner’s utility or production target is fully satisfied. In this case, as mentioned before, in the whole market, for some goods producers can not satisfy the consumers’ demand under the shadow price; and for others, producers supply more than the consumers willingness to buy under the shadow price. Its worth noting that the shadow price of each goods should be a realistic economic policy of price regulation for the central planner to achieve his/her economic planning. Certainly, many other price vectors which satisfy the condition that $qL = \sum_{i=1}^{n} p_iC_i$ are potentially available policy options of price regulation for central planner given the predetermined production plans set by central commands, and it is also true that consumers are still willing to buy all the goods provided by central planner under the price controlled by government other than the shadow price. For example, central planner can set the price of each good at the level of market clearing ($\hat{p}_i = \frac{\partial}{\partial p_i} p_i$, where $p_i$ is the shadow price derived in proposition 1), but proposition 2 told us if this price policy is implemented, all firms are not operating at the profit maximizing level, some firms are earning positive profits, some are losing money. The central planner has to redistribute profits between all firms to make each firm financially balanced. This is not a easy job, although central planner has full control for each firm, it is still very costly to monitor each firms financial situation. The firms which earn profits will hide them and the firms are in loss will exaggerate their loss and ask for subsidies, in this situation government can hardly hold the expenditure and revenue in balance. By contrast, if central planner priced each goods at its shadow price level which correctly reflects the production cost of each unit, profits are maximized in each SOE. Central planner can largely avoid the situation of transferring economic profits between thousands of SOEs.
Theoretically, we may never know which price policy had been chosen by central planner in a command economy in the real world, proposition 2 only pointed out that no policy can satisfy the central planner, firms and representative agent simultaneously if there is difference in preference between central planner and representative agent. In a market economy, representative agent and firms are satisfied; instead, in command economy central planner and firms are satisfied.

It is well known that the price was distorted in socialist economy such as FSU and China in pre-reform periods. Comparing to the world prices, prices of energy and raw materials were undervalued significantly, they might be very different from the shadow prices although the shadow price vector can also predict the shortage which can be seen as a mark of command economy. This model doesn’t tell the story how the price were regulated and why some prices were regulated at such low level by government. Theoretically, in this economy, both central planner and representative agent can be satisfied by eliminating the shortage to make each market clear if setting the price of good $i$ as $\hat{p}_i = \frac{\hat{\theta}_i}{\theta_i} p_i$, $p_i$ is the shadow price determined by technology sector $i$; but by proposition 2, firms are not maximizing profits. For those goods which are valued more by the representative agent than by central planner ($\hat{\theta}_i > \theta_i$), the market clearing price $\hat{p}_i$ will be higher than the shadow price $p_i$, typically, in a socialist economy, those goods are something like necessities of livings, like foods, cloths, etc. Maybe higher price in the necessities are not optional for political considerations, prices are intentionally regulated at a low price level but the production is not favored by central planner, the shortage is a natural consequence in such economic system.

Anyway, this paper is not going to discuss the price control, it only intends to understand the huge output drop in the beginning of economic transition and focuses on the interconnection between various production units, so I’m not going to argue that whether the prices are actually regulated by government at the shadow price level or not. Proposition 2 also indicates that this policy is a feasible option for central planner and equation (1.b) tells us that this price vector is irrelevant to preference, instead it is only determined by technologies, so the shadow price vector actually reveal the true value of those goods in a command economy like FSU and China, since both economies were relatively isolated from the world market, world prices actually were not as appropriate as the
shadow prices to measure the real value of each product. So in this paper, I continue to use the shadow price vector to calculate the real output drop during the transition.

How this model can be applied to explain the instant output drop in transitional economy? We can see that this model depicts a circulate flow command economy without any technology progress, shocks or institutional changes. There were huge structural changes and external shocks in the beginning year of economic transition in FSU republics, those changes affected the incentives of economic agents—firms and consumers. During the last years of this huge empire, enormous of reforms have been implemented in order to save this huge socialist organization. In 1987, fundamental reform on state owned enterprise was promulgated and came into force in 1988. Under this reform the compulsory plan of targets on production was officially aborted, enterprises have more freedom in setting prices and wages (Aslund, 1995). Also CMEA (Council for Mutual Economic Assistance) was dissolved in the beginning of 1991, which definitely increased the trade costs between FSU and its socialistic political allies in eastern European. Bulk of price liberalization was launched in 1991 in FSU before the whole union was dissolved. In Jan 1991, production prices were significantly liberalized; and in April 1991, retail prices were freed which increased the retail prices level by about 70% (Aslund, 1995). Certainly, all those changes affected the economic performance of the whole union, but the natural question is which one is the major reason for huge output drop?

We need to notice the fact that in different time of transition the the severity of economic downturn was quite different, i.e, according to table 1, the output drop in 1990 is only 2% comparing to 1989; but in 1991, output drop was more than 6% comparing to 1990; from 1992, output drop reached more than 10% and this situation continued until 1994; after 1994, the economic downturn became less severe. Why there was such different economic performance during the transitional period? Surely, different structural changes or external shocks contributed to this situation in different times, we need to understand which was the main cause of economic downturn in different period.

I believe that Shleifer, Vishny and Murphy provided a good direction to understand the economic downturn in the very early years of economic transition (Shleifer & Vishny, 1991; Murphy, Shleifer & Vishny, 1992). As I pointed out in section 2, their theory might be only valid before the bulk
price liberalization, in 1991, with most of prices were liberalized, the mechanism they pointed out might not be in dominance. The sudden price liberalization in 1991 was really damaging for the whole economy, since the production process adjusted slowly in short run due to that some production factors can not change quickly, such as labor and capital. In this model, we assume that labor can not change in such a short time, actually, we can view the labor as all the inputs other than the intermediate goods if you wish. Empirical evidence found in FSU republics is consistent with our assumption, during the early years of transition, capital stock was forbidden to change because of tight credit rationing (Calvo & Coricelli, 1993); and banks were unable or unwilling to finance capital investment through long term credit loans (Boycko et al., 1995, Cohen et al., 1995); Duflo and Senik-Leygonie also concluded in their paper that firms were unable to sell the installed capital (Duflo & Senik-Leygonie, 1997). In the labor market, both employment and labor mobility were sluggish, i.e, employment was changing very slowly (Commander et al., 1993, 1995); also Layard and Richter showed that only 1.5% employees in 1993 were laid off (Layard & Richter, 1994); the labor entries and exits in labor market were small, reallocation of labor among industries was slow and weak (Duflo & Senik-Leygonie, 1997). Local government also imposed pressures on employers to maintain employment in order to reduce the possible social and political consequences of “Open unemployment” (McKinsey Global Institute report, 1999 and World bank report, 2003). Enterprises typically maintained employment through labor hoarding in exchange for tax and social contribution relief (Pinto et al., 2001). Those situations were so typical in the beginning years of transitional economies in socialistic countries, many case studies in Chinese economic literatures also documented the sluggishness of labor layoffs and job to job mobility, managers in SOEs just can not fire workers for certain political considerations since managers’ payoffs were highly relied on those political considerations.

Under this situation, this model predicts that the sudden price liberalization was harmful to the whole economy, the interconnection between various production units will amplify this effect significantly. To simplify our analysis, we further assume that there is no job layoff and no job mobility between industries. When the prices were freed, production can not adjusted fully. As result, for those goods were previously in shortage, the prices went up significantly to equalize the supply and
demand. In this model, as proposition 1 stated that the competitive equilibrium price was irrelevant to preference, so if production can fully adjusted according to consumer’s preference, the market equilibrium price should equal to the shadow price as we defined before. As of the assumption be made in this model, firms can not fully adjust their production, the price level after the liberalization was not the same as the shadow price level. After the central planner stepped out, representative agent stepped in to dominate the economy, market demand was changed according to consumer’s preference, this is the source of demand shock, in this model demand shock in good \( i \) is specified as \( d\theta = \hat{\theta}_i - \theta_i \); although labor can not be laid off, the actual labor force in use in each firm/sector can actually change, for those firms which need more labor force can not be satisfied, there will be a shortage in labor; for those firms which actually need cut the labor input off was unable to laid them off according to the discussions before, there will be some idle workers in their factory. This will undoubtedly result in loss-making of some firms, theoretically, government is able to compensate those loss-making firms by collecting profits from those profit-making firms. In reality, government subsidized those loss-making firms through noncash settlement for utility payments or soft budget constraints (World bank report, 2003). In the whole picture, since no labor is laid off, all workers get paid. In this model, we equalize the wage rate to the shadow wage rate level \( q = \frac{1}{L} \), which will not affect anything, since we only care about the real output change. Moreover, as mentioned above, SOEs has more freedom to decide the production, it’s reasonable to assume that the profit of each firm/sector became the manager’s priority. Under this circumstance, consumer’s demand \( \vec{\hat{\theta}} \) compose the final expenditure, therefore, the system equation becomes:

\[
\begin{pmatrix}
\hat{s}_1 \\
\hat{s}_2 \\
\vdots \\
\hat{s}_n
\end{pmatrix}
= \begin{pmatrix}
\hat{\theta}_1 \\
\hat{\theta}_2 \\
\vdots \\
\hat{\theta}_n
\end{pmatrix}
+ \begin{pmatrix}
(1 - b_1)\phi_{11} & (1 - b_2)\phi_{12} & \cdots & (1 - b_n)\phi_{1n} \\
(1 - b_1)\phi_{21} & (1 - b_2)\phi_{22} & \cdots & (1 - b_n)\phi_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
(1 - b_1)\phi_{n1} & (1 - b_2)\phi_{n2} & \cdots & (1 - b_n)\phi_{nn}
\end{pmatrix}
\begin{pmatrix}
\hat{s}_1 \\
\hat{s}_2 \\
\vdots \\
\hat{s}_n
\end{pmatrix}
\]

We get \( \vec{\hat{s}} = \vec{\hat{\theta}} + W\vec{\hat{s}} \) which implies \( \vec{s} = (I - W)^{-1}\vec{\hat{\theta}} \). So \( d\vec{s} = \vec{s} - \vec{s} = (I - W)^{-1}d\vec{\hat{\theta}} \). Here \( d\vec{s} \) is the change of gross output in each sector, and \( d\vec{\theta} = \vec{\hat{\theta}} - \vec{\theta} \) is the shock from the demand side, by model construction \( \mathbf{1}'d\vec{\theta} = 0 \). Here, demand shock comes from the restructuring of the final
expenditure, under the command economy system, as proposition 2 suggests that consumers can not choose what they really want to consume, they accept what the central planner gives; once, central planner gives up his/her plan, consumers’ choices dominated the economy, therefore final expenditures restructured according to consumers’ preference, this results a big change in the whole economy.

The key point in this model is the assumption that some production factors, labor in use in this model, is unable to increase; it can decrease, not by laying off labors, but by putting some redundant workers in idle. It is necessary to calculate the decrease of labor in use in each sector; however, the change of labor in use in each sector can not be determined only from the demand shock in single one specific sector without investigating the network structure of the production function. The reason for this is quite straightforward, let’s say if there is a negative shock in demand in sector $i$, and there is a positive demand shock in sector $j$, sector $j$’s positive demand shock intend to increase the demand for more inputs which may contain good $i$ as raw materials, this effect intend to increase the demand for $i$, so the total effect of demand shock is ambiguous. The proposition 3 states the condition of the change of the labor in use.

**Proposition 3:** $dL_i = 0 \iff ds_i \geq 0$; and $dL_i < 0 \iff ds_i < 0$.

Proposition 3 is very instructive since we can not calculate $dL_i$ directly, instead $ds_i$ can be easily captured in equation (11), it largely simplify the analysis of the output change in each sector.

$ds_i = \hat{p}_i \hat{Y}_i - p_i Y_i$ is the change of gross output in sector $i$, it can be captured by equation (11) as:

$$ds_i = e'_i d\vec{s} = e'_i (I - W)^{-1} d\theta. \quad (2.12)$$

Where $e'_i = (0, 0, \cdots, 1, \cdots, n)$, a vector with $i^{th}$ element equals to 1, others equal to 0.

After the price liberalization, all prices are changed except for wage rate which is set to be equal in the model for the purpose of comparing output before and after price liberalization. Define a price index $P_I = \prod_{i=1}^{n} \left( \frac{p_i}{\hat{p}_i} \right)^{\theta_i}$ as a general price level, and the composite consumption index $C_I =$
Here I use the weight $\hat{\theta}_i$ rather than $\theta_i$ because the former one reveals the living costs from the consumers’ side. So the consumer’s utility function can be represented as $U = \ln C_I; \text{ budget constraint can be represented as } P_I C_I = q L; \text{ real wage can be measured by } \frac{q}{P_I}. \text{ It is easy to derive that the change of price level } \frac{dP_I}{P_I} \text{ is } \sum_{i=1}^{n} \hat{\theta}_i \frac{dp_i}{p_i}. \text{ Now, important thing is to capture the change of price of good } i, \text{ namely } \frac{dp_i}{p_i}. \text{ } 

\textbf{Proposition 4}: \text{ The price in each sector increase, i.e, } \frac{dp_i}{p_i} > 0 \text{ for all } i; \text{ and general price level increase after the price liberalization. i.e } \frac{dP_I}{P_I} > 0. \text{ } 

The model predicts that shocks from demand side push up the general price level, this is consistent with the facts happened in FSU countries. This price index directly measures the consumer’s purchasing power, welfare and real wage rate. Increase in general price level implies real wage rate decrease and welfare loss. After the price liberalization, there were huge decrease in real wage rate in FSU republics, our economic model successfully predict such result.

However, the purpose of this paper is trying to understand the instant output drop caused by the sudden price liberalization. There are 2 ways to calculate the final output change. Since wage rate is set equal before and after the price liberalization, one way is to calculate the income of labors, although as the model assumed that no one is laid off, only part of labors are creating values because some workers in some sectors are idle, only those workers who are really creating values should be taken into consideration. The another way is calculate the value of final products, since the price of each good might be changed after price liberalization, we need to use the same price to calculate the value of each good. The two accounting methods of final GDP should give the same result.

\textbf{Proposition 5}: \text{ The percentage change of final output in real term is } \triangle GDP = \sum_{i=1}^{n} 1_{[d_{s_i}<0]} b_i d_{s_i}. \text{ And again the sign of } d_{s_i} \text{ is determined by } d\tilde{s} = (I - W)^{-1} d\tilde{\theta}. \text{ } 

This proposition implies that real GDP will decrease comparing to the level before price liberalization due to the sluggishness of labor mobility between sectors. Without this assumption, as the following proposition shows that GDP level will not change although some sectors will shrink and others will expand.
Proposition 6: If labor (or other factors except for the intermediate goods) can fully move between sectors, GDP level will remain unchanged.

As equation (12) points out, $ds_i$ is determined by the demand shock, since the effect of interconnection is captured by the matrix $W$, the demand shock propagates in the network through the interconnection among production units. The effect of interconnection may amplify the demand shock which makes the GDP downturn larger and more pervasive, or canceling the demand shock which makes the real GDP downturn smaller and less pervasive. Which situation is actually happened is decided by the property of demand shock and the property of the interconnection. Before I do any analysis on the properties of demand shock and interconnections, there is a simple example to illustrate how the demand shock comes from; how the labor force changes in each sector; and how much the real GDP will drop. I will also propose another economy with different property of interconnections to further illustrate how different demand shock and different interconnections affect the economy in different way.

Example: Suppose an economy, let’s call it as economy 1, is depicted as the figure below, there are only 3 sectors. The specification of a economy is specifying the production parameters and demand shocks, to make the example even simpler, with out loss of generality, here assuming that $b_1 = b_2 = b_3 = \frac{1}{2}$, which means the cost share of labor in all 3 sectors is 0.5, and the cost share of other inputs those are from other sectors is 0.5 also. For economy 1, the interconnection matrix $W_1 = \frac{1}{2} \begin{pmatrix} 0.2 & 0 & 0 \\ 0.4 & 1 & 0 \\ 0.4 & 0 & 1 \end{pmatrix}$, that is to say, for sector 1, 20% of the intermediate costs other than labor is from its own sector, 40% is from sector 2, and the rest of 40% is from sector 3. Suppose the central planner’s preference is specified by vector $\vec{\theta} = (0.34, 0.35, 0.31)'$. By equation (9), $\vec{s} = (I - W_1)^{-1} \vec{\theta} = (\frac{3.4}{9}, \frac{7.66}{9}, \frac{6.94}{9})'$, so the total gross output $\sum_{i=1}^{3} s_i = 2.0$. Since by equation (10), GDP is normalized to 1, wage rate $q = \frac{1}{L}$; and by equation (8), $\frac{L_i}{L} = s_i b_i = \frac{1}{2} s_i$. There has $\frac{L_1}{L} = \frac{1.7}{9}$, $\frac{L_2}{L} = \frac{3.83}{9}$ and $\frac{L_3}{L} = \frac{3.47}{9}$. As assumed before, representative agent in economy has different preference than central planner, suppose it is $\vec{\hat{\theta}} = (0.30, 0.355, 0.345)'$, it suggests that representative put more weights on goods 2 and 3 and less weights on goods 1 than that of central planner. Now,
central planner is no longer taking part as a role in economic decision and all prices were liberalized, suddenly, the firms produces goods 1 find that consumers need their products more, to maximize profits those firms need to produce more but they can not fully adjust their productions because they can not hire more labors. So they have to partially adjust their productions by inputting more goods 2 and 3 and increase prices of product 1. For firms produce goods 2 and 3, they are facing a downturn of the demand from consumers but upturn of the demand from firms produce good 1 they will also partially adjust their productions accordingly. As described before, all workers were still officially employed and get paid as the same wage rate before although some of them are idle in the plant. The final demand adjust according to their preferences, namely, $\tilde{s}$, as result, $\tilde{s} = (I - W_1)^{-1} \tilde{\theta} = \left(\frac{1}{9}, \frac{7.59}{9}, \frac{7.41}{9}\right)$, and labor demand for each sector becomes $\frac{L_1}{L} = \frac{1.5}{9}, \frac{L_2}{L} = \frac{3.795}{9}$ and $\frac{L_3}{L} = \frac{3.705}{9}$. Sector 3 needs more labors, sector 1 and sector 2 need to cut off labor force, if the economy can fully adjust, there will be labors move from sector 1 and sector 2 to sector 3, but none of them can actually do this and there will be no labor mobility. As a consequence, sector 1 and sector 2 put less labor in use, and sector 3 still use the same amount of labor as before, so the labor in use in all 3 sectors becomes $\frac{L_1}{L} = \frac{1.5}{9}, \frac{L_2}{L} = \frac{3.795}{9}$ and $\frac{L_3}{L} = \frac{3.47}{9}$, clearly, comparing to the situation before demand restructuring, less labors are working for creating GDP. Although the total gross output $\sum_{i=1}^{3} \tilde{s}_i$ is still 2, it is mainly due to the increase of general price level—the same amount of wage payments (in this model, it is normalized by $qL = \frac{1}{L}L = 1$, which is the product of wage and labor force) is spent on fewer amount of final goods.

To illustrate the importance of interconnections, there suppose another economy, let’s call it as economy 2, that can be described by matrix $W_2 = \frac{1}{2} \begin{pmatrix} 1 & 0.4 & 0.4 \\ 0 & 0.6 & 0 \\ 0 & 0 & 0.6 \end{pmatrix}$, figure 3 depicts the network representation of both economies. Clearly, the same shock will behave quite differently between economy 1 and economy 2. Let suppose the demand shock $d\tilde{\theta} = (-0.04, 0.005, 0.035)'$, which implies that there is a negative demand shock in sector 1, positive demand shocks in sector 2 and sector 3. That is to say, consumers shift their consumption from product 1 to product 2 and product 3.
Thus, we can calculate the change of gross output in each sector by equation (12). Namely, the
change of gross output in sector 1, \( ds_1 = \left( -\frac{0.4}{9}, -\frac{0.07}{9}, \frac{0.47}{9} \right) \); and the change of gross output in sector
2, \( ds_2 = \left( -\frac{0.18}{7}, \frac{0.05}{7}, \frac{0.35}{7} \right) \). Apparently, In economy 1 both sector 1 and sector 2 have recession al-
though that sector 2 has positive shock, this is because sector 1 is the downstream producer of sector
2, negative shock on sector 1 propagate to sector 2 through the network. In use of the conclusion
in proposition 5, we can calculate the output change in economy 1 is \( -\frac{0.47}{18} \). However, in economy
2, the demand shock has limited effect on the whole economy, only sector 1 experiences a decline
in its gross output. Furthermore, the the demand shock in sector 1 is partly be eliminated by the
positive shock on sector 2 and sector 3 since they are upstream producer of sector 1, their positive
demand shock also propagate to it. As a whole, the final output change of economy 2 is \( -\frac{0.09}{7} \) which
is less than that of economy 1.

This simple example illustrates the importance the consumption restructuring (demand shock) and
the network property of a economy during the economic transition. This may help to understand the
situation observed in FSU republics and some Eastern European countries, during the first years of
economic transition, most of sectors have experienced a decline in productions.

Given the complexity of the economic interconnection between various sectors, it is hard to analyse
the propagation of the demand shock. In general, we need to capture some general properties of
the network and the demand shock. Such as, under which case, more sectors will experience gross
output drop; and under what circumstances there are bigger economic downturn. Certainly, the answer to those questions can be directly revealed by the matrix \((I - W)^{-1}\), which is also called as Leontif inverse matrix.

As we showed that all eigenvalues of matrix \(W\) is inside the unit circle in a complex plane (see the appendix, claim 1 in the proof of proposition 4). So we can extend the Leontif inverse matrix \((I - W)^{-1} = \sum_{n=0}^{\infty} W^n\), so we have:

\[
d\vec{s} = \sum_{n=0}^{\infty} W^n d\vec{\theta}.
\]

Different terms in equation (13) represents different effects of the interconnection, higher order terms implies weaker effect of the interconnection. For example, the first term \(Id\vec{\theta}\) is the zeroth order effect of the network because \(I\) is a identity matrix, it preserves all the demand shock; \(Wd\vec{\theta}\) represents the 1st order effect of the network; \(W^2d\vec{\theta}\) represents the 2nd order effect of the network; and so on. For any sector \(k\), by equation (13), we get:

\[
ds_k = \underbrace{d\theta_k}_{0^{th} \text{ order}} + \underbrace{\sum_{i=1}^{n} (1 - b_i)\phi_{ik}d\theta_i}_{1^{st} \text{ order}} + \underbrace{\sum_{i=1}^{n} \sum_{j=1}^{n} (1 - b_j)(1 - b_i)\phi_{ij}\phi_{jk}d\theta_i}_{2^{nd} \text{ order}} + \cdots.
\]  

\[
(2.14)
\]

2.3.1 0th order interconnection and island economy

The first term in equation (14) depicts the situation of an island economy, the 0th order effect captures the effect of demand shock on the whole economy when all sectors are totally isolated. In this case, \(ds_k = d\theta_k\), and according to proposition 5, \(\Delta GDP = \sum_{i=1}^{n} 1_{d\theta_i < 0} b_i d\theta_i\). In an island economy, only those sectors with negative demand shock will have real output drop; and only those sectors with positive demand shock will have price increase.
2.3.2 First order interconnection

The demand shock vector \((d\theta_1, d\theta_2, \cdots, d\theta_n)'\) can be decomposed as a linear combination of basis vectors in \(\mathbb{R}^n - e_1, e_2, \cdots, e_n\), where \(e_k = (0, \cdots, 1, \cdots, 0)'\) which has 1 for its \(k^{th}\) components and 0 for others. As result, \((d\theta_1, d\theta_2, \cdots, d\theta_n)' = \sum_{i=1}^{n} d\theta_i e_i\), and \(d\vec{s} = (I - W)^{-1} \sum_{i=1}^{n} d\theta_i e_i\). This implies that total effect of the demand shock can be viewed as a linear combination of \(n\) simple shocks, namely, \(d\theta_i e_i\) for \(i = 1, 2, \cdots, n\), which only happens on a single sector. Furthermore, since \((I - W)^{-1} = \sum_{n=0}^{\infty} W^n\), we get \((I - W)^{-1} d\theta_i e_i = \sum_{n=0}^{\infty} W^n d\theta_i e_i = d\theta_i \sum_{n=0}^{\infty} W^n e_i\). Each entry in matrix \(W\) is nonnegative, it implies that if \(d\theta_i \geq 0\), \((I - W)^{-1} d\theta_i e_i \geq 0\); and if \(d\theta_i \leq 0\), \((I - W)^{-1} d\theta_i e_i \leq 0\). So a nonnegative simple shock contributes its shock to each sector non-negatively; and a nonpositive simple shock contributes its shock to each sector non-positively. The total effect is the summation of all these simple shocks.

**Definition 1.** Define vector \(d_k = ((1 - b_1)\phi_{1k}, (1 - b_2)\phi_{2k}, \cdots, (1 - b_n)\phi_{nk})'\) and \(v_k = (1 - b_k)\phi_{k1}, (1 - b_k)\phi_{k2}, \cdots, (1 - b_k)\phi_{kn}\) of a sector \(k\); \(\|d_k\|_1 = \sum_{i=1}^{n} (1 - b_i)\phi_{ik}\) is the out-degree of sector \(k\) and \(\|v_k\|_1 = \sum_{i=1}^{n} (1 - b_i)\phi_{ki}\) = \((1 - b_k)\) is the in-degree of sector \(k\).

The first order interconnections is captured by the second term in equation (14). A simple demand shock in sector \(i\) propagates to sector \(k\) by the first order effect is \((1 - b_i)\phi_{ik} d\theta_i\). On average, this simple shock on sector \(i\) propagate to each sector by first order interconnection is \(\frac{\sum_{i=1}^{n} (1 - b_i)\phi_{ik} d\theta_i}{n} = \frac{(1 - b_i) \sum_{i=1}^{n} \phi_{ik}}{n} = \frac{(1 - b_i) d\theta_i}{n}\). The figure below depicts how the demand shock in sector \(i\) propagates to its upstream producers by the first order interconnections. We can see that, in the figure below, if sector \(i\) has a large in-degree (large cost share of intermediate inputs), a negative demand shock in sector \(i\) has relative large negative effect on other sectors, hence, more sectors can be negatively affected.
2.3.3 Second order interconnection

The second order effect of a simple demand shock in sector $i—d\theta_i$ (and assume that $d\theta_i > 0$) on sector $k$ can be represented by the 3rd term in equation (14), that is:

\[
d s_{k2} = \sum_{j=1}^{n} (1 - b_i)\phi_{ij} (1 - b_j)\phi_{jk} d\theta_i \\
\leq d\theta_i||v_i||_\infty \sum_{j=1}^{n} (1 - b_j)\phi_{jk} \\
= d\theta_i||v_i||_\infty ||d_k||_1.
\]

Here $||v_i||_\infty = (1 - b_i) \max_j \phi_j \leq (1 - b_i) = ||v_i||_1$. Second order effect decays the demand shock from other sectors to sector $k$ slower than the first order effect if it has a large enough out-degree. Figure 5 demonstrates the second order effect of a simple shock from sector $i$ on sector $k$. 

Figure 2.4: The first order effect of interconnections: sector $i$’s negative demand shock propagates to other sectors through the network. $i$ is downstream producers of sector 1, 2, 3, $\ldots$, $n$. So the in-degree of sector $i—1 - b_i$ determines how important this sector can affect others. The larger in-degree of sector $i$, more importantly sector $i$ can affect other sectors; the smaller in-degree of sector $i$, less importantly sector $i$ has effect on other sectors.
**Example 2:** Consider an economy with 3 sectors, sector 1 is a major supplier to sector 2 and 3, as figure 6 shows below. Again, assume $b_i = \frac{1}{2}$ for all $i$, as result matrix $W = \begin{pmatrix} 1 & 0.4 & 1 \\ 0 & 0 & 0 \\ 0 & 0.6 & 0 \end{pmatrix}$. The out-degrees are 1.2, 0 and 0.3 for sector 1, 2 and 3 respectively. If there is a positive demand shock $\delta$ in sector 2, then it propagates to sector 1 by first order effect is $0.2\delta$; and by the second order effect is $0.25\delta$ which outperforms the first order effect. Under this circumstance, the second order effect is not negligible.
If some sectors are major suppliers in an economy, it tends to be affected more by the demand shock from other sectors by the second order effect. Since the higher order effect eventually converges to 0 and has few intuitive interpretations for the whole economy, in the analysis, I only expand to 3rd order effect.

2.3.4 3rd order interconnection

3rd order effect of demand shock in sector \( i \) (assuming the demand shock is \( d\theta_i \)) on sector \( k \) can be captured by \( W^3 \). Then we have:

\[
\begin{align*}
    ds_{k3} &= \sum s d\theta_i (1 - b_i) \phi_{is} \sum_j (1 - b_j) \phi_{sj} (1 - b_j) \phi_{jk} \\
    &\leq d\theta_i \|v_i\|_\infty \sum_j (1 - b_j) \phi_{jk} \sum_s (1 - b_s) \phi_{sj} \\
    &= d\theta_i \|v_i\|_\infty \sum_j (1 - b_j) \phi_{jk} \|d_j\|_1 \\
    &= d\theta_i \|v_i\|_\infty q_k.
\end{align*}
\]

Acemoglu et al. (2012) defines \( q_k \) as a second order degree of sector \( k \). If \( q_k \) has a large value, it means that sector \( k \) is a major supplier of other sectors which are also major suppliers in the economy. Demand shock from other sectors can largely propagate to sector \( k \) with large \( \|d_k\|_1 \) and \( q_k \), by the second and 3rd order effect of interconnections even though the first order effect is trivial; if second order effect is also not significant, 3rd order effect may be important since large \( q_k \) means sector \( k \) closely connects to some sectors which have large out-degree.

2.3.5 The effect of interconnection

In proposition 5, I showed that \( \Delta GDP = \sum_{i=1}^n 1_{\{ds_i < 0\}} b_i d_i \), \( \sum_{i=1}^n 1_{\{ds_i < 0\}} \) decides the scale of the economy recession, if more \( i \in \{1, 2, \cdots, n\} \) satisfies \( ds_i < 0 \), more sectors experience gross output downturn. The in-degree—\( 1 - b_i \); the out-degree—\( d_i \) and the second order out-degree—\( q_i \) of sector \( i \) roughly determines how large the demand shock will propagate to other sectors and how much
it receives demand shock from other sectors. We can think of the demand shock as combination of \( n \) simple shocks, as we discussed before, positive simple shocks contribute to all sectors non-negatively and negative simple shocks contribute to all sectors negatively. We can expect that more industries will experience recession, if large negative simple shocks happen on those sectors with large in-degree; and small positive simple shocks happen on those sectors with large out-degree and second order out-degree such that this small simple shock can be largely cancelled by negative simple shocks from other sectors. In this case, more sectors might have a gross output drop \( (d_{si} \leq 0) \).

Table 2 below displays information on the in-degree, out-degree and second order degree of 16 sectors for China, FSU and USA economy. It is worth noting that those sectors who have large out-degree tend to have large second order degree, which implies that as a major supplier to other sectors, their downstream producers also tend to be a major suppliers in the whole economy. Table 2 also tells a very different pattern of sectoral interconnections in those economies, i.e., in FSU economy, those sectors with large in-degree also tend to have large out-degree (they are serially positively correlated); instead, in USA economy, the situation reversed (in-degree and out-degree tend to serially negatively correlated). Furthermore, in USA economy, service sectors (“Trade”, “T&C”, “Fin&ins”, “Business”, “PEDH”) have higher out-degree than those in FSU economy, which implies their more important roles in supporting other sectors in production. This is highly likely due to the difference in economic institution, planned economy allocates resources by direct order and less rely on the business services; instead free market depends more on business services. Finally, sectors in FSU economy tend to be more variational in out-degrees and more clustered than that in USA economy, this information is revealed by the standard deviation of sample degrees sequence of all sectors. For the out-degree sequence, ratio of sample standard deviation to sample mean measures the variation of out-degrees for the whole economy (See Acemoglu, 2012), higher ratio means there are some “dominant” sectors play as a major suppliers in the whole economy. FSU economy has a higher ratio than USA economy. The variation of second order out-degree measures the extent to which major suppliers in the economy are also major suppliers of other “dominant” sectors, it takes higher value when major suppliers in the economy connect to each other more.
closely. It tells that in FSU economy, sectors were more concentratively connected within a small
group; instead in USA economy, sectors were more widely connected.

For example, in FSU economy, both “Chemical” and “Power” sectors have large out-degree (they
are major suppliers in the economy), they share a common supplier—“Fuel”, at mean time “Fuel”
is also a major suppliers in the economy. However, in USA, “Business” sector has highest out-
degree, as major suppliers of “Fuel”, “Trade”, “Fin&ins” and “RS” sectors, only “Trade” sector has
relatively large out-degree. Different structural properties of the interconnections between sectors
responds to the demand shock very differently. In FSU economy, service sectors are relatively
isolated, they have small in-degree and small out-degree, so they have limited effect on propagating
demand shocks to other sectors and receive demand shock from other sectors; also their small
value of second order degree implies that they are normally not connected to those major suppliers
closely, instead they tend to connect to other service sectors closely, thus the third order effect of
interconnection is also very weak for service sectors. Larger extent of sectoral clustering (implied
by the higher variation of second order degree) implies that demand shocks will normally preserve
in a small group of sectors, i.e., demand shock in “Chemical”, “Power” or “Metal” industry will
largely propagate to “Fuel” sector rather than other sectors; and demand shock in “Trade”, “T&C”
or “Fin&ins” sectors will largely propagate to “Business” sector rather than other sectors.
### Table 2.2: 1989 IO table: China, FSU and USA.

<table>
<thead>
<tr>
<th>Industry</th>
<th>China 1997 IO table</th>
<th>FSU 1989 IO table</th>
<th>USA 1989 IO table</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$1 - b_i$</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>AFF</td>
<td>0.429006</td>
<td>0.933693</td>
<td>0.575674</td>
</tr>
<tr>
<td>Fuel</td>
<td>0.484152</td>
<td>0.562105</td>
<td>0.427795</td>
</tr>
<tr>
<td>Food</td>
<td>0.800451</td>
<td>0.396841</td>
<td>0.241694</td>
</tr>
<tr>
<td>Light</td>
<td>0.749719</td>
<td>1.079367</td>
<td>0.788888</td>
</tr>
<tr>
<td>WPP</td>
<td>0.732539</td>
<td>0.683641</td>
<td>0.388057</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.812374</td>
<td>1.324395</td>
<td>1.11953</td>
</tr>
<tr>
<td>Metal</td>
<td>0.833023</td>
<td>0.591537</td>
<td>0.525059</td>
</tr>
<tr>
<td>MBMW</td>
<td>0.756432</td>
<td>1.943153</td>
<td>1.444354</td>
</tr>
<tr>
<td>Power</td>
<td>0.736659</td>
<td>0.454705</td>
<td>0.254801</td>
</tr>
<tr>
<td>Construction</td>
<td>0.697002</td>
<td>0.228847</td>
<td>0.079132</td>
</tr>
<tr>
<td>Trade</td>
<td>0.586715</td>
<td>0.815812</td>
<td>0.501495</td>
</tr>
<tr>
<td>T&amp;C</td>
<td>0.476894</td>
<td>0.592055</td>
<td>0.318776</td>
</tr>
<tr>
<td>Fin&amp;ins</td>
<td>0.525196</td>
<td>0.313942</td>
<td>0.172466</td>
</tr>
<tr>
<td>Business</td>
<td>0.519178</td>
<td>0.133142</td>
<td>0.076812</td>
</tr>
<tr>
<td>RS</td>
<td>0.719863</td>
<td>0.258632</td>
<td>0.120475</td>
</tr>
<tr>
<td>PDEH</td>
<td>0.559386</td>
<td>0.106722</td>
<td>0.039245</td>
</tr>
<tr>
<td>mean</td>
<td>0.651162</td>
<td>0.651162</td>
<td>0.442141</td>
</tr>
<tr>
<td>std</td>
<td>0.135739</td>
<td>0.486004</td>
<td>0.392355</td>
</tr>
<tr>
<td>std/mean</td>
<td>0.208457</td>
<td>0.746364</td>
<td>0.887397</td>
</tr>
</tbody>
</table>
From table 2 one can see that on average sectors connect more closely than both that in USA and FSU economy; and sectors were even more concentratively connected. In use of Monte Carlo simulation with random shock on demand side, I’m able to evaluate how the interconnections affect the GDP downturn. Two preference vectors can be generated by uniformly distributed random vector with fixed sum 1 on the support [0, 1], and demand shock is represented by taking the difference of those two preference vectors. Table 3 displays the result of GDP fall, and the effect of interconnections.

Table 2.3: Monte Carlo simulation for the randomly generated demand shock with 10000 trails.

<table>
<thead>
<tr>
<th>Mean</th>
<th>China</th>
<th>FSU</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP Fall</td>
<td>-0.1006</td>
<td>-0.1298</td>
<td>-0.1364</td>
</tr>
<tr>
<td>0th order effect</td>
<td>-0.085 (84.5%)</td>
<td>-0.1155 (89%)</td>
<td>-0.1195 (87.6%)</td>
</tr>
<tr>
<td>Effect of interconnections</td>
<td>-0.021 (15.5%)</td>
<td>-0.0143 (11%)</td>
<td>-0.0169 (12.4%)</td>
</tr>
<tr>
<td>No. of negative shocks</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>No. of negative output fall</td>
<td>10.64</td>
<td>10.8</td>
<td>10.79</td>
</tr>
</tbody>
</table>

On average, China suffered the least from the demand shock because of its large average in-degree, larger in-degree implies more factors are adjustable, so the 0th order effect on the output fall is weaker than both FSU and USA economy. Furthermore, in Chinese economy, the effect of interconnections is stronger due the higher in-degree and out-degrees, which implies a stronger first order, second order and third order effect on propagating demand shocks. Finally, in all of three economies, interconnection between sectors makes more sectors suffering real output drop, which helps to understand the pervasive output fall in transitional economies.

2.3.6 Technological shock and China’s experience

As mentioned above, degree of sector \( i \), \( d_i \), measures the importance of sector \( i \) to other sectors. For one sector with large degree, it contributes a lot as an input to other sectors. The effect of large
degree sectors becomes even more important when there are technology shocks in those sectors (Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi, 2012), supply side shock (especially technology shock) can propagates its shock to downstream sectors, large degree means many sector use intermediate inputs from this sector. So negative supply side shock will be amplified significantly, this also helps us to understand the big output downturn in transitional economies. When subsidies disappeared after the crash down of the central planning system, there were huge technological deterioration in some sectors, say, MBMW sector, the consequence could be fatal given the situation that such huge degree of MBMW department. Moreover, the disconnection of the links between a sector which has large degree and other sectors will cause serious damage to the whole economy, since once the links become disconnected or the connection becomes really weak, which were usually caused by the increase in the costs of trade between sectors or trade quota set by government, more upstream sectors will suffered by either the increase in production costs or by shortage of inputs. This situation was widespread after the disunion of U.S.S.R in year 1991. Most of the former FSU republics favor import rather than export because of the uncertainty of the payment and the instability of the ruble zone, licensing on export were widespread in CIS countries (Michalopoulos and Tarr, 1992). Trade barriers caused serious damages to FSU republics given the fact that the production process were sparsely distributed in various members of U.S.S.R.

In China, during the initial years of transition, technological progress in agricultural sector contributed a lot to economic growth, and due to the fact that agricultural sector played as a major supplier in Chinese economy (in China’s I/O table, it can be seen that agricultural sector had a very large out-degree than that in both FSU and USA economy), agricultural technological progress could largely propagate to other sectors by decreasing the costs of input and contribute to economic growth.

Basically, restructuring of final expenditures due to the preference change generates demand shocks in each sector, those demand shocks propagates to other sectors. In the next part, we use numerical methods to simulate how industries are going to restructure and GDP output drop correspond to certain demand shocks.
2.4 Numerical calibration

Matrix $W$ can be obtained from an input-output table. GTAP (Global Trade Analysis Project) composed 1989 IO table for FSU with 57 sectors, but the classification of industries are too specific such that some sectors should be in the same industry according to ISIC (International Standard Industrial Classification). Moreover, GTAP sectoral classification (GSC2) is very different from FSU’s industry classification which only contained information of 12 sectors in FSU’s 1989 IO table. GTAP disaggregated 12 sectors to 37 sectors just simply use the North Korean’s proportion and multiply by the total value in USSRs I/O in GTAP3 data base (Wahl & Yu, 1992); then in GTAP5 database 37 industries were further disaggregated to 57 sectors. To eliminate the error generated by such disaggregation, in this part, I narrowed 57 industries to recovery USSR sectors, since Agriculture, forestry and fishing industry, fuel industry, food industry, light industry and MBMW (Machine Building and Metal Working industries were highly disaggregated, and they composed large portion of the whole economy, those sectors are recovered by adding up corresponding sectors; moreover, since USSR attributed a lot of service sectors as “Others” in its industry classification standard, those departments are partially recovered since I expect that there will be huge restructuring in those service sectors during the transition. Finally, 57 GTAP sectors are narrowed down to 16 new sectors in this paper, table 3 lists those 16 industries and the corresponding industries in the original GTAP IO table and their counterparts of USSR industries.

It’s worth noting that in table 3 department “PDEH” contains too many sectors in GTAP data base, it includes “Public administration”, “Defense”, “Education” and “Health”. Certain information is inevitably lost by this aggregation because in FSU national defense is highly relied on other sectors, such as MBMW; but other sectors in “PDEH” are not. After the whole union disbanded, there was huge structural change in final expenditure, share of national defense dropped significantly and the share of others increased. Aggregating those sectors together undoubtedly makes this information lost and unable to evaluate the effect of demand restructuring in those sectors. 1987 world bank IO table separated those sectors; but unfortunately, I can not find comparable data of the end use of final products for other countries at the same period or for the FSU economy in later years to
target the end point of demand restructure. So in this part, GTAP data are used to calculate the IO coefficients and the share of end use in each sector. Because our model assumes that final product are distorted by central planner, empirical evidence from Russia also supports this assumption (Gregory and Lazarev, 2004); we need to quantify how large the distortion was in USSR, in this part, I use the data of the end use of final products in 1989 in EU countries to target the destination of the demand restructuring for FSU economy. The reason of using EU countries’ domestic end use of final products is that FSU and EU have similar geographical location, the real preference of people in EU and FSU should be similar; and also EU countries were market economy in 1989. The share of domestic end use of GDP are presented in table 4.
### Table 2.4: Industry classification correspond to USSR I/O sectors

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>USSR sector</th>
<th>GTAP sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFF</td>
<td>Agriculture, forestry and fishing</td>
<td>Agriculture, forestry and fishing</td>
<td>Paddy rice; wheat; cereals; vegetables; fruits; nuts; oil seeds; sugar cane;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sugar beet; plant-based fibers; crops nec; Bovine cattle, sheep and goats;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>horses; animal products; raw milk; wool; silk-worm cocoons, forestry; fishing</td>
</tr>
<tr>
<td>Fuel</td>
<td>Petro, coal and gas</td>
<td>Fuel</td>
<td>Coal; oil; gas; minerals nec</td>
</tr>
<tr>
<td>Food</td>
<td>Food</td>
<td>Food</td>
<td>Bovine meat products; Meat products nec; vegetable oils and fats; dairy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>products; processed rice; sugar; food products nec; beverages and tobacco</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>products Textiles; wearing apparel; leather products; mineral products nec</td>
</tr>
<tr>
<td>Light</td>
<td>Light industry</td>
<td>Light (part)</td>
<td></td>
</tr>
<tr>
<td>WPP</td>
<td>Wood, paper and publishing</td>
<td>Wood &amp; Light (part)</td>
<td>Wood products; paper products; publishing</td>
</tr>
<tr>
<td>Chemicals</td>
<td>Chemical and petrochemical industry</td>
<td>Chemicals</td>
<td>Petroleum, coal products; chemical, rubber, plastic products</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>Ferrous and nonferrous metals</td>
<td>Metallurgy</td>
<td>Ferrous metals; Metals nec</td>
</tr>
<tr>
<td>MBMW</td>
<td>Machine Building and Metal Working</td>
<td>MBMW</td>
<td>Metal products; motor vehicles and parts; transport equipment; electronic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>equipment; machinery and equipment nec; manufactures nec</td>
</tr>
<tr>
<td>Power</td>
<td>Electric production, Gas manufacture and</td>
<td>Power</td>
<td>Electricity; Gas manufacturing and distribution; water</td>
</tr>
<tr>
<td></td>
<td>distribution, steam and hot water supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade</td>
<td>Construction</td>
<td>Construction</td>
<td>Construction; dwelling</td>
</tr>
<tr>
<td>T&amp;C</td>
<td>Sales, wholesale trade, retail trade, hotels and</td>
<td>T&amp;T (part)</td>
<td>Trade</td>
</tr>
<tr>
<td>Fin&amp;Insur.</td>
<td>Financial service and insurance</td>
<td>Others (part)</td>
<td>Transport nec; water transport; air transport; communication</td>
</tr>
<tr>
<td>BServ.</td>
<td>Business services nec</td>
<td>Others (part)</td>
<td>Financial services nec; insurance</td>
</tr>
<tr>
<td>RS</td>
<td>recreational, cultural and sporting activities</td>
<td>Others (part)</td>
<td>Business services nec</td>
</tr>
<tr>
<td>PDEH</td>
<td>Public administration and defense, education,</td>
<td>Others (part)</td>
<td>Recreational and other services</td>
</tr>
<tr>
<td></td>
<td>health</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

100
Table 2.5: Domestic end use of final GDP for USSR and EU countries in 1989 (Percentage).

<table>
<thead>
<tr>
<th></th>
<th>USSR</th>
<th>EU</th>
<th>Difference</th>
<th>1 – ( b_i )</th>
<th>( d_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFF</td>
<td>0.022035</td>
<td>0.020629</td>
<td>-0.001406</td>
<td>0.554205</td>
<td>0.557658</td>
</tr>
<tr>
<td>Fuel</td>
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</table>

*Difference = EU shares – USSR shares. Data source: GTAP Data Base.

As expected, service sectors are highly overlooked by central planner, for example, “Bserv.” (Business Service) was about 6% below than EU’s, “PDEH” (Public administration, Defense, Education and Health) was 7.7% below than EU’s, and Trade sector was 5.1% below than EU’s level. After liberalization, structure of final expenditure would adjust accordingly. Namely, expenditures on “AFF”, “Fuel”, “Food”, “Light”, “Metal”, “Power”, “Construction”, “T&C”, “Fin&Insur.” and “RS” sectors would reduce; expenditures on other sectors would increase relatively. It’s worth noting that although in some sectors, the share of domestic final expenditures in FSU were higher than
that of in EU countries; this doesn’t necessarily implies that there were no shortage. There are couple of reasons: firstly, the share of government spending in total final domestic expenditure on those sectors were much higher in FSU than that in EU countries, consumers might still experienced heavy shortages; secondly, those sectors are highly aggregated, for example, “AFF” sector incorporates 14 agricultural sectors, “Food” sector contains 8 industries, “MBMW” contains 6 sectors. Some sectors contained in those highly aggregated sectors may have substantial lower level of expenditure share than that in EU countries, However, after aggregation of those sectors, as stated above large amount of information lost. However, the important thing here is to simulate the change of real GDP, aggregation of sectors gains benefits of accuracy.

2.4.1 Numerical results

Given the demand shock in table 4, total output drop is 13.12% and the general price level increase by 18.31%. Comparing to the realities, our numerical results overstates the output drop a little bit but seriously underestimate the inflation. In table 1 we can see that, output drop in 1990 was 2.42%, 6.32% in 1991 and 14.49% in 1992. Our model emphasizes on the harm of expenditure restructuring due to sudden price liberalization, in 1991, there was only partial price liberalization, total price liberalization happened in 1992. Although this model fits FSU’s economic downturn in 1992, the effect of restructuring of final expenditure on output drop would not be such big as calibrated because part of restructuring was proceeded by the partial price liberalization in 1991, bulk price liberalization in 1992 shouldn’t have such big effects on the final output drop. General price level increased more than the model predicted, after the first round of price liberalization in April 1991 inflation rate exceeded 70%, in Jan. 1992 when Russia freed prices for various commodities, prices for many goods doubled, even tripled for some commodities. However, increasing in USSR’s price level was largely due to the monetary overhang created by the increase in nominal wages after the state owned enterprise were given more freedom in 1988 (Aslund, 1995; Gros and Steinherr, 1991); and the increasing in money supply by state owned banks’ credit expansion to finance the deficits of state owned enterprises and government. In this paper, the model predicts that general price level
will increase due to the restructuring of final expenditure, money is not included in this model.

The numerical results for detailed output change in industry level are presented in Table 5. From column 1 and column 3 we can see that nearly all negative demand shocks are amplified by the interconnections of industries which is implied by the result that $d\theta_i > ds_i$ for most of industries except for “Construction”, “Business”, “RS” and “PDEH” (note that if $d\theta_i > 0$, $d\theta_i > ds_i$ means that the positive demand shock in sector $i$ is weakened by interconnections; if $d\theta_i < 0$, $d\theta_i > ds_i$ means that this negative demand shock is strengthened by interconnections. Since without interconnection, $d\theta_i$ should equal to $ds_i$). Furthermore, if there is no interconnections which means there is only $0^{th}$ order effect, GDP downturn is 11.1%. So the interconnections contributes 2% of GDP downturn.
<table>
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<tr>
<th>Industry</th>
<th>$d\theta_i$</th>
<th>$ds_i$</th>
<th>$\frac{ds_i}{s_i}$</th>
<th>$\frac{dY_i}{Y_i}$</th>
<th>$\frac{dp_i}{p_i}$</th>
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</table>

*d\theta_i$ and $ds_i$ are change of the values, $s_i$ is the gross output in sector $i$, $Y_i$ is the real gross output in sector $i$, $\frac{dY_i}{Y_i}$ is the change of percentage rate of real gross output in sector $i$, and $\frac{dp_i}{p_i}$ is the percentage change of price of good/sector $i$.

Table 4 shows that those sectors which have big positive demand shock—“Trade”, “Business” and “PEDH” were slightly depend on intermediate inputs (small $1 - b_i$), so their positive demand shock have very limit effects on other sectors. “Chemical” sector serves as an important supplier to “Power” and “AFF” industry (This can be seen from the coefficient matrix in table 6). Their negative shock prorogated to “Chemical” industry and largely cancelled the external positive demand shock. Real output decrease in more sectors, 12 of 16 industries experienced real output drop, interconnections of industries propagated demand shock to more industries because if we ignore
such interconnections we should conclude that $\frac{dp_i}{p_i} = 1_{dS_i \geq 0} \frac{dS_i}{S_i} = 1_{d\theta_i \geq 0} \frac{d\theta_i}{\theta_i}$, so for those sectors with positive demand shocks, real output change should be 0 since $dY_i = \frac{dS_i}{S_i} - \frac{p_i}{p_i} = 0$; only those sectors with negative demand shock would experience real output drop. This helps us to understand the pervasive real output decline in most of sectors during the transitional periods.
Table 2.7: Coefficient matrix of 16 industries for FSU in 1989. Data source: GTAP Data Base.

<table>
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<tr>
<th></th>
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If I target the destination of expenditure restructuring with the pattern of whole FSU in 1997, the result may be more meaningful. Although the FSU didn’t exist in 1997, fortunately, GTAP database collect such data for all FSU republics in 1997. As table 7 shows that comparing to 1997, expenditures on food, agriculture, power, business service and public administration, defense, education and health sectors were suppressed in 1989. Fuel (Fuel), industry (Light), wood, paper and publishing (WPP), chemical, metal, machine building and metal working (MBMW), wholesale trade, transportation and communication, finance and recreational service industries were highly emphasized by government.
Table 2.8: Share of domestic final expenditure in each sector for FSU in 1989 and 1997. Source: GTAP Data Base.

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<td>WPP</td>
<td>0.019250908</td>
<td>0.004787</td>
<td>-0.0144635</td>
<td>0.626347</td>
<td>0.534735</td>
</tr>
<tr>
<td>Chemicals</td>
<td>0.030347792</td>
<td>0.029748</td>
<td>-0.0005999</td>
<td>0.835373</td>
<td>0.937333</td>
</tr>
<tr>
<td>Metal</td>
<td>0.002558076</td>
<td>0.000408</td>
<td>-0.0021503</td>
<td>0.711506</td>
<td>0.312007</td>
</tr>
<tr>
<td>MBMW</td>
<td>0.068726628</td>
<td>0.025072</td>
<td>-0.0436548</td>
<td>0.604547</td>
<td>0.69662</td>
</tr>
<tr>
<td>Power</td>
<td>0.035571479</td>
<td>0.162063</td>
<td>0.1264919</td>
<td>0.824499</td>
<td>0.799283</td>
</tr>
<tr>
<td>Construction</td>
<td>0.061983066</td>
<td>0.015184</td>
<td>-0.0467987</td>
<td>0.496609</td>
<td>0.155403</td>
</tr>
<tr>
<td>Trade</td>
<td>0.125152116</td>
<td>0.100792</td>
<td>-0.0243599</td>
<td>0.387674</td>
<td>0.576679</td>
</tr>
<tr>
<td>T&amp;C</td>
<td>0.095046276</td>
<td>0.056346</td>
<td>-0.0387001</td>
<td>0.392496</td>
<td>0.524787</td>
</tr>
<tr>
<td>Fin&amp;ins</td>
<td>0.065911478</td>
<td>0.004906</td>
<td>-0.0610051</td>
<td>0.197262</td>
<td>0.370301</td>
</tr>
<tr>
<td>Business</td>
<td>0.033237919</td>
<td>0.06296</td>
<td>0.0297223</td>
<td>0.307662</td>
<td>0.612513</td>
</tr>
<tr>
<td>RS</td>
<td>0.079939642</td>
<td>0.016858</td>
<td>-0.0630812</td>
<td>0.523554</td>
<td>0.249518</td>
</tr>
<tr>
<td>PDEH</td>
<td>0.192667917</td>
<td>0.233533</td>
<td>0.0408653</td>
<td>0.245884</td>
<td>0.08659</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>0.525371</td>
<td>0.525371</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If the whole economy restructured according to the pattern showed in 1997 immediately after the price liberalization, the total GDP decline would be 19.90% and the general price level would increase by 35.1%. If there is only 0th order effect, GDP downturn is 17.2%, which means that interconnection between sectors contributes 2.7% to the GDP downturn. The detailed industry restructuring of output and price level are listed in table 8. Nominal gross output for “Fuel” industry will increase mainly due to the huge positive demand shock happened in “Power” industry largely
propagated to it due to its importance to “Power” industry. Again, we can observe decline in real output in more sectors due to the interconnection between industries.

In reality, no such big output drop occurred in 1992 for FSU economy, because, as mentioned above, part of restructuring has been started in 1991 because of the partial price liberalization, so restructuring in 1992 was also partial. After combining the output drop in 1991 and 1992, the accumulative output drop until 1992 was about 22% comparing to the GDP level of 1989, which is higher than the model predicts. Actually, this model tend to overestimate the effect of the restructuring of final expenditure because not all price were freed in 1992, prices of those goods which were key inputs for other industries were still controlled, for example, price of fuel and some raw materials were still controlled at a very low level by Russian government. So those industries heavily relied on Fuel industry continued to benefit from the low price of key inputs, for example, “Chemical”, “Metal” and “Power” industries. As result there shouldn’t be such big output change if the price liberalization for some key industries were only partial. Furthermore, empirical evidence indeed suggested that other fixed production factors were sluggish, but it doesn’t means that there was no mobility, small amount of factor mobility will weaken the effects of restructure of final expenditure on output drop.
Table 2.9: Restructuring of each industry with demand shock.

<table>
<thead>
<tr>
<th>Industry</th>
<th>$d\theta_i$</th>
<th>$d\delta$</th>
<th>$\frac{d\delta}{\delta}$</th>
<th>$\frac{dy_i}{y_i}$</th>
<th>$\frac{dp_i}{p_i}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFF</td>
<td>0.101059</td>
<td>0.11991</td>
<td>1.130321</td>
<td>0.383746</td>
<td>0.746575</td>
</tr>
<tr>
<td>Fuel</td>
<td>-0.00141</td>
<td>0.078624</td>
<td>0.569747</td>
<td>0.11372</td>
<td>0.456027</td>
</tr>
<tr>
<td>Food</td>
<td>0.016167</td>
<td>0.025828</td>
<td>0.143197</td>
<td>-0.26304</td>
<td>0.406238</td>
</tr>
<tr>
<td>Light</td>
<td>-0.01809</td>
<td>-0.03181</td>
<td>-0.33783</td>
<td>-0.47871</td>
<td>0.140888</td>
</tr>
<tr>
<td>WPP</td>
<td>-0.01446</td>
<td>-0.02736</td>
<td>-0.37833</td>
<td>-0.51344</td>
<td>0.135111</td>
</tr>
<tr>
<td>Chemicals</td>
<td>-0.0006</td>
<td>0.034488</td>
<td>0.231335</td>
<td>-0.13371</td>
<td>0.365044</td>
</tr>
<tr>
<td>Metal</td>
<td>-0.00215</td>
<td>-0.00893</td>
<td>-0.34826</td>
<td>-0.59335</td>
<td>0.245086</td>
</tr>
<tr>
<td>MBMW</td>
<td>-0.04365</td>
<td>-0.0607</td>
<td>-0.38087</td>
<td>-0.49754</td>
<td>0.11667</td>
</tr>
<tr>
<td>Power</td>
<td>0.126492</td>
<td>0.182332</td>
<td>1.532415</td>
<td>0.867044</td>
<td>0.665371</td>
</tr>
<tr>
<td>Construction</td>
<td>-0.0468</td>
<td>-0.04612</td>
<td>-0.57007</td>
<td>-0.65542</td>
<td>0.08535</td>
</tr>
<tr>
<td>Trade</td>
<td>-0.02436</td>
<td>-0.03297</td>
<td>-0.1716</td>
<td>-0.25927</td>
<td>0.087667</td>
</tr>
<tr>
<td>T&amp;C</td>
<td>-0.0387</td>
<td>-0.04557</td>
<td>-0.27417</td>
<td>-0.34864</td>
<td>0.074468</td>
</tr>
<tr>
<td>Fin&amp;ins</td>
<td>-0.06101</td>
<td>-0.05881</td>
<td>-0.52663</td>
<td>-0.55526</td>
<td>0.028639</td>
</tr>
<tr>
<td>Business</td>
<td>0.029722</td>
<td>0.023388</td>
<td>0.207621</td>
<td>0.00096</td>
<td>0.206661</td>
</tr>
<tr>
<td>RS</td>
<td>-0.06308</td>
<td>-0.06822</td>
<td>-0.6084</td>
<td>-0.7186</td>
<td>0.110204</td>
</tr>
<tr>
<td>PDEH</td>
<td>0.040865</td>
<td>0.041044</td>
<td>0.200279</td>
<td>-0.00648</td>
<td>0.206755</td>
</tr>
</tbody>
</table>

$d\theta_i$ is the demand shock in sector $i$.

More importantly, if there were only one time of restructuring, this effect would ceased once restructuring was finished. Probably what really happened in FSU and other EE countries was that only partial restructuring continued during the transitional periods and it contributed to the economic downturn continues until the mobility of factors was no longer sluggish. This implies that some other reasons contributed as an important reason to such huge economic downturn during the transitional periods, such as the collapse of intra-republics trade or the disconnection of the supply chain between industries.
2.5 Conclusion and discussion

This model illustrates how the restructure of final expenditure brought by sudden price liberalization might bring down the output level. When the central planning system was aborted during the beginning years of transition, SOEs had more freedom to produce in their own favor, but they can not change all the production factors in such a short time when there was a huge uncertainty in future. Sudden price liberalization eliminated serious shortage created by central planning by increasing prices, however, production can not fully adjusted because of the mobility of labor force and other factors were sluggish. The interconnections between various production units propagated the demand shocks to other producers will produce pervasive real gross output drop in many industries. This effect might be long lasting if the restructuring were only partial and lasted long time and the mobility of production factors were sluggish in a long periods. Both situations happened in FSU republics after 1991, when bulk of privatization process has been launched in Russia at 1994, factors mobility would be more flexible, model predicts that the effect of restructuring would be weakened. Actually we can see that economic performance indeed improved since 1994 from table 1. Privatization helps factor mobility, especially for labor, only from supply side; private firms were able to fire those unneeded workers, this helps increase the labor supply to other sectors; however, reemployment of them also need the force from demand side. Unlike China and Poland, new entrance of private enterprises were very slow and rare in Russia (McMillan and Woodruff, 2002), demand for labors and other factors were small to restructure the production resources, this undoubtedly created long term high unemployment rate and serious economic recession.

During the transitional periods, so many complicated elements contributed to the large economic downturn in FSU and in other EE countries. It is impossible to provide a comprehensive explanations to this problem, this paper only focus on the interconnection of industries and slow adjustment of production process, it points out that slow adjustment of production to the change of final demand contributed to the output fall during the early years of economic transition. Interconnections between industries would propagates demand shock to the whole economy, this helps us to understand the pervasive real output drop in most of industries in the economic transition.
In a planned economy, production and final expenditure were distorted by central planner. The “big bang” approach reform excluded the role of central planner played in the final expenditure but didn’t exclude his/her role in the production. Adjustment of production was not so quick, under this circumstance, full price liberalization will only pushed up the price level and jeopardize people’s welfare; numerical methods also tells us that price level increase is not symmetric in each industry, prices increase more in some sectors and less in others, this is even less favourable than the situation that all prices increase equally because some sectors may experience large increase in real costs. China’s “gradualism” approach reform was better, central planner didn’t fully step out of the whole economy, compulsory plan on each state owned firm still existed during the beginning year of economic transition, price were controlled by government. Gradual stepping out of the central planner prevented huge restructure in final demand by price control and state order on production, at the same time production factors mobility were loosened by government; those prevented the economy from huge economic recession. Agricultural technology progress freed huge amount of labor force and also propagated to other sectors by lowering the price of raw materials in industrial departments largely contributed to the economic growth. Unfortunately, no such TFP growth were found in agricultural sectors in CIS countries and CEE countries, some empirical studies concluded that there was long term declines of TFP in those countries (Swinnen, Herck and Vranken, 2010, 2012).
2.6 References


Commander, S. and R. Yemtsov, “Characteristics of the Russian Unemployment.”, mimeo, Wash-


Jo Swinnen, Kristine Van Herck and Liesbet Vranken, “Agricultural productivity paths in Central and Eastern Europe and the Former Soviet Union: The role of reforms, initial conditions and in-


McKinsey Global Institute, “Unlocking Economic Growth in Russia.” (1999). Available at Mckin-
sey Research Report.


Wahl, Tom and Yu, Lan, “Global Trade Assistance and Protection: The GTAP 3 Data Base.”, *GTAP 3 Data Base Documentation, Chapter 16*, Center for Global Trade Analysis, Purdue University, 1998.

2.7 Appendix A: proofs of propositions

**Proof of proposition 1:** Since we have \( \bar{s} = \bar{\theta} + W \bar{s} \), then define a mapping \( T : \mathbb{R}^n \to \mathbb{R}^n \), that \( T \bar{s} = \bar{\theta} + W \bar{s} \). Here we claim that \( T \) is a contraction mapping in the norm linear space \((\mathbb{R}^n, \| \cdot \|_1)\).

The proof of the claim is straightforward, take \( S_1 \) and \( S_2 \) in \( \mathbb{R}^n \), where \( S_1 = (s^{(1)}_1, s^{(1)}_2, \ldots, s^{(1)}_n)' \), \( S_2 = (s^{(2)}_1, s^{(2)}_2, \ldots, s^{(2)}_n)' \). Clearly, \( TS_1 = \bar{\theta} + W S_1 \) and \( TS_2 = \bar{\theta} + W S_2 \). Since

\[
TS_1 - TS_2 = W(S_1 - S_2)
\]

\[
= 
\begin{pmatrix}
(1 - b_1)\phi_{11} & (1 - b_2)\phi_{12} & \cdots & (1 - b_n)\phi_{1n} \\
(1 - b_1)\phi_{12} & (1 - b_2)\phi_{22} & \cdots & (1 - b_n)\phi_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
(1 - b_1)\phi_{1n} & (1 - b_2)\phi_{2n} & \cdots & (1 - b_n)\phi_{nn}
\end{pmatrix}
\begin{pmatrix}
(s^1_1 - s^2_1) \\
(s^1_2 - s^2_2) \\
\vdots \\
(s^1_n - s^2_n)
\end{pmatrix}
\]

\[
= 
\begin{pmatrix}
\sum_{i=1}^n (1 - b_i)\phi_{i1}(s^1_i - s^2_i) \\
\sum_{i=1}^n (1 - b_i)\phi_{i2}(s^1_i - s^2_i) \\
\vdots \\
\sum_{i=1}^n (1 - b_i)\phi_{in}(s^1_i - s^2_i)
\end{pmatrix}
\]
Then,

\[
\|TS'_1 - TS'_2\|_1 = \sum_{j=1}^{n} \sum_{i=1}^{n} |(1 - b_i)\phi_{ij}(s_i^1 - s_i^2)| \\
\leq \sum_{j=1}^{n} \sum_{i=1}^{n} |(1 - b_i)\phi_{ij}|s_i^1 - s_i^2| \\
= \sum_{i=1}^{n} \sum_{j=1}^{n} |(1 - b_i)\phi_{ij}|s_i^1 - s_i^2| \\
= \sum_{i=1}^{n} (1 - b_i)|s_i^1 - s_i^2| \sum_{j=1}^{n} \phi_{ij} \\
= \sum_{i=1}^{n} (1 - b_i)|s_i^1 - s_i^2| (\text{since } \sum_{i=1}^{n} \phi_{ij} = 1 \text{ by assumption.}) \\
\leq \max_{1 \leq i \leq n} (1 - b_i) \sum_{i=1}^{n} |s_i^1 - s_i^2| \\
= \max_{1 \leq i \leq n} (1 - b_i)\|S_1 - S_2\|_1
\]

Since \((1 - b_i) < 1\), for \(\forall i = 1, 2, 3, \ldots, n\), it implies that \(\max_{1 \leq i \leq n} (1 - b_i) < 1\). So \(T\) is an contraction mapping in \(\mathbb{R}^n\). Then by contraction mapping theorem, there exists an unique fixed point \(\tilde{s}^*\) such that \(\tilde{s}^* = TS^* = \tilde{\theta} + W\tilde{s}^*\). So the solution for the equation \(\tilde{s} = \tilde{\theta} + W\tilde{s}\) is unique. That is, there is an unique solution for equation \((\mathbf{I} - \mathbf{W}) \tilde{s} = \tilde{\theta}\), for \(\forall \tilde{\theta} \in \mathbb{R}^n\), which implies the square matrix \((\mathbf{I} - \mathbf{W})\) is invertible, and \(\tilde{s}^* = (\mathbf{I} - \mathbf{W})^{-1} \tilde{\theta}\). Once the output vector \(\tilde{s}^* = (s_1^*, s_2^* \cdots s_n^*)\) is uniquely determined, from equation (8) we have \(b_is_i^* = qL_i\), that is \(\sum_{i=1}^{n} b_is_i^* = q \sum_{i=1}^{n} L_i = qL\). So the wage rate \(q = \frac{\sum_{i=1}^{n} b_is_i^*}{L} = \frac{1}{L}\) is also uniquely determined. Since \(L_i = \frac{b_is_i^*}{q} = \frac{b_is_i^*}{\sum_{i=1}^{n} b_is_i^*}L = b_is_i^*L\), clearly, employment in each sector \(L_i\) is also uniquely determined. We still need to verify that, the consumption vector \(\bar{C} = (C_1, C_2, \cdots, C_n)\), the production vector \(\bar{Y} = (Y_1, Y_2, \cdots, Y_n)\), the intermediate input vector \(\bar{X}_i = (X_{i1}, X_{i2}, \cdots, X_{in})\) for \(\forall i = 1, 2, 3 \cdots, n\); and the price vector \(\bar{P} = (p_1, p_2, \cdots, p_n)\) are uniquely determined.
By the production function in assumption 2: $Y_i = \lambda_i \exp[b_i \ln L_i + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln X_{ik}]$, we get:

$$\ln Y_i = \ln \lambda_i + b_i \ln L_i + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln X_{ik}$$

(Since $s_i = p_i Y_i$ and $s_i(1 - b_i)\phi_{ik} = p_k X_{ik}$)

$$\Rightarrow \ln s_i - \ln p_i = \ln \lambda_i + b_i \ln L_i + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}[\ln(s_i(1 - b_i)\phi_{ik}) - \ln p_k]$$

$$\Rightarrow \ln s_i - \ln p_i = \ln \lambda_i + b_i \ln L_i + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}[\ln(s_i(1 - b_i)\phi_{ik})] - \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln p_k$$

$$\Rightarrow \ln p_i = \ln s_i - \ln \lambda_i - b_i \ln L_i - (1 - b_i)\ln s_i - (1 - b_i)\ln(1 - b_i) - (1 - b_i)\sum_{k=1}^{n}\phi_{ik}\ln \phi_{ik} + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln p_k$$

$$\Rightarrow \ln p_i = -\ln \lambda_i - b_i \ln b_i - b_i \ln L - (1 - b_i)\ln(1 - b_i) - (1 - b_i)\sum_{k=1}^{n}\phi_{ik}\ln \phi_{ik} + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln p_k$$

(Since $L_i = b_i s_i L$, which implies: $\ln L_i = \ln b_i + \ln s_i + \ln L$)

$$\Rightarrow \ln p_i = b_i \ln s_i - \ln \lambda_i - b_i \ln b_i - b_i \ln L - (1 - b_i)\ln(1 - b_i) - (1 - b_i)\sum_{k=1}^{n}\phi_{ik}\ln \phi_{ik} + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln p_k$$

$$\Rightarrow \ln p_i = -\ln \lambda_i - b_i \ln b_i - b_i \ln L - (1 - b_i)\ln(1 - b_i) - (1 - b_i)\sum_{k=1}^{n}\phi_{ik}\ln \phi_{ik} + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln p_k$$

(1.a)

Denote $-\ln \lambda_i - b_i \ln b_i - b_i \ln L - (1 - b_i)\ln(1 - b_i) - (1 - b_i)\sum_{k=1}^{n}\phi_{ik}\ln \phi_{ik}$ as $\omega_i$, then we have $\ln p_i = \omega_i + \sum_{k=1}^{n}(1 - b_i)\phi_{ik}\ln p_k$. Here we can see that $\omega_i$ is irrelevant to preference parameter vector, namely, $\vec{\phi}$. Write this equation for all sectors, we get:

$$\begin{pmatrix}
\ln p_1 \\
\ln p_2 \\
\vdots \\
\ln p_n
\end{pmatrix} = \begin{pmatrix}
\omega_1 \\
\omega_2 \\
\vdots \\
\omega_n
\end{pmatrix} + \begin{pmatrix}
(1 - b_1)\phi_{11} & (1 - b_1)\phi_{12} & \cdots & (1 - b_1)\phi_{1n} \\
(1 - b_2)\phi_{21} & (1 - b_2)\phi_{22} & \cdots & (1 - b_2)\phi_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
(1 - b_n)\phi_{n1} & (1 - b_n)\phi_{n2} & \cdots & (1 - b_n)\phi_{nn}
\end{pmatrix} \begin{pmatrix}
\ln p_1 \\
\ln p_2 \\
\vdots \\
\ln p_n
\end{pmatrix}$$

(1.b)

We can write it as: $\vec{\ln p} = \vec{\omega} + W^T \vec{\ln p}$. The matrix $W$ is the same matrix defined before, $\vec{\omega} = \begin{pmatrix}
\omega_1 \\
\omega_2 \\
\vdots \\
\omega_n
\end{pmatrix}$.

Since the matrix $I - W$ is invertible as I showed before, so the matrix $I - W'$ is also invertible. Because
\[ \text{rank}(I - W') = \text{rank}((I - W)' = \text{rank}(I - W) = n, \text{which means matrix } I - W' \text{ is full rank, So it is invertible. It implies the equation } \ln \tilde{P} = \tilde{\Omega} + W' \ln \tilde{P} \text{ has unique solution: } \ln \tilde{P} = (I - W')^{-1} \tilde{\Omega}. \text{Again, since } \tilde{\Omega} \text{ doesn’t contain anything related to preference parameter, the equilibrium price is irrelevant to preference. Here, we verified that price vector is uniquely determined, so } \tilde{Y} = (Y_1, Y_2, \ldots, Y_n) \text{ is also uniquely determined because } s_i = p_i Y_i \text{ is uniquely determined as I showed before. By equations (6) and (7), we can see that } \tilde{C} = (C_1, C_2, \ldots, C_n) \text{ and } \tilde{X}_i = (X_{i1}, X_{i2}, \ldots, X_{in}) \text{ for } \forall i = 1, 2, 3 \ldots, n \text{ are uniquely determined.}

\textbf{Proof of corollary 1:} Suppose central planner has a different preference vector } \tilde{\theta} = (\tilde{\theta}_1, \tilde{\theta}_2, \ldots, \tilde{\theta}_n) \text{ and he/she maximizes utility under this preference parameter vector. By equation (9) we have:}

\[
\begin{pmatrix}
\tilde{s}_1 \\
\tilde{s}_2 \\
\vdots \\
\tilde{s}_n
\end{pmatrix} = \begin{pmatrix}
\tilde{\theta}_1 \\
\tilde{\theta}_2 \\
\vdots \\
\tilde{\theta}_n
\end{pmatrix} + \begin{pmatrix}
(1 - b_1)\phi_{11} & (1 - b_2)\phi_{21} & \cdots & (1 - b_n)\phi_{n1} \\
(1 - b_1)\phi_{12} & (1 - b_2)\phi_{22} & \cdots & (1 - b_n)\phi_{n2} \\
\vdots & \vdots & \ddots & \vdots \\
(1 - b_1)\phi_{1n} & (1 - b_2)\phi_{2n} & \cdots & (1 - b_n)\phi_{nn}
\end{pmatrix}
\begin{pmatrix}
\tilde{s}_1 \\
\tilde{s}_2 \\
\vdots \\
\tilde{s}_n
\end{pmatrix}.
\]

That is } \tilde{S} = \tilde{\theta} + WS, \text{ as we showed in proposition 1, this equation has unique solution for } \tilde{S} = (I - W)^{-1} \tilde{\theta}, \text{ and the matrix } (I - W) \text{ is full rank. So for } \tilde{\theta} \neq \tilde{\theta}, \text{ we have } \tilde{S} \neq \tilde{S}. \text{ Again, as showed in proposition 1, the shadow price vector is irrelevant to preference. So shadow price vector is the same under the maximization problem of different preference parameters } \tilde{\theta} \text{ and } \tilde{\theta}. \text{ So the production plan } (Y_1, Y_2, \ldots, Y_n) \text{ is different since } Y_i = \frac{s_i}{p_i} \neq \frac{s_i}{\tilde{p}_i} = \tilde{Y}_i. \text{ And hence } (X_{i1}, X_{i2}, \ldots, X_{in}) \text{ for } \forall i = 1, 2, 3 \ldots, n \text{ and } \tilde{C} = (C_1, C_2, \ldots, C_n) \text{ are different.}

\textbf{Proof of proposition 2:} Firstly, we are going to prove that } (p_1, p_2, \ldots, p_n) \text{ and } q \text{ can maximize each firm’s profit if the production is controlled at the quantity we derived in proposition 1. Given the condition that all prices are controlled by government, all firms are price taker, so for firm } i, \text{ the
maximization problem solves:

\[
\max \pi_i = p_i Y_i - \sum_{k=1}^{n} p_k X_{ik} - qL_i \\
= p_i \lambda_i \exp \left[ b_i L_i + \sum_{k=1}^{n} (1 - b_i) \phi_{ik} \ln X_{ik} \right] - \sum_{k=1}^{n} p_k X_{ik} - qL_i
\]

First order conditions satisfy:

\[
\frac{\partial \pi_i}{\partial X_{ik}} = p_i Y_i \frac{(1 - b_i) \phi_{ik}}{X_{ik}} - p_k = 0 \text{ for } k = 1, 2, \cdots, n. \tag{2.a}
\]

\[
\frac{\partial \pi_i}{\partial L_i} = p_i Y_i \frac{b_i}{L_i} - q = 0. \tag{2.b}
\]

equations (2.a) and (2.b) are equivalent to equation (7) and (8), which means that given the production plan \(Y_i\) and \(X_{ik}\) controlled by government the shadow prices satisfy the firm \(i\)'s first order condition of profit maximization.

We have argued that the market demand derived from representative agent’s utility for final products—\((C^d_1, C^d_2, \cdots, C^d_n)\) are different from the goods supplied by each firm, we need to check that consumers’ still will buy all the products provided by government under the shadow price vector \((p_1, p_2, \cdots, p_n)\) and \(q\). But there is a huge social welfare costs, since representative agents can not achieve their maximum level of utility, alternatively they have to chose the second best.

An representative agent solve his/her problem as:

\[
\max_{\mathcal{C}_i} : U_r = \sum_{i=1}^{n} \hat{\theta}_i \ln C_i, \tag{2.c}
\]

subject to:

\[
\sum_{i=1}^{n} p_i C_i \leq qL = 1. \text{ (from equation (10) } qL = 1.) \tag{2.d}
\]

\[
C_i \leq \bar{C}_i = \frac{\theta_i}{p_i}, \text{ for } \forall i \in \{1, 2, 3, \cdots, n\}. \tag{2.e}
\]
Here, we use Lagrangian method, we can rewrite this problem as:

$$\min_{c_i} : -U_r = -\sum_{i=1}^n \hat{\theta}_i \ln C_i.$$  \hspace{1cm} (2.f)

subject to: $$\sum_{i=1}^n p_i C_i - 1 \leq 0.$$ (from equation (10) qL = 1.) \hspace{1cm} (2.g)

$$C_i - \frac{\theta_i}{p_i} \leq 0, \text{ for } \forall i \in \{1, 2, 3, \ldots, n\}. \hspace{1cm} (2.h)$$

Budget constraints (2.h) implies (2.g), if (2.h) holds, (2.g) holds automatically. So this problem is equivalent to:

$$\min_{\{C_i \text{ for } \forall i=1,2,\ldots,n\}} \max_{\{\lambda_i \text{ for } \forall i=1,2,\ldots,n\}} : -\sum_{i=1}^n \hat{\theta}_i \ln C_i + \sum_{i=1}^n \lambda_i (C_i - \frac{\theta_i qL}{p_i})$$ \hspace{1cm} (2.i)

The first order condition yields:

$$\frac{\partial}{\partial C_i} : -\frac{\hat{\theta}_i}{C_i} + \lambda_i = 0, \text{ for } \forall i = 1, 2, \ldots, n. \hspace{1cm} (2.j)$$

$$\frac{\partial}{\partial \lambda_i} : \begin{cases} C_i - \frac{\theta_i}{p_i} = 0 & \text{if } \lambda_i > 0 \\ C_i - \frac{\theta_i}{p_i} < 0 & \text{if } \lambda_i = 0 \end{cases} \text{ for } \forall i = 1, 2, \ldots, n. \hspace{1cm} (2.k)$$

There may have three cases for the solution of this problem: all $\lambda_i > 0$, all $\lambda_i = 0$ and some $\lambda_i > 0$ others equal to 0. Let’s consider those situations one by one:

Case 1: $\lambda_i > 0$ for $\forall i = 1, 2, \ldots, n$. In this case, $C_i = \frac{\theta_i}{p_i}$ for $\forall i = 1, 2, \ldots, n$ and $\sum_{i=1}^n p_i C_i = 1$. Which implies $\lambda_i = \frac{\hat{\theta}_i}{C_i} = \frac{p_i \hat{\theta}_i}{\theta_i} > 0$. So this solution is logically consistent, it may be a potential solution for this problem.

Case 2: $\lambda_i = 0$ for $\forall i = 1, 2, \ldots, n$. In this case, equation (2.j) implies that $\frac{\hat{\theta}_i}{C_i} = 0$ for $\forall i = 1, 2, \ldots, n$. It means that $C_i \to \infty$ for $\forall i = 1, 2, \ldots, n$. This will never happen because the upper bound of $C_i$ is $\frac{\theta_i}{p_i}$ by equation (2.k). So we get a contradiction in this case.

Case 3: $\lambda_i = 0$ for some $i \in \{1, 2, \ldots, n\}$ and $\lambda_i > 0$ for others. For those $\lambda_i > 0$, we get $\lambda_i = \frac{p_i \hat{\theta}_i}{\theta_i} > 0$; but for those $\lambda_i = 0$, we have $\frac{\hat{\theta}_i}{C_i} = 0$, this is the same as case 2 which contradicts to condition (2.k).
So only case 1 is consistent with all the conditions, which implies the solution for the consumer’s maximization is \( C_i = \frac{\theta_i}{p_i} \) for \( \forall i = 1, 2, \cdots, n \). This means that consumer will buy all products provided by government under the shadow prices which are regulated by government.

**Proof of proposition 3:** Firm/sector \( i \)'s profit maximization condition is given by equation (2.b) no matter what the market price of good \( i \) is, here we assume that it is \( \hat{p}_i \). So we get \( \hat{p}_i \hat{Y}_i b_i = q \hat{L}_i \), therefore \( \hat{s}_i b_i = q \hat{L}_i \). Since \( q \) is set as \( \frac{1}{T} \), we get \( \hat{s}_i b_i = \frac{\hat{L}_i}{T} \). This implies \( ds_i = \frac{dL_i}{\pi T} \), where \( ds_i = \hat{s}_i - s_i \) and \( dL_i = \hat{L}_i - L_i \). As assumed, \( dL_i \) can never be greater than 0, so we get \( dL_i = 0 \iff ds_i \geq 0 \); and \( dL_i < 0 \iff ds_i < 0 \).

**Proof of proposition 4:** By proposition 3, \( ds_i < 0 \implies dL_i < 0 \), since \( b_i s_i = q L_i \) from equation (8), we get \( \frac{ds_i}{s_i} = \frac{dL_i}{L_i} \); and \( ds_i \geq 0 \implies dL_i = 0 \). In proposition (1.a) I’ve already derived that:

\[
lnp_i = b_i ln s_i - ln \lambda_i - b_i ln L_i - (1 - b_i) ln(1 - b_i) - (1 - b_i) \sum_{k=1}^{n} \phi_{ik} ln p_k + \sum_{k=1}^{n} (1 - b_i) \phi_{ik} ln p_k.
\]

Differentiate it on both sides yield:

\[
\frac{dp_i}{p_i} = b_i \frac{ds_i}{s_i} - b_i \frac{dL_i}{L_i} + \sum_{k=1}^{n} (1 - b_i) \phi_{ik} \frac{dp_k}{p_k}
\]

for those \( ds_i \geq 0 \), we have \( b_i \frac{ds_i}{s_i} - b_i \frac{dL_i}{L_i} = b_i \frac{ds_i}{s_i} \); for those \( ds_i < 0 \), we have \( b_i \frac{ds_i}{s_i} - b_i \frac{dL_i}{L_i} = 0 \). So we can write \( b_i \frac{ds_i}{s_i} - b_i \frac{dL_i}{L_i} = 1_{[ds_i \geq 0]} b_i \frac{ds_i}{s_i} \), where \( 1_{[ds_i \geq 0]} \) is an indicator function. Therefore, we can get:

\[
\frac{dp_i}{p_i} = 1_{[ds_i \geq 0]} b_i \frac{ds_i}{s_i} + \sum_{k=1}^{n} (1 - b_i) \phi_{ik} \frac{dp_k}{p_k}
\]

Write it as matrix form we get:

\[
\begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix} = \begin{pmatrix}
1_{[ds_1 \geq 0]} b_1 \frac{ds_1}{s_1} \\
1_{[ds_2 \geq 0]} b_2 \frac{ds_2}{s_2} \\
\vdots \\
1_{[ds_n \geq 0]} b_n \frac{ds_n}{s_n}
\end{pmatrix} + \begin{pmatrix}
(1 - b_1) \phi_{11} & (1 - b_1) \phi_{12} & \cdots & (1 - b_1) \phi_{1n} \\
(1 - b_2) \phi_{21} & (1 - b_2) \phi_{22} & \cdots & (1 - b_2) \phi_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
(1 - b_n) \phi_{n1} & (1 - b_n) \phi_{n2} & \cdots & (1 - b_n) \phi_{nn}
\end{pmatrix} \begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix}
\]

(4.b)
Finally, we can get 1
\[ (I - W')^{-1} = \begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix}
= \begin{pmatrix}
1_{|ds_1| \geq 0}b_1 d_{s_1} \\
1_{|ds_2| \geq 0}b_2 d_{s_2} \\
\vdots \\
1_{|ds_n| \geq 0}b_n d_{s_n}
\end{pmatrix}
\]

**Claim 1:** All the eigenvalues of matrix \( W \) is inside the unit circle in the complex plane, i.e \( |\eta| < 1 \), for any eigenvalue \( \eta \).

**Proof.** Suppose vector \( \nu \in \mathbb{C}^n \) is the respective eigenvector of eigenvalue \( \eta \), \( \nu = (\nu_1, \nu_2, \cdots, \nu_n)' \).

Since \( \mathbb{C}^n \) is a finite dimensional space, all norms are equivalent, without of loss of generality, in the proof, I adopt \( \| \cdot \|_1 \). Since \( W\nu = \eta \nu \), we have \( \| W\nu \|_1 = |\eta| \|\nu\|_1 \), which implies \( \| W\nu \|_1 = |\eta| \|\nu\|_1 \).

So \( |\eta| = \frac{\| W\nu \|_1}{\|\nu\|_1} = \frac{\sum_{i=1}^n |\sum_{j=1}^n (1-b_i)\phi_{ij}| \|\nu\|_1}{\|\nu\|_1} \leq \frac{\sum_{i=1}^n \sum_{j=1}^n |(1-b_i)\phi_{ij}| \|\nu\|_1}{\|\nu\|_1} = \frac{\sum_{i=1}^n |(1-b_i)| |\nu_i|}{\|\nu\|_1} \leq \frac{\max_{1 \leq i \leq n} |1-b_i| \sum_{i=1}^n |\nu_i|}{\|\nu\|_1} \). Because \( (1-b_i) < 1 \) for \( \forall i = 1, 2, \cdots, n \), \( \max_{1 \leq i \leq n} |1-b_i| < 1 \). Hence, \( |\eta| < \frac{\sum_{i=1}^n |\nu_i|}{\|\nu\|_1} = 1 \). \( \square \)

**Claim 2:** There is at least 1 component of vector \( ds \) is strictly greater than 0.

**Proof.** Remember that from equation (11) and (12), we have \( d^2\hat{s} = (I - W)^{-1}d\hat{\theta} \). Since matrix \( I - W \) has full rank and \( d\hat{\theta} \neq 0 \), therefore \( d\hat{s} \neq 0 \). Now we can suppose that all components of vector \( d\hat{s} \) is no greater than 0, i.e \( ds_i \leq 0 \) for \( \forall i = 1, 2, \cdots, n \). Hence, \( 1'd\hat{\theta} = 1'(I - W)d\hat{s} = 1'd\hat{s} - 1'Wd\hat{s} \).

Since \( 1'W = (1-b_1, 1-b_2, \cdots, 1-b_n) \), so \( 1'Wd\hat{s} = (1-b_1)ds_1 + (1-b_2)ds_2 + \cdots + (1-b_n)ds_n \). Finally, we can get \( 1'd\hat{\theta} = \sum_{i=1}^n ds_i - \sum_{i=1}^n (1-b_i)ds_i = \sum_{i=1}^n b_i ds_i \). As we supposed, if \( ds_i \leq 0 \) for \( \forall i = 1, 2, \cdots, n \), \( 1'd\hat{\theta} \leq 0 \), the equality holds only when \( ds_i = 0 \) for \( \forall i = 1, 2, \cdots, n \), which is \( d\hat{s} = 0 \), this is impossible as I showed above. So we get \( 1'd\hat{\theta} < 0 \), which contradicts the fact that \( 1'd\hat{\theta} = 0 \). So there is at least 1 component of vector \( ds \) is strictly greater than 0. \( \square \)

With the fact that \( W \) and \( W' \) have the same eigenvalues, therefore all the eigenvalues of matrix \( W' \) are inside the unit circle in the complex plane. So \( (I - W')^{-1} \) can be expanded as \( \sum_{i=1}^n (W')^i \). So
equation (4.c) can be written as:

$$\left(\begin{array}{c}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{array}\right) = \left(\begin{array}{c}
1_{[ds_1>0]}b_1 \frac{ds_1}{x_1} \\
1_{[ds_2>0]}b_2 \frac{ds_2}{x_2} \\
\vdots \\
1_{[ds_n>0]}b_n \frac{ds_n}{x_n}
\end{array}\right) \left(\begin{array}{c}
dL_1 \\
dL_2 \\
\vdots \\
dL_n
\end{array}\right)$$

(4.d)

In equation (4.d) we can see that \((W^i)^j > 0\) for \(\forall i \in \mathbb{N}\) because \(W^i > 0\); also vector

$$\left(\begin{array}{c}
1_{[ds_1>0]}b_1 \frac{ds_1}{x_1} \\
1_{[ds_2>0]}b_2 \frac{ds_2}{x_2} \\
\vdots \\
1_{[ds_n>0]}b_n \frac{ds_n}{x_n}
\end{array}\right) \geq 0$$

and as least there is one component which is strictly greater than 0 as claim 2 proved. So we can conclude that vector

$$\left(\begin{array}{c}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{array}\right) > 0,$$

which means that \(\frac{dp_i}{p_i} > 0\), for \(\forall i = 1, 2, \cdots, n\). Also it directly yields the conclusion that the change of price index \(\frac{dp_i}{p_i} > 0\).

**Proof of proposition 5:** By equation (10) \(\text{GDP} = qL = q \sum_{i=1}^{n} L_i\), \(\text{dGDP} = q \sum_{i=1}^{n} dL_i\). By proposition 3, \(dL_i = 1_{[dS_i<0]}dL_i\). Equation (8) gives that when \(dS_i < 0\), \(dL_i = \frac{ds_i}{x_i} L_i\). Hence, \(dL_i = 1_{[dS_i<0]} \frac{ds_i}{x_i} L_i\). So \(\text{dGDP} = q \sum_{i=1}^{n} \frac{ds_i}{x_i} L_i\). Also by equation (8) \(b_i s_i = q_i L_i\), then \(\text{dGDP} = \sum_{i=1}^{n} 1_{[dS_i<0]} \frac{ds_i}{x_i} b_i s_i = \sum_{i=1}^{n} 1_{[dS_i<0]} b_i dS_i\). \(\Delta \text{GDP} = \frac{\text{dGDP}}{\text{GDP}} = \frac{d\text{GDP}}{\text{GDP}} = \sum_{i=1}^{n} 1_{[dS_i<0]} b_i dS_i\).

It is proved by this way, we need to check that whether it is true by another accounting method.

\(\text{GDP} = \sum_{i=1}^{n} p_i C_i = 1\) before the demand shock, and \(p_i C_i = \theta_i\) by equation (6). After the demand shock, \(\hat{p}_i \hat{C}_i = \hat{\theta}_i\), to calculate the real output change, we need to use the same price to calculate the value of each good. So the real GDP after the price liberalization, \(\text{dGDP} = \sum_{i=1}^{n} p_i dC_i\). \(p_i C_i = \theta_i \Rightarrow \frac{dp_i}{p_i} + \frac{dC_i}{C_i} = \frac{dp_i}{p_i}\), So \(\text{dGDP} = \sum_{i=1}^{n} p_i \left(\frac{dp_i}{p_i} - \frac{dp_i}{p_i}\right) C_i = \sum_{i=1}^{n} \theta_i \left(\frac{dp_i}{p_i} - \frac{dp_i}{p_i}\right) = \sum_{i=1}^{n} d\theta_i - \sum_{i=1}^{n} \frac{dp_i}{p_i} \theta_i\).
By equation (9), \( \vec{\theta} = (I - W) \vec{s} \), and by equation (4.c),
\[
\begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix}
= (I - W^T)^{-1}
\begin{pmatrix}
1_{[d_{s1} \geq 0]} b_1 \frac{ds_1}{s_1} \\
1_{[d_{s2} \geq 0]} b_2 \frac{ds_2}{s_2} \\
\vdots \\
1_{[d_{sn} \geq 0]} b_n \frac{ds_n}{s_n}
\end{pmatrix},
\]
we have
\[
dGDP = \sum_{i=1}^{n} d\theta_i - \sum_{i=1}^{n} \frac{dp_i}{p_i} \theta_i = -\vec{\theta}^T \begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix} = \sum_{i=1}^{n} d\theta_i - \vec{s}^T (I - W^T)^{-1} \begin{pmatrix}
1_{[d_{s1} \geq 0]} b_1 \frac{ds_1}{s_1} \\
1_{[d_{s2} \geq 0]} b_2 \frac{ds_2}{s_2} \\
\vdots \\
1_{[d_{sn} \geq 0]} b_n \frac{ds_n}{s_n}
\end{pmatrix} = \sum_{i=1}^{n} d\theta_i - s^T \vec{\theta} (I - W^T)^{-1} (I - W)^T \begin{pmatrix}
1_{[d_{s1} \geq 0]} b_1 \frac{ds_1}{s_1} \\
1_{[d_{s2} \geq 0]} b_2 \frac{ds_2}{s_2} \\
\vdots \\
1_{[d_{sn} \geq 0]} b_n \frac{ds_n}{s_n}
\end{pmatrix} = \sum_{i=1}^{n} d\theta_i - s^T (I - W)^T (I - W)^{-1} \begin{pmatrix}
1_{[d_{s1} \geq 0]} b_1 \frac{ds_1}{s_1} \\
1_{[d_{s2} \geq 0]} b_2 \frac{ds_2}{s_2} \\
\vdots \\
1_{[d_{sn} \geq 0]} b_n \frac{ds_n}{s_n}
\end{pmatrix} = \sum_{i=1}^{n} d\theta_i - s^T \vec{\theta} (I - W)^T (I - W)^{-1} (I - W)^T \begin{pmatrix}
1_{[d_{s1} \geq 0]} b_1 \frac{ds_1}{s_1} \\
1_{[d_{s2} \geq 0]} b_2 \frac{ds_2}{s_2} \\
\vdots \\
1_{[d_{sn} \geq 0]} b_n \frac{ds_n}{s_n}
\end{pmatrix}
\]
As we expected, the two accounting methods yield the same result.

**Proof of proposition 6:** If labor can fully move between sectors, simply there will be no idle workers in any sector, \( GDP = qL = 1 \), which is the same as that before price liberalization.

By another accounting method, as proposition 5 shows that \( dGDP = \sum_{i=1}^{n} p_i (\frac{dp_i}{p_i} - \frac{dp_i}{p_i}) C_i = \sum_{i=1}^{n} \phi_i (\frac{dp_i}{p_i} - \frac{dp_i}{p_i}) = \sum_{i=1}^{n} d\theta_i - \sum_{i=1}^{n} \frac{dp_i}{p_i} \theta_i \). As assumed in assumption \( \sum_{i=1}^{n} d\theta_i = 0 \), and equation (8) implies that \( \frac{dp_i}{p_i} = \frac{dL}{L} \), then equation (4.a) becomes \( \frac{dp_i}{p_i} = 0 + \sum_{k=1}^{n} (1 - b_i) \phi_{ik} \frac{dp_k}{p_k} \). By matrix notation, we have
\[
(I - W') \begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix} = \vec{0}.
\]
Because matrix \( (I - W') \) is invertible, hence \( (I - W') \) is also invertible. The above system equation only has solution \( \begin{pmatrix}
\frac{dp_1}{p_1} \\
\frac{dp_2}{p_2} \\
\vdots \\
\frac{dp_n}{p_n}
\end{pmatrix}' = 0 \). Which immediately can yield the conclusion that \( dGDP = \sum_{i=1}^{n} d\theta_i - \sum_{i=1}^{n} \frac{dp_i}{p_i} \theta_i = 0 \).