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A Study on Intersectoral Migration of Agricultural Labor and Inflation in the Developing Countries

by

Jingbei Hu

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Stanford University
John A. and Cynthia Fry Gunn Building, 366
Galvez Street

Stanford, CA 94305-6015

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Abstract

This paper investigates a chain through which migration of labor between agricultural and nonagricultural sectors will have effects on inflation measured by changes in general level of prices or in Consumer Price Index (CPI). It first elaborates that equilibrium migration of labor in a period, characteristic of stability of the relative price between products of both the sectors in the same period, may exist along with capital accumulation. A hypothesis that there is a nonagricultural bias of investments in contemporary developing countries is put forward to explain a source of disequilibrium of labor migration with relative price fluctuations. Then the mechanisms of transmitting fluctuations in relative price to the price level and to CPI are described. It demonstrates that relative price matters with economy-wide inflations if monetary expansions have to be implemented to alleviate slowdowns of the economy resulting from increases in relative price. An empirical link between labor migration and food relative price within CPI will be found through tests with data from China.

Keywords: Intersectoral migration of agricultural labor, Equilibrium of labor migration, Nonagricultural bias of investments, Relative price fluctuations, CPI-inflation, Chinese economy,

JEL Classification No.: E32, O11, O41

* Chinese-German School for Graduate Studies of Tongji University, Shanghai, China and visiting scholar at the Stanford Center for International Development of Stanford University (SCID), Stanford, CA, United States. Email: jingbeihu@yahoo.com, website: www.hujingbei.net.

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1. Introduction

In many developing countries the Consumer Price Index (CPI) functions as the key indicator of inflation for the public and policy maker. Usually, statistics of price indexes of several subgroups of goods in the CPI-Basket will be published with that of CPI together. We depict from China, the largest developing country, data on growth rates of both CPI and food price in Table 1.1 and find there are remarkable differences between both the indexes in most of the years from 2001 to 2010. The differences relative to CPI in the fourth column exceeded the benchmark of 1 in 6 of 10 years. In consideration of much higher Engel's coefficients in the developing countries than developed ones, the large differences between growth rates of food price and CPI suggest that the former must have apparent effects on the latter in the developing countries.

Table 1.1 Growth Rates of FPI and CPI in China, 2001-2010

%

Year	FPI	CPI	FPI-CPI	(FPI-CPI)/CPI
2001	0.0	0.7	-0.7	-98.0
2002	-0.6	-0.8	0.2	-20.7
2003	3.4	1.2	2.3	193.7
2004	9.9	3.9	6.0	154.5
2005	2.9	1.8	1.1	60.8
2006	2.3	1.5	0.9	59.9
2007	12.3	4.8	7.6	158.6
2008	14.3	5.9	8.5	144.4
2009	0.7	-0.7	1.4	-207.7
2010	7.2	3.3	3.9	118.2

Note: FPI: food price index. Growth rate of CPI is not equal to zero.

Source: China Statistical Yearbook (CSY) 2011, Table 9-6.

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An economic conception to grasp the difference of (FPI-CPI) is the relative price of food while nonfood is regarded as the numeraire goods. We estimate growth rates of China's nonfood price (NFP) and food relative price (FRP) from 2001 to 2010 in the Table 1.2 and design two scenarios to see effects of each of NFP and FRP on CPI. Scenario I shows there would still have been CPI fluctuations with deflation (-0.2% of CPI growth rate in 2002) and inflations (4.5% and 5.4% of CPI growth rate in 2007 and 2008) even when NFP had taken zero-value during the whole decade concerned. In contrast, zero-value of FRP would have eliminated fluctuations in CPI substantially since growth rate of CPI would then have moved only in a very narrow range between -1.5% and 1.2%. Both scenarios imply that the CPI inflations may result mainly from changes in FRP in China. Monetary factors which could be represented by changes in NFP might play only a secondary role in China during the period from 2001 to 2010.

Table 1.2 Estimations of Growth Rates of Nonfood Price and
Food Relative Price and their Effects in China, 2001-2010

%

Year	FPI	CPI	NFP	FRP	Scenario I		Scenario II	
					NFP	CPI	FRP	CPI
2001	0.0	0.7	1.17	-1.14	0.00	0.01	0.00	1.17
2002	-0.6	-0.8	-0.84	0.25	0.00	-0.22	0.00	-0.84
2003	3.4	1.2	-0.17	3.61	0.00	1.27	0.00	-0.17
2004	9.9	3.9	0.25	9.60	0.00	3.72	0.00	0.25
2005	2.9	1.8	1.17	1.72	0.00	1.07	0.00	1.17
2006	2.3	1.5	0.98	1.36	0.00	0.84	0.00	0.98
2007	12.3	4.8	0.46	11.83	0.00	4.48	0.00	0.46
2008	14.3	5.9	0.70	13.54	0.00	5.43	0.00	0.70
2009	0.7	-0.7	-1.52	2.31	0.00	0.27	0.00	-1.52
2010	7.2	3.3	1.13	6.00	0.00	2.57	0.00	1.13

Note: Engel’s coefficients of the urban households are regarded as weights of food expenditure in China. Explanations are in section 7 and Appendix II.

Sources: As to Table 1.1 and CSY 2011, Table 10-2.

The present paper will address agricultural and food relative price in combination with CPI inflation and put forward an argument that labor migration between agriculture and nonagriculture may be one of the main economic forces leading both relative prices to change.

Labor migration from traditional agriculture to modern or capitalist nonagriculture is a striking characteristic of economic growth in the developing countries. Its long-run growth effects are well known at least after Lewis' seminal paper (1954). The aim of the present paper is to explore its short-run effects on inflation in the economies with mass migration of labor. Short-run fluctuations of economic activities are also important phenomena in these economies. They intertwine with inflations together. In fact, almost all major economic fluctuations take place with extraordinarily strong inflations. It is because economic growth is restricted with supply bottlenecks of resources such as labor and capital in the short run. But as long as the limitation of resources has not been transferred into unusually strong increases in their prices, it is not recognizable. What finally limits growth and forces it to slowdown or shift to a recession is a big and unexpected spike in price. Therefore, there must be some mechanisms transmitting changes in migration of agriculture labor to that of the price level if labor migration would have any short-run relevance with economic fluctuations. One of the mechanisms may be imagined through the following chain of thoughts:

A) Labor migration is closely linked with the relative price between products of both agriculture and nonagriculture.

B) Changes in relative prices which are caused by disequilibrium of migration may lead to an economy-wide inflation.[1]

[1] A common sense of economics is that changes in relative prices do not affect the general level of prices because changes in some relative prices in a direction should be offset by that in other relative prices in the opposite direction, see e.g. Friedman (1975). However, Ball and Mankiw (1995) points out that adjustments of relative prices to great shocks may cause price level changes when firms adjust their individual prices costly. This "menu costs" explanations will be followed by Lach and Tsiddon (1996), Buckle and Carlson (2000). On the other side, that inflation may bring about relative price changes captures more attention of economists. For example, Hayek (1931, 1933) points out that too much money injected into the circulation can distort relative prices and lead economic agents to make wrong decisions. At the same period of time, Mills (1927) and Graham (1930) find through their statistical analysis that variations between selected relative prices will extend with increasing inflation. Recent studies of effects of inflation on relative prices are Okun (1971), Vining and Elwertowski (1976), Driffill, Mizon and Ulph (1990), Reinsdorf (1994), Kashyap (1995), Fielding and Mizen (2000). The present paper tries to explain that rises in agricultural relative prices will lead to economy-wide inflations through forcing the monetary authority to expand money supply in order to avoid or delay

C) Inflation is combined with economic fluctuations.

This paper will follow this chain of thoughts to inquiry into relationships between migration and inflation. In what follows, Point A will be investigated first and the functional relations between migration and relative price be confirmed more strictly than in the literature so far. Then Point B will be elaborated detailedly because it is the key link of the chain combining migration and inflation, while Point C is a common sense in economics and will not be dealt with explicitly in this paper. Finally, data from China will be used to check if the links of migration and relative price exist empirically. Our findings are (1) Equilibrium of each of both migration and relative price depends on that of the other. Disequilibrium of labor migration between agriculture and nonagriculture will cause changes in relative price of agricultural products; (2) That investments are often allocated too much in nonagriculture will lead too much labor to migrate out of agriculture. As a result, relative price will rise. (3) Rises in relative price will force nonagricultural price and nonfood price to fall if monetary expansions are absent. (4) Monetary expansions which are used to ease pressure of falling prices on nonagricultural and nonfood industries will lead to an economy-wide inflation. Tests with data from China show an empirical link between labor migration and food relative price may exist in some developing countries.

2. Migration and Relative Price.

Let L represent labor and l nonagricultural labor share while superscripts A and N stand for agriculture and nonagriculture, respectively, we have[2]

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slowdowns caused by the relative price rises. In some sense, it can be seen as an attempt to explain why the monetary expansions occur in an economy with massive labor migration.

[2] Usually, agricultural labor share, l^A, is used in the literature on migration of agricultural labor. Hu (2009) proved that its difference in absolute value is migration rate as defined by (2.2) in this paper. But the usage of absolute value makes mathematical proofs and explanatory descriptions inconvenient. We shift to l, nonagricultural labor share, in this paper. Because of $l=1-l^A$ if the economy in question is divided only between the two sectors and no unemployment exists, all theoretical and empirical studies about l^A are easy and consistent to be transferred into that about l.

$$(2.1)\quad l_t = \frac{L^N_t}{L_t},\ l_t^A = \frac{L^A_t}{L_t} = 1 - l_t$$

at the time point t, $l \in (0, 1)$. Migration of agricultural labor into nonagriculture can be expressed by a rise of l. We assume that migrations or rises of l occurs in a period of time whose beginning and ending points can be well defined and whose length of time is limited. Let $\mathbf{t}$ denote the set of time points within the whole period of labor migration including the two extremes. $\mathbf{t}=(1, 2, \ldots, t, \ldots, N)$ is an ordered and limited set of real numbers. Each element $t \in \mathbf{t}$ is clearly definable and N is a big enough but finite number. The increasing order of numbers in $\mathbf{t}$ is the successive time order of labor migration at the same time. We denote rate of labor migration out of agriculture with h as follows:

$$(2.2)\quad h_{t,t+1} \equiv l_{t+1} - l_t = \Delta l_{t,t+1}$$

in the discrete time case, $t, t+1 \in \mathbf{t}$, and

$$(2.3)\quad h_t \equiv \lim_{\Delta t \to 0} \frac{l(t+\Delta t) - l(t)}{\Delta t} = \frac{dl}{dt}$$

in the continuous time case, $t \in \mathbf{t}$. Apparently, h is the velocity of rise in l. We will use (2.2) to investigate the relationships between migration and inflation. It means that we shall use the comparative static method in our investigations. One of its advantages is that the short-run transmitting mechanisms from migration to inflation may be elaborated more clearly and intuitively with this method. At the same time, the comparative static researches are useful in thinking on and dealing with the topic dynamically according to the correspondence principle (Samuelson, 1941; Gandolfo, 1997: 314-318).

With the comparative static method an economy on two different points of time will be compared. While two different points of time specify a period of time during which the economy changes, they must pose a question of unlimited dividedness of time within the period. Hence conceptions about units of time should be defined unambiguously. We distinguish between two short-run concepts of time as point and phase. $t \in \mathbf{t}$ is a point of time with its neighboring fields at which the total amount of capital and its sectoral allocation do not vary and total labor is constant, but labor can be reallocated. $(t, t+1) \in \mathbf{t}$ is a phase between two neighboring time points $t \in \mathbf{t}$ and t+1$\in$**t** inclusive in which total amounts of both capital and labor can change one and only one time while both of them may be reallocated between the sectors many times. Accordingly, intersectoral migration of labor takes place only in the phase (t, t+1)$\in$**t**, but not at the point of time t$\in$**t**. Labor reallocation at t$\in$**t** will not be seen as migration in strict sense. In contrast to the long run with continuous growth in total amount of capital and labor, the phase still belongs to the short run. In an analysis of an economy with two sectors of agriculture and nonagriculture, L, L^A and L^N are stocks, l represents sectoral allocation of L at a certain point of time, while labor migration is a flow and h denotes changes in l during a certain phase. In order to analyze short-run equilibrium of migration and its rate, h, we have to make the difference between point and phase of time.

Hu (2009) set up a model to analyze interactions of migration and relative price. This paper will take Hu's model as the starting point. There are two markets in his model, labor and goods markets, represented by superscripts L and G, respectively, described with following two equations:

$$\text{(2.4)}\quad p^{L}{}_{t}\frac{f_t^A[(1-\theta_t)K_t,(1-l_t)L_t]}{(1-l_t)L_t}=\frac{df_t^N(\theta_t K_t, l_t L_t)}{d(l_t L_t)}\text{ : labor market}$$

and

$$\text{(2.5)}\quad p^{G}{}_{t}f^{A}{}_{t}[(1-\theta_t)K_t,\ (1-l_t)L_t]=c_t\{p^{G}{}_{t}f^{A}{}_{t}[(1-\theta_t)K_t,\ (1-l_t)L_t]+f^{N}{}_{t}(\theta_t K_t,\ l_t L_t)\}\text{:}$$

goods market

where f stands for sectoral production functions, K for capital, θ for its sectoral allocation and c for preference for agricultural product given aggregate output. Note both f^A and f^N are functions of the standard neoclassical characteristics. The aggregate output in monetary form, $\mathbf{Y}_t$, is expressed by

$$\begin{aligned}\text{(2.6)}\quad \mathbf{Y}_t &= p^{A}{}_{t}Y^{A}{}_{t}+p^{N}{}_{t}Y^{N}{}_{t}\\ &= p^{N}{}_{t}(p_t Y^{A}{}_{t}+Y^{N}{}_{t})\\ &= p^{N}{}_{t}Y_t\end{aligned}$$

where p^A and p^N represent agricultural and nonagricultural price, respective. $p_t=(p^{A}{}_{t}/p^{N}{}_{t})$ denotes relative price of agricultural product with nonagricultural product being the numeraire. The aggregate output measured by relative price with $p^{N}_{t}=1$, Y_t, is defined as follows:

$$(2.7)\quad Y_t=p_tY^{A}_{t}+Y^{N}_{t}$$
$$=p_tf^{A}_{t}[(1-\theta_t)K_t, (1-l_t)L_t]+f^{N}_{t}(\theta_tK_t, l_tL_t)$$

It is supposed that labor and capital are fully utilized, hence $(1-l)+l=1$ and $(1-\theta)+\theta=1$. (2.4) assumes that agricultural wage rate is determined with average product of labor as the left-hand side of this equation shows, while nonagricultural one with marginal product on the right-hand side. Labor market will equilibrate when both wages come to match each other at p^{L}_{t} through (2.4). On the other hand, (2.5) gives the equilibrium condition for goods market where the term on the left-hand side represents supply function of agricultural product and that on the right-hand side the demand function. Goods market will be cleared at p^{G}_{t}. Hu shows the equilibrium solution for the model, (l^{E}_{t}, p^{E}_{t}) with $p^{E}=p^{L}=p^{G}$, exists and is unique, where superscript E denotes equilibrium values of variables. Furthermore, we write the parameter and solution at $t\in\mathbf{t}$ together as $Z_t(K_t, L_t, \theta_t, c_t; l_t, p_t)$, $t\in\mathbf{t}$ and l_t is the equilibrium allocation of labor and p_t the equilibrium relative price at $t\in\mathbf{t}$. Note Z_t is valid for every $t\in\mathbf{t}$, that is, the economy can equilibrate at every point of time during the whole period of labor migration.

According to Hu (2009), equilibrium migration of labor during the phase $(t, t+1)\in\mathbf{t}$ will be realized if and only if $p_{t+1}=p_t$.[3] We denotes equilibrium migration as $h^{E}_{t,t+1}\equiv l_{t+1}(p_{t+1}=p_t)-l_t(p_t)$. Note (l_t, p_t) and (l_{t+1}, p_{t+1}) are equilibrium solutions at both t and $t+1\in\mathbf{t}$. Therefore, equilibriums at two neighboring points t and $t+1\in\mathbf{t}$ are not enough for migration equilibrium during the phase

[3] Lewis (1954) already pointed out the importance of agricultural relative price for labor migration out of agriculture and expresses his fears that increases in this price may block the migration. All remarkable models of labor migration of this kind in the "traditional" development economics have to deal with the price, see e.g. Ranis and Fei, 1961; Jorgenson, 1961; Mas-Colell and Razin, 1973. Kongsamut, Rebelo and Xie (2001) may be the first who find the constancy of prices of agricultural and service products relative to that of manufacturing ones may be one of the main characteristics of the labor migration from agriculture into manufacturing sector and further into service industries. They define the labor migration with constant relative prices analytically. But what they analyze is the long-run trend of the migration. In the earlier version of their paper (1997) they also investigate the case of decreasing price of agricultural products to induce outmigration of agricultural labor.

(t, t+1)$\in$**t**. Only a particular equilibrium with p_{t+1}=p_t at t+1$\in$**t** can realize migration equilibrium during (t, t+1)$\in$**t**. The definition of equilibrium migration combines relative price with migration together: migration is in equilibrium only when relative price is stable during a phase during which migration takes place. Changes in relative price imply that migration or migration rate is quantitatively too great or too small. Hence migration equilibrium is observable through changes of relative price. But Hu failed to offer a strict proof of the existence of $h^E_{t,t+1}$ except a descriptive explanation with figures. In what follows we try to prove it and set up a solid foundation for further studies on relationships among migration, relative price and inflation.

Let $Z_{t+1}(K_{t+1}, L_{t+1}, \theta_{t+1}, c_{t+1}; l_{t+1}, p_{t+1}) \neq Z_t(K_t, L_t, \theta_t, c_t; l_t, p_t)$, t, t+1$\in$**t**. Note both Z_t and Z_{t+1} are equilibrium sets at t and t+1$\in$**t**. What we need to do is to prove the existence of $\mathbf{Z}_{t+1}(K_{t+1}, L_{t+1}, \theta_{t+1}, c_{t+1}; l_{t+1}, p_{t+1}=p_t)$, $\mathbf{Z}_{t+1} \in Z_{t+1}$. From all four parameters which may vary during (t, t+1)$\in$**t**, θ cannot vary autonomously since K_t is assumed to be a stock and is not changed after it is finally allocated at t$\in$**t,** while no depreciations in K_t will be taken into account. Hence it is possible for θ_t to vary only after K_t has changed. Out of K_t, L_t and c_t which vary autonomously, we assume that L_t is constant during (t, t+1)$\in$**t** and c_t, the preference, does not change when aggregate income remains unchanged. Consequently, we let K_t change first and pay particular attention to accumulation of capital during (t, t+1)$\in$**t** and its effects on other parameters as well as on the solution (l_{t+1}, p_{t+1}), that is, we study the case of K_{t+1}>K_t and its effects. Thus we have to show the existence of a subset of Z_{t+1}, $\mathbf{Z}_{t+1}(K_{t+1}>K_t, L_{t+1}=L_t, \theta_{t+1}, c_{t+1}; l_{t+1}, p_{t+1}=p_t)$. If $\mathbf{Z}_{t+1}$ exists, then $h^E_{t,t+1}$ also exists since p_{t+1}=p_t. It means that concerted changes in reallocations of both capital and labor during (t, t+1)$\in$**t** after a one-time growth in total amount of capital may make changes in relative price during (t, t+1)$\in$**t** unnecessary for the realization of the simultaneous equilibrium of the labor and goods markets at t+1$\in$**t** at the same time.

We begin our proof with (2.4) and (2.5). Formally, $\mathbf{Z}_{t+1}(K_{t+1}>K_t, L_{t+1}=L_t, \theta_{t+1}, c_{t+1}; l_{t+1}, p_{t+1}=p_t) \neq Z_t(K_t, L_t, \theta_t, c_t; l_t, p_t)$ originally since $K_{t+1} \neq K_t$. Because a change in K_t means somewhat happens during (t, t+1)$\in$**t**, we will omit the time subscripts of t and t+1 in the following proof. Look at (2.4). Because l^E is already known, we have p^L=$p^L(l^E)$ for (2.4). Since only K changes, we get

$$(2.8)\quad p^{\mathrm{L}}=\frac{(1-l^{\mathrm{E}})\mathrm{L}}{f^{\mathrm{A}}[(1-\theta)\mathrm{K},(1-l^{\mathrm{E}})\mathrm{L}]}\ \frac{\mathrm{d}f^{\mathrm{N}}[\theta\mathrm{K},l^{\mathrm{E}}\mathrm{L}]}{\mathrm{d}(l^{\mathrm{E}}\mathrm{L})}$$

$$=\frac{[1-l^{\mathrm{E}}(\mathrm{K})]\mathrm{L}(\mathrm{K})}{f^{\mathrm{A}}\{[1-\theta(\mathrm{K})]\mathrm{K},[1-l^{\mathrm{E}}(\mathrm{K})]\mathrm{L}(\mathrm{K})\}}\ \frac{\mathrm{d}f^{\mathrm{N}}[\theta(\mathrm{K})\mathrm{K},l^{\mathrm{E}}(\mathrm{K})\mathrm{L}(\mathrm{K})]}{\mathrm{d}[l^{\mathrm{E}}(\mathrm{K})\mathrm{L}(\mathrm{K})]}$$

$$=p^{\mathrm{L}}[l^{\mathrm{E}}(\mathrm{K}),\ \theta(\mathrm{K}),\ \mathrm{L}(\mathrm{K}),\ \mathrm{K}]$$

Note the terms at the right-hand side of the first equation sign is a scalar number as soon as K, L, θ, l^{E} are known. But the terms at the right-hand side of the second equation sign is a function since K becomes a variable and also leads l^{E}, θ, L and p^{L} to change. Therefore, p^{L} is a function of K now. Differentiate (2.8) with respect to K gives

$$(2.9)\quad \frac{\mathrm{d}p^{\mathrm{L}}}{\mathrm{dK}}=\frac{\partial p^{\mathrm{L}}}{\partial l^{\mathrm{L}}}\ \frac{\mathrm{d}l^{\mathrm{L}}}{\mathrm{dK}}+\frac{\partial p^{\mathrm{L}}}{\partial \theta^{\mathrm{L}}}\ \frac{\mathrm{d}\theta^{\mathrm{L}}}{\mathrm{dK}}+\frac{\partial p^{\mathrm{L}}}{\partial \mathrm{L}}\ \frac{\mathrm{dL}}{\mathrm{dK}}+\frac{\partial p^{\mathrm{L}}}{\partial \mathrm{K}}$$

$$=\mathrm{A}\frac{\mathrm{d}l^{\mathrm{L}}}{\mathrm{dK}}+\mathrm{B}\frac{\mathrm{d}\theta^{\mathrm{L}}}{\mathrm{dK}}+\mathrm{C}$$

where (dL/dK) is supposed to be zero and

$$(2.10)\quad \mathrm{A}=\frac{\partial p^{\mathrm{L}}}{\partial l^{\mathrm{L}}}$$

$$=-\frac{1}{l}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\ \frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)\,e_{\mathrm{L,MPL}}^{\mathrm{N}}]<0$$

$$(2.11)\quad \mathrm{B}=\frac{\partial p^{\mathrm{L}}}{\partial \theta^{\mathrm{L}}}$$

$$=\frac{1}{\theta(1-\theta)}(1-l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\ \frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[\theta\,e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)\,e_{\mathrm{K,MPL}}^{\mathrm{N}}]>0$$

and

$$(2.12)\quad \mathrm{C}=\frac{\partial p^{\mathrm{L}}}{\partial \mathrm{K}}$$

$$=(1\text{-}l)\frac{1}{\mathrm{K}}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[e^{\mathrm{N}}_{\mathrm{K,MPL}}-e^{\mathrm{A}}_{\mathrm{K}}]$$

where $e^{\mathrm{A}}_{\mathrm{L}}\in(0,\ 1)$ and $e^{\mathrm{A}}_{\mathrm{K}}\in(0,\ 1)$ stand for output elasticities with respect to L and K in agriculture, respectively, while $e^{\mathrm{N}}_{\mathrm{L,MPL}}\in(-1,\ 0)$ and $e^{\mathrm{N}}_{\mathrm{K,MPL}}\in(0,\ 1)$ for elasticities of marginal product of labor with respect to L and K in nonagriculture. The computations of A, B and C are in Appendix I. Here is to mention that A, B and C exist and are well defined. Therefore, $\mathrm{d}p^{\mathrm{L}}/\mathrm{dK}$ exists when we assume the existence of both $\mathrm{d}l^{\mathrm{L}}/\mathrm{dK}$ and $\mathrm{d}\theta^{\mathrm{L}}/\mathrm{dK}$ for now. We look for conditions for $(\mathrm{d}p^{\mathrm{L}}/\mathrm{dK})=0$, that is, conditions for $p^{\mathrm{L}}[l(\mathrm{K}),\ \theta(\mathrm{K}),\ \mathrm{K}]=p^{\mathrm{L}*}$ where the superscript * denotes a constant. Let $(\mathrm{d}p^{\mathrm{L}}/\mathrm{dK})=0$ and rearrange (2.9) to obtain

$$(2.13)\quad \frac{\mathrm{d}l^{\mathrm{L}}}{\mathrm{dK}}=-\frac{\mathrm{B}}{\mathrm{A}}\frac{\mathrm{d}\theta^{\mathrm{L}}}{\mathrm{dK}}-\frac{\mathrm{C}}{\mathrm{A}}$$

Since A<0, B>0, we know -(B/A)>0. (2.13) shows a condition for $(\mathrm{d}p^{\mathrm{L}}/\mathrm{dK})=0$ is that both l^{L} and θ^{L} change in the same direction in response to varying K. It can be explained that, if θ decreases after a growth in total amount of capital, that is, if agricultural share of capital rises, l has to decline and a part of labor force should be reallocated into agriculture to restrain the enhancement of average product of agricultural labor in kind in order to maintain equilibrium of labor market with unchanged relative price. In contrast, l should increase and labor migrate into nonagriculture, if θ goes up with capital growth, in order that the speed of increase in average product of agricultural labor in kind can catch up with that of increase in marginal product of nonagricultural labor, which may make changes in p unnecessary. Therefore, adjustments of both θ and l in the same direction resulting from changes in total capital may be able to clear labor market without having resort to adjust p.

We now observe the goods market. With a procedure similar to the above, (2.5) is transferred into

$$(2.14)\quad p^{\mathrm{G}}=\gamma\frac{f^{\mathrm{N}}(\theta\mathrm{K},l^{\mathrm{E}}\mathrm{L})}{f^{\mathrm{A}}[(1\text{-}\theta)\mathrm{K},(1\text{-}l^{\mathrm{E}})\mathrm{L}]}$$

$$= \gamma(\mathrm{K}) \frac{f^{\mathrm{N}}[\theta(\mathrm{K})\mathrm{K}, l^{\mathrm{E}}(\mathrm{K})\mathrm{L}(\mathrm{K})]}{f^{\mathrm{A}}\{[1\text{-}\theta(\mathrm{K})]\mathrm{K}, [1\text{-}l^{\mathrm{E}}(\mathrm{K})]\mathrm{L}(\mathrm{K})\}}$$

$$= p^{\mathrm{G}}[\gamma(\mathrm{K}), l^{\mathrm{E}}(\mathrm{K}), \theta(\mathrm{K}), \mathrm{L}(\mathrm{K}), \mathrm{K}]$$

where

$$\text{(2.15)} \qquad \gamma = \frac{c}{1\text{-}c}$$

$\gamma > 0$ and denotes ratio of value of agricultural output to that of nonagricultural one as demonstrated as follows:

$$\text{(2.16)} \qquad \gamma = \frac{c}{1\text{-}c} = \frac{\dfrac{p\mathrm{Y}^{\mathrm{A}}}{\mathrm{Y}}}{1 - \dfrac{p\mathrm{Y}^{\mathrm{A}}}{\mathrm{Y}}} = \frac{\dfrac{p\mathrm{Y}^{\mathrm{A}}}{\mathrm{Y}}}{\dfrac{(p\mathrm{Y}^{\mathrm{A}} + \mathrm{Y}^{\mathrm{N}})(\text{-}p\mathrm{Y}^{\mathrm{A}}}{\mathrm{Y}}} = \frac{p\mathrm{Y}^{\mathrm{A}}}{\mathrm{Y}^{\mathrm{N}}}$$

Hence γ is also an important measure of economic structure by itself and $\gamma > c$ because Y^{N} as the denominator of γ is smaller than Y in the definition of c while both numerators are same. Since

$$\text{(2.17)} \qquad \frac{\mathrm{d}c}{\mathrm{d}\gamma} = \frac{1}{(1+\gamma)^2} > 0,$$

we can use γ in place of c. Note that the right-hand side of the first equation sign of (2.14) is a scalar number because all of γ, θ, K, L and l^{E} are known now. However, the right-hand side of the second equation sign is a function since K is now allowed to vary and its changes have effects on γ, θ, l^{E} and L as well as p^{G}. Thus p^{G} becomes a function of K. Differentiate p^{G} with respect to K to get

$$\text{(2.18)} \qquad \frac{\mathrm{d}p^{\mathrm{G}}}{\mathrm{dK}} = \frac{\partial p^{\mathrm{G}}}{\partial \gamma}\frac{\mathrm{d}\gamma}{\mathrm{dK}} + \frac{\partial p^{\mathrm{G}}}{\partial l^{\mathrm{G}}}\frac{\mathrm{d}l^{\mathrm{G}}}{\mathrm{dK}} + \frac{\partial p^{\mathrm{G}}}{\partial \theta^{\mathrm{G}}}\frac{\mathrm{d}\theta^{\mathrm{G}}}{\mathrm{dK}} + \frac{\partial p^{\mathrm{L}}}{\partial \mathrm{L}}\frac{\mathrm{dL}}{\mathrm{dK}} + \frac{\partial p^{\mathrm{G}}}{\partial \mathrm{K}}$$

$$= \mathrm{Q}\frac{\mathrm{d}\gamma}{\mathrm{dK}} + \mathrm{R}\frac{\mathrm{d}l^{\mathrm{G}}}{\mathrm{dK}} + \mathrm{S}\frac{\mathrm{d}\theta^{\mathrm{G}}}{\mathrm{dK}} + \mathrm{T}$$

where (dL/dK) is again supposed to be zero and

$$\text{(2.19)} \qquad \mathrm{Q} = \frac{\partial p^{\mathrm{G}}}{\partial \gamma} = \frac{f^{\mathrm{N}}}{f^{\mathrm{A}}} > 0$$

$$(2.20)\quad \mathrm{R}=\frac{\partial p^{\mathrm{G}}}{\partial l^{\mathrm{G}}}$$

$$=\gamma\frac{1}{l(1\text{-}l)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[l\,e_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)\,e_{\mathrm{L}}^{\mathrm{N}}]>0$$

$$(2.21)\quad \mathrm{S}=\frac{\partial p^{\mathrm{G}}}{\partial \theta^{\mathrm{G}}}$$

$$=\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[\theta\,e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)\,e_{\mathrm{K}}^{\mathrm{N}}]>0$$

and

$$(2.22)\quad \mathrm{T}=\frac{\partial p^{\mathrm{G}}}{\partial \mathrm{K}}$$

$$=\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}(e_{\mathrm{K}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})$$

where $e_{\mathrm{L}}^{\mathrm{N}}\in(0,\ 1)$ and $e_{\mathrm{K}}^{\mathrm{N}}\in(0,\ 1)$ stand for output elasticities with respect to L and K in nonagriculture, respectively. The computations of Q, R, S and T also are in the Appendix I. Here is to mention that T is well-defined. dp^{G}/dK exists since Q, R, S and T are definable and dγ/dK, dl^{G}/dK and dθ^{G}/dK are assumed to exist first. Let (dp^{G}/dK)=0 and rearrange (2.18) to get

$$(2.23)\quad \frac{\mathrm{d}l^{\mathrm{G}}}{\mathrm{dK}}=-\frac{\mathrm{S}}{\mathrm{R}}\frac{\mathrm{d}\theta^{\mathrm{G}}}{\mathrm{dK}}-\frac{\mathrm{Q}}{\mathrm{R}}\frac{\mathrm{d}\gamma}{\mathrm{dK}}-\frac{\mathrm{T}}{\mathrm{R}}$$

(2.23) makes clear that one of the conditions for dp^{G}/dK=0 is both l^{G} and θ^{G} vary in opposite directions to changes in K because of R>0, S>0 and –(S/R)<0. It means l will increase with capital growth while θ decreases in response to the same growth of capital so that goods market can remain in equilibrium with unchanged p after capital accumulates. The economic reasoning lies in that a decrease in θ will lead more new capital into agriculture, which raises agricultural production more quickly if l does not increase to move labor out of agriculture. Therefore, in order to let goods market remain in equilibrium with the original price, labor should migrate from agriculture into nonagriculture to repress agricultural growth on the one hand and increase demand for agricultural products through expanding nonagricultural and aggregate output and income on the other. If, however, θ goes up as capital grows and nonagricultural capital share rises, aggregate output and hence demand for agricultural products will increase correspondingly. In order to ensure that agricultural supply will match its demand without changing prices, labor should be reallocated more into agriculture, that is, l should go down accordingly.

The second condition for $(dp^G/dK)=0$ from (2.23) is that both l^G and γ change in opposite directions. Note that changes in K will affect γ through a chain as follows:

$$\text{(2.24)} \quad \frac{d\gamma}{dK} = \frac{d\gamma}{dc}\frac{dc}{dY}\frac{dY}{dK} < 0$$

where $(d\gamma/dc)>0$ is known by (2.17). There is $(dc/dY)<0$ according to the Engel's law that share of expenditure for agriculture products in the total consumption will decline along with growth in income. $(dY/dK)>0$ is based on the supposition that growth in total amount of capital alone will raise aggregate output or income even if others remain unchanged. Hence γ should decrease in the process of capital accumulation. Since Q>0, R>0 and -(Q/R)<0, we get $(-\frac{Q}{R}\frac{d\gamma}{dK})>0$. It means l^G will rise as γ falls in response to growth in K if p does not need to vary along with change in γ. It implies that decrease in γ will cause relative reductions in demand for agricultural product, l must rise and labor migrate out to nonagriculture in order to restrict agricultural production while expanding nonagricultural production and aggregate income in aiming at keeping good market in equilibrium with unchanged price. On the other hand, l has to decrease and labor to be reallocated into agriculture to supply more agricultural product for the increased demand triggered by a rise in γ when good market equilibrates on unchanged p.

We illustrate (2.13) and (2.23) in Figure 2.1 where the horizontal axis represents $d\theta/dK$ and the vertical one dl/dK. For the sake of simplicity, dl^L/dK and dl^G/dK are depicted as lines in Figure 2.1. The curve of dl^L/dK shows the combinations of dl^L/dK and $d\theta^L/dK$ for which labor market is in equilibrium with constant p^L as capital grows, while the curve of dl^G/dK is a locus of points of equilibrium in the goods market which is ensured by concerted responses in l and θ to varying K without adjustments in p^G. As (2.13) and (2.23) respectively show, the dl^L/dK curve is drawn upward-slopping and the dl^G/dK curve downward-slopping to changes in $d\theta/dK$. But both labor and goods markets cannot be cleared with more than one value of $d\theta/dK$ at the same time. The simultaneous equilibrium of both the markets can reach on the earlier price level only at the intersection of both the curves where $(d\theta^L/dK)=(d\theta^G/dK)=(d\theta^E/dK)$ and $(dl^L/dK)=(dl^G/dK)=(dl^E/dK)$.

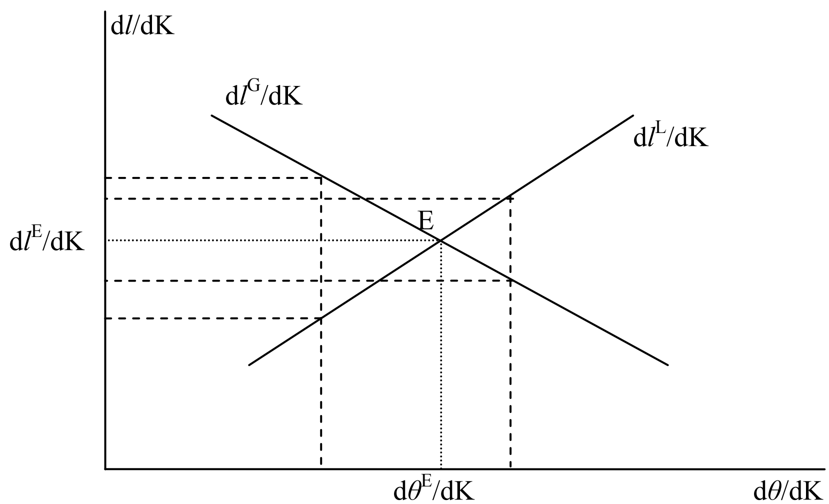

Figure 2.1 Short-Run Equilibrium of Intersectoral Migrations of Capital and Labor after Capital Growth

To show the existence of dl^E/dK and $d\theta^E/dK$, we combine (2.13) and (2.23) to eliminate dl/dK and get

$$(2.25) \quad -\frac{B}{A}\frac{d\theta^L}{dK}-\frac{C}{A}=-\frac{S}{R}\frac{d\theta^G}{dK}-\frac{Q}{R}\frac{d\gamma}{dK}-\frac{T}{R}$$

Solve for $(d\theta^L/dK)=(d\theta^G/dK)=(d\theta^E/dK)$ from (2.25) and rearrange it as follows:

$$(2.26) \quad \frac{d\theta^E}{dK}=\frac{\frac{Q}{R}\frac{d\gamma}{dK}+\frac{T}{R}-\frac{C}{A}}{\frac{B}{A}-\frac{S}{R}}$$

$$=\frac{\mathrm{AQ}}{\mathrm{BR\text{-}AS}}\frac{\mathrm{d}\gamma}{\mathrm{dK}}+\frac{\mathrm{AT-CR}}{\mathrm{BR-AS}}$$

$$=\tau\frac{1}{\gamma}\frac{\mathrm{d}\gamma}{\mathrm{dK}}+u$$

$$=\tau\frac{\dot{\gamma}}{\gamma}+u$$

where we assume that all changes in γ occurring during the phase (t, t+1)$\in\mathbf{t}$ are attributed to changes in K during the same phase and substitute $\dot{\gamma}$ for dγ/dK. $\dot{\gamma}/\gamma$ represents growth rate of γ during (t, t+1)$\in\mathbf{t}$, $\dot{\gamma}/\gamma\in(-1, 1)$, while τ is a coefficient denoting effects of $\dot{\gamma}/\gamma$ on dθ^{E}/dK and

$$(2.27)\qquad \tau\frac{1}{\gamma}=\frac{\mathrm{AQ}}{\mathrm{BR\text{-}AS}}<0$$

$$(2.28)\qquad \tau<0$$

and

$$(2.29)\qquad u=\frac{\mathrm{AT-CR}}{\mathrm{BR-AS}}$$

τ<0 because of γ>0, A<0, Q >0 and (BR-AS)>0. The full expressions of both τ and u are given as follows:

$$(2.30)\qquad \tau=-\frac{\theta(1\text{-}\theta)[l(1\text{-}e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}{[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}][le_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}][l(1\text{-}e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}$$

$$(2.31)\qquad u=\tau\frac{1}{\mathrm{K}}\frac{(e_{\mathrm{K}}^{\mathrm{N}}\text{-}e_{\mathrm{K}}^{\mathrm{A}})[l(1\text{-}e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]+(e_{\mathrm{K,MPL}}^{\mathrm{N}}\text{-}e_{\mathrm{K}}^{\mathrm{A}})[le_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)e_{\mathrm{L}}^{\mathrm{N}}]}{l(1\text{-}e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

where every term in the denominators of (2.30) and (2.31) are positive. Hence τ and u are also definable. The computations of τ and u are in Appendix I. Apparently, dθ^{E}/dK exists since A<0, B>0, R>0, S>0 and AR≠0, (BR-AS)≠0.

Introduce (2.26) into (2.13) to solve for dl^{E}/dK, we obtain

$$(2.32)\qquad \frac{\mathrm{d}l^{\mathrm{E}}}{\mathrm{dK}}=-\frac{\mathrm{B}}{\mathrm{A}}(\tau\frac{\dot{\gamma}}{\gamma}+u)-\frac{\mathrm{C}}{\mathrm{A}}$$

$$= -\tau\frac{\mathrm{B}}{\mathrm{A}}\frac{\dot{\gamma}}{\gamma} - \frac{1}{\mathrm{A}}(u\mathrm{B}+\mathrm{C})$$

$$=\upsilon\frac{\dot{\gamma}}{\gamma}+v$$

where

$$(2.33)\quad \upsilon=-\tau\frac{\mathrm{B}}{\mathrm{A}}$$

$$=-\frac{l(1\text{-}l)[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}]}{[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}][le_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}][l(1\text{-}e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}$$

$$<0$$

and

$$(2.34)\quad v=-\frac{1}{\mathrm{A}}(u\mathrm{B}+\mathrm{C})$$

$$=\frac{l(1\text{-}l)}{\theta(1\text{-}\theta)}\frac{1}{\mathrm{K}}\frac{u\mathrm{K}[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}]+\theta(1\text{-}\theta)[e_{\mathrm{K,MPL}}^{\mathrm{N}}\text{-}e_{\mathrm{K}}^{\mathrm{A}}]}{l(1\text{-}e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

$\upsilon<0$ since $\tau<0$, A<0 and B>0. The computations of υ and v also are in Appendix I. Note all terms in the denominators of (2.33) and (2.34) are positive and both υ and v are well defined. Because of $\mathrm{A}\neq0$ and existence of υ and v, $dl^{\mathrm{E}}/d\mathrm{K}$ exists. Therefore, we have shown the existence of both $d\theta^{\mathrm{E}}/d\mathrm{K}$ and $dl^{\mathrm{E}}/d\mathrm{K}$. Accordingly, $dp/d\mathrm{K}=0$ must exist in the value domain of $dp/d\mathrm{K}$. In other words, adjustments of θ and l are enough for the economy to get equilibrated with $\Delta p_{\mathrm{t,t+1}}=0$ again at $\mathrm{t+1}\in\mathbf{t}$ after capital grows during the phase $(\mathrm{t, t+1})\in\mathbf{t}$, even when $\dot{\gamma}/\gamma$ is still a variable dependent on K.[4] Changes in relative price are not completely necessary. We substitute $\Delta\theta_{\mathrm{t,t+1}}$ and $\Delta l_{\mathrm{t,t+1}}$ for $d\theta^{\mathrm{E}}/d\mathrm{K}$ and $dl^{\mathrm{E}}/d\mathrm{K}$, respectively, if $\Delta\mathrm{K}_{\mathrm{t,t+1}}$ is given. Thus we have $\theta_{\mathrm{t+1}}=\theta_{\mathrm{t}}+\Delta\theta_{\mathrm{t,t+1}}$ and

4 $d\theta^{\mathrm{E}}/d\mathrm{K}$ and $dl^{\mathrm{E}}/d\mathrm{K}$ will become known as soon as $\dot{\gamma}/\gamma$ is given since elasticities in τ, u, υ and v can be seen as constant at least in the short-run. But $\dot{\gamma}/\gamma$ depends on aggregate output, Y. Y is in turn dependent, among other things, on intersectoral allocations of labor and capital after K changes. Hence $\dot{\gamma}/\gamma$ cannot be known as long as $d\theta^{\mathrm{E}}/d\mathrm{K}$ and $dl^{\mathrm{E}}/d\mathrm{K}$ are not determined. It shows that a analysis more general than in this paper is needed for studying migration equilibrium.

$l_{t,t+1}=l_t+\Delta l_{t,t+1}$ and the equilibrium solution of (l_{t+1}, $p_{t+1}=p_t$) at $t+1\in\mathbf{t}$ with a change in capital during $(t, t+1)\in\mathbf{t}$. Consequently, the equilibrium migration of labor, $h^E_{t,t+1}=\Delta l_{t,t+1}(p_{t+1}=p_t)$, exists. Meanwhile, there is only one value for each of $\Delta\theta_{t,t+1}$ and $\Delta l_{t,t+1}$ to any given $\dot{\gamma}/\gamma$ since both of $\Delta\theta_{t,t+1}$ and $\Delta l_{t,t+1}$ are linear functions of $\dot{\gamma}/\gamma$. Therefore, there is only one unique $h^E_{t,t+1}$ possible.

Note that $\tau<0$ in (2.26) and $\upsilon<0$ in (2.32), which means θ as well as l will vary in opposite directions to changes of γ when all of them respond to capital growth. The economic meanings for the negative relations between θ and l on the one side and γ on the other can be understood as follows: A decline in γ resulting from a new capital accumulation will reduce demand for agricultural products. In order to keep goods market in equilibrium without to change price, agricultural production should contract and nonagricultural one expand to increase aggregate output and then demand for agricultural products. But all these imply capital and labor should be reallocated more into nonagriculture. Therefore, θ and l will rise along with declines in γ in the process of capital accumulation.

If γ does not vary at all as capital grows, we will have $(d\theta^E/dK)=u$ and $(dl^E/dK)=v$, changes in θ and l will be completely subject to technologies employed in both agriculture and agriculture because there are only output elasticities of different kinds beside parameters in u and v. In comparison with the case of changes in γ, however, it is not clear through (2.31) and (2.34) in which directions technologies will change after K grows since we do not know if and how great the effects of a given capital increase on these elasticities represented in (2.31) and (2.34) may be. But it can be pointed out to some extent that a new technique will lead θ and l to increase when it particularly heightens the output elasticities of agricultural capital and labor, and lead θ and l to decline when it enhances only nonagricultural productivities. But in the short-run, we may assume constant technologies used in both sectors.[5]

[5] A comparison of our model with the well-known IS-LM model (Hicks, 1937) is interesting. Both are of comparative static analysis and assume constant technologies in the short-run. But our model has to take changes in preference between two equilibrium points into account explicitly. More important is that there is a variable in our model whose changes between the two equilibrium points should get equilibrated. Such complexities do not occur in the IS-LM model.

Back to relations between migration and relative price, we find there exists an unique subset of $\mathbf{Z}_{t+1}(K_{t+1}=K_t+\Delta K_{t,t+1},\ L_{t+1}=L_t,\ c_{t+1};\ \theta^E_{t+1},\ l^E_{t+1},\ p_{t+1}=p_t)$ from all possible subsets of the equilibrium set of $Z_{t+1}(K_{t+1}=K_t+\Delta K_{t,t+1}, L_{t+1}=L_t, c_{t+1}; \theta_{t+1}, l_{t+1}, p_{t+1})$ if $Z_t(K_t, L_t, c_t, \theta_t; l_t, p_t)$ exists, t, t+1$\in$**t**. Look at the increments and subtract Z_t from $\mathbf{Z}_{t+1}$ to get

$$\begin{aligned}(2.35)\quad \Delta\mathbf{Z}_{t,t+1}&=\mathbf{Z}_{t+1}-Z_t\\&=\Delta\mathbf{Z}_{t,t+1}(\Delta K_{t,t+1}, \Delta L_{t,t+1}, \Delta c_{t,t+1}; \Delta\theta_{t,t+1}, \Delta l_{t,t+1}, \Delta p_{t,t+1})\\&=\Delta\mathbf{Z}_{t,t+1}(I_{t,t+1}, 0_{t,t+1}, \Delta c_{t,t+1}; \Delta\theta_{t,t+1}, h_{t,t+1}, 0_{t,t+1})\end{aligned}$$

From discussions above, h is determined by interactions of I, Δc and $\Delta\theta$ when K, L, c and θ are known and dp is given from outside. Therefore, h is a function of I, Δc and $\Delta\theta$ as follows

$$(2.36)\quad h=h(I, \Delta c, \Delta\theta)$$

for every given Δp, $h\in(-1, 1)$, $\Delta p\in(-p, \infty)$. We rewrite $\Delta p_{t,t+1}$ as $dp_{t,t+1}$ in case that μ_{t+1} changes continuously and each time unlimited small after $I_{t,t+1}$ is given. Thus we have

$$(2.37)\quad dp=g[h(I, \Delta c, \Delta\theta)]$$

since effects of changes in K, c and θ on p is realized through their effects on l or h in our model. In other words, effects of h on p contain all information of changes of other variables on p. Hence dp can be seen as a function of only h when h is in turn a function of other variables and parameters allowed to vary. We transfer (2.37) into (2.38) as follows:

$$(2.38)\quad \frac{dp}{p}=\varphi^A(h)=\frac{1}{p}g(h)$$

$p\neq0$. $\varphi^A\in(-1, \infty)$ stands for growth rate of relative price of agricultural product. $\varphi^A(h)$ has following properties:

$$(2.39)\quad \frac{d\varphi^A}{dh}>0$$

and

$$(2.40)\quad \varphi^A(h=h^E)=0$$

We illustrate $\varphi^A(h)$ as a straight line in Figure 2.2. It shows that φ^A and h vary in the same direction and $\varphi^A=0$ if and only if $h=h^E$.

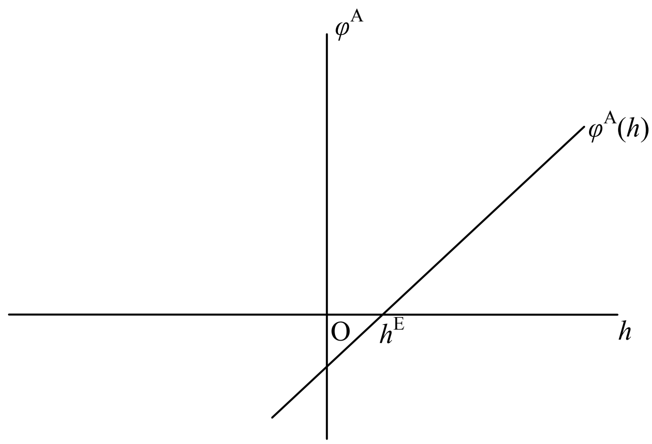

Figure 2.2 Migration Rate (h) and Growth Rate of Relative Price (φ^A)

3. Bias for Nonagricultural Investments

In the mechanism described above, adjustments of intersectoral migrations of capital and labor after capital growth can lead the economy to a new equilibrium with the price of an earlier time point before capital growth. But the mechanism does not imply at all that price remains unchanged within the phase under review. In fact, it is fluctuations of relative price during the phase (t, t+1)$\in\mathbf{t}$ that essentially guarantee the re-establishment of equilibrium with $p_{t+1}=p_t$ at t+1$\in\mathbf{t}$. As mentioned above, the phase (t, t+1)$\in\mathbf{t}$ can be divided into subphases infinitely in theory. We limit us to the subphases of the first order, that is, the phase (t, t+1)$\in\mathbf{t}$ is divided only into points of time t, t+I, t+II, …, t+1-I, t+1$\in\mathbf{t}$ and into the subphases defined by any two neighboring points t, t+I, t+II, …, t+1-I, t+1$\in\mathbf{t}$. Changes in p between the subphases deliver signals which direct reallocations of investments and labor. When p falls, ΔK_t and L_t will move from agriculture into nonagriculture. In the opposite cases, both will flow more into agriculture. The migration equilibrium solution of (l_{t+1}, $p_{t+1}=p_t$) means only that p will come to and stabilize on its earlier level of p_t at the end of the phase (t, t+1)$\in\mathbf{t}$ when the economy finally comes into a new equilibrium at t+1$\in\mathbf{t}$.

In the reality, the economy often realizes equilibrium with $p_{t+1} \neq p_t$ at $t+1 \in \mathbf{t}$, that is, without migration equilibrium at the same time because the solution (l_{t+1}, $p_{t+1}=p_t$) is only one of many possible equilibrium solutions of the economy at $t+1 \in \mathbf{t}$. Moreover, p even fluctuates very strongly in practice, which is clear beyond the framework of our model for migration equilibrium. Accordingly, migration of agricultural labor is often not on the equilibrium path. What causes strong price fluctuations and leads migration out of equilibrium if the equilibrium is assumed at the beginning of a phase? To answer it we have to resort to a hypothesis that there would be a bias of allocating investments in favor of nonagriculture in the economy where migration of agricultural labor is a main driving force to expand production. The hypothesis says that ΔK, that is, investments, is often allocated too much to nonagriculture. Economic reasons for it may be listed as follows:

(1) Productivity is assumed much higher in nonagriculture and can offer profits for nonagricultural investments in our model. Investments in agriculture enhance production and farmers' income, but do not bring about profits.

(2) Farmers are not assumed "economic man" in the neoclassical sense in our model and do not estimate marginal productivities of resources at their dispose before allocating them between both the sectors. They invest in agriculture mainly for maintaining and increasing their incomes, not for profits, since they regard all their incomes as labor income, as our assumption of average-product-wage in agriculture already implies. Therefore, they may invest into nonagriculture if more incomes there are expected rationally.

(3) In an economy where there is a central planning authority which gets incomes for private agents and then invests, it may often invest too much into nonagriculture in pursuit of speedy economic growth.[6]

The bias for nonagricultural investments can be understood as a form of the

[6] There are still two reasons of more technical characteristics. The first one is that demands for nonagricultural products grow much more quickly than that for agricultural ones because of the Engel's law and the second lies in that there is more certainty to raise production in nonagriculture than agriculture since the latter is subject more to e.g. weather and other natural factors. Both the reasons may explain why private investors are more optimistic to returns of nonagricultural investments as our hypothesis means.

modernization-impulse particularly found in the contemporary developing countries regardless political systems and ideologies. Modernization is closely linked with de-agriculturalization. To accelerate de-agriculturalization by means of out-migration of agricultural labor force, the intersectoral allocations of investments are a powerful tool available to policy maker of the central planning authority. Therefore, a certain quantity of investments may often be allocated inadequately in favor of nonagriculture, which, according to our analysis above, induces too much labor migrated from agriculture to nonagriculture and further causes increases in agricultural relative price. Consequently, migration equilibrium during a phase is not possible although equilibrium at the beginning and the end of the phase can still be realized.

We look at the channels by which modernization impulse with too much investment for nonagriculture may lead to disequilibrium of migration. Recall the assumption that the stock of capital at $t \in \mathbf{t}$, K_t, is not depreciated and hence cannot be reallocated between sectors after it is finally invested at $t \in \mathbf{t}$. Therefore reallocations of capital refer only to new capital or investment. It is supposed that the economy decides the distribution of its aggregate income between consumption and savings at $t \in \mathbf{t}$ and all savings at $t \in \mathbf{t}$ will be used as investment during the phase $(t, t+1) \in \mathbf{t}$, $I_{t,\, t+1}$. Thus we have

$$(3.1) \quad K_{t+1}=K_t+I_{t,t+1}=K_t+\Delta K_{t+1}$$

Let μ_t stand for nonagricultural share of investments at $t \in \mathbf{t}$, $\mu_t=\Delta K^N_t/\Delta K_t$, $\mu_t \in [0, 1]$, we get the nonagricultural K at $t+1 \in \mathbf{t}$ as follows (Hu, 2009)

$$(3.2) \quad K^N_{t+1}=\theta_{t+1}(K_t+\Delta K_{t+1})$$

$$(3.3) \quad K^N_{t+1}=\theta_t K_t+\mu_{t+1}\Delta K_{t+1}$$

Combine (3.2) and (3.3) and solve for θ_{t+1} to get

$$(3.4) \quad \theta_{t+1}=\frac{\theta_t K_t+\mu_{t+1}\Delta K_{t+1}}{K_t+\Delta K_{t+1}}$$

$$=\frac{\theta_t}{1+g_{K;t,t+1}}+\frac{g_{K;t,t+1}}{1+g_{K;t,t+1}}\mu_{t+1}$$

$$=\theta_{t+1}(\mu_{t+1})$$

where $g_{K;t,t+1}$=($\Delta K_{t+1}/K_t$) is growth rate of total amount of capital stock during (t, t+1)$\in$**t** and be known at t+1$\in$**t**, $g_{K;t,t+1}$>0. Obviously, $\theta_{t+1}(\mu_{t+1})$ is a linear function with

$$(3.5)\quad \frac{d\theta_{t+1}}{d\mu_{t+1}}>0$$

Therefore, there is one and only one value of μ_{t+1} in its value range, $\mu^E{}_{t+1}$, that leads to $\theta^E{}_{t+1}$ with the equilibrium migration solution of ($l^E{}_{t+1}$, $p^E{}_{t+1}=p_t$). $\mu^E{}_{t+1}$ can be realized by try and error through market mechanisms with moderate fluctuations in all variables of μ, θ, p, l and c during (t, t+1)$\in$**t**. But the bias for nonagricultural investments will regularly push μ too high with $\mu_{t+1}>\mu^E{}_{t+1}$. It results in $\theta_{t+1}>\theta^E{}_{t+1}$, that is, too much capital allocated in nonagriculture than needed for migration equilibrium with $p_{t+1}=p_t$. It causes migration of too much labor from agriculture into nonagriculture in order to bring the labor market into equilibrium. The goods market will experience more demand for than supply of agricultural products and relative price must rise correspondingly. The economy booms with $h_{t.t+1}>h^E{}_{t,t+1}$ and $p_{t+1}>p_t$, then faces too high price of agricultural products which will reduce profits of nonagricultural capital and finally force a slowdown or even a recession.

4. From Relative Price to General Level of Prices

The bias for nonagricultural investments may cause too much capital and labor reallocated in nonagricultural sector and result in strong increases in relative price of agricultural products. The core question is, however, if and how increases in relative price will affect the general level of prices and lead to the economy-wide inflation. This section will deal with the questions.

Recall that $\varphi^A(h)$ represents growth rate of relative price as a function of migration rate during (t, t+1)$\in$**t** and

$$(4.1)\quad \varphi^A{}_{t,t+1}=\frac{p_{t+1} - p_t}{p_t}$$

Recall again that p=(p^A/p^N). Let b stand for growth rate of p^N defined in the same form as

(4.1) and consider the case of $p^{\mathrm{N}}\neq 1$, we rewrite (2.6), that is, aggregate output in monetary prices, at t+1 $\in$ **t** as follows:

$$(4.2)\quad \mathbf{Y}_{t+1}=p^{\mathrm{N}}{}_{t+1}\mathrm{Y}_{t+1}$$

$$=p^{\mathrm{N}}{}_{t+1}(p_{t+1}\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1})$$

Introduce $p^{\mathrm{N}}{}_{t}$ and p_t with their growth rates b and φ^{A} during (t, t+1) $\in$ **t** into (4.2) to obtain

$$(4.3)\quad \mathbf{Y}_{t+1}=p^{\mathrm{N}}{}_{t+1}(p_{t+1}\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1})$$

$$=(1+b_{t,t+1})p^{\mathrm{N}}{}_{t}[(1+\varphi^{\mathrm{A}}{}_{t,t+1})p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1}]$$

$$=p^{\mathrm{N}}{}_{t}(p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1})+p^{\mathrm{N}}{}_{t}\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+b_{t,t+1}p^{\mathrm{N}}{}_{t}[(1+\varphi^{\mathrm{A}}{}_{t,t+1})p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1}]$$

$$=\mathbf{Y}^{*}{}_{t+1}+p^{\mathrm{N}}{}_{t}\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+b_{t,t+1}p^{\mathrm{N}}{}_{t}[(1+\varphi^{\mathrm{A}}{}_{t,t+1})p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1}]$$

where

$$(4.4)\quad \mathbf{Y}^{*}{}_{t+1}=p^{\mathrm{N}}{}_{t}(p_t\mathrm{Y}^{\mathrm{A}}{}_{t+1}+\mathrm{Y}^{\mathrm{N}}{}_{t+1})$$

is the so-called real or deflated aggregate output at t+1 $\in$ **t** computed with prices of t $\in$ **t**. Divide (4.3) by $\mathbf{Y}^{*}{}_{t+1}$ and get

$$(4.5)\quad \frac{\mathrm{Y}_{t+1}}{\mathrm{Y}^{*}_{t+1}}=1+\frac{p_t^{\mathrm{N}}\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+b_{t,t+1}p_t^{\mathrm{N}}[(1+\varphi^{\mathrm{A}}{}_{t,t+1})p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1}]}{\mathrm{Y}^{*}_{t+1}}$$

$$=1+\pi^{\mathrm{A}}{}_{t,t+1}$$

where $\pi^{\mathrm{A}}{}_{t,t+1}\in(-1,\infty)$ denotes growth rate of general level of prices during (t, t+1) $\in$ **t**. Expand π^{A} to get its functions of φ^{A} and b, respectively [7]

$$(4.6)\quad \pi^{\mathrm{A}}{}_{t,t+1}(\varphi_{t,t+1})=\frac{p_t^{\mathrm{N}}\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+b_{t,t+1}p_t^{\mathrm{N}}[(1+\varphi^{\mathrm{A}}{}_{t,t+1})p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1}]}{p_t^{\mathrm{N}}(p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1})}$$

$$=\frac{\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+b_{t,t+1}[p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1}]}{p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1}}$$

$$=\frac{b_{t,t+1}(p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1})+\varphi^{\mathrm{A}}{}_{t,t+1}p_t\mathrm{Y}^{\mathrm{A}}_{t+1}(1+b_{t,t+1})}{p_t\mathrm{Y}^{\mathrm{A}}_{t+1}+\mathrm{Y}^{\mathrm{N}}_{t+1}}$$

$$=b_{t,t+1}+(1+b_{t,t+1})\lambda^{\mathrm{A}}{}_{t+1}\varphi^{\mathrm{A}}{}_{t,t+1}$$

[7] $\pi^{\mathrm{A}}=b+\lambda^{\mathrm{A}}\varphi^{\mathrm{A}}$ in the continuous time case.

and

$$\text{(4.7)}\quad \pi^{A}_{t,t+1}(b_{t,t+1})=\lambda^{A}_{t+1}\varphi^{A}_{t,t+1}+(1+\lambda^{A}_{t+1}\varphi^{A}_{t,t+1})b_{t,t+1}$$

where

$$\text{(4.8)}\quad \lambda^{A}_{t+1}=\frac{p_t Y^{A}_{t+1}}{p_t Y^{A}_{t+1}+Y^{N}_{t+1}}$$

$\lambda^{A}_{t+1}\in(0, 1)$ is ratio of agricultural to aggregate output at $t+1\in\mathbf{t}$, but calculated with price of $t\in\mathbf{t}$. Note both $\pi^{A}_{t,t+1}(\varphi^{A}_{t,t+1})$ and $\pi^{A}_{t,t+1}(b_{t,t+1})$ are linear functions. For the sake of simplicity without confusions, we omit time subscripts in the following texts. Obviously, there are several relations between π^{A} on the one hand and φ^{A} and b on the other as follows:

$$\text{(4.9)}\quad \frac{d\pi^{A}}{d\varphi^{A}}=(1+b)\lambda^{A}>0$$

$$\text{(4.10)}\quad \frac{d\pi^{A}}{db}=(1+\lambda^{A}\varphi^{A})>0$$

$$\text{(4.11)}\quad \pi^{A}(\varphi^{A}=0)=b$$

$$\text{(4.12)}\quad \pi^{A}(b=0)=\lambda^{A}\varphi^{A}$$

$$\text{(4.13)}\quad b(\varphi^{A}, \pi^{A}=0)\rightarrow b=-\frac{\lambda^{A}\varphi^{A}}{1+\lambda^{A}\varphi^{A}}$$

(4.9) and (4.10) show that the price level varies positively with the relative price as well as the numeraire good price, while (4.11) and (4.12) make clear that π^{A} will vary as soon as each of both the relative price and numeraire good price changes. What is proved through (4.9) and (4.12) is that changes in relative price do have effects on the general price level. In other words, relative price matters with changes in price level. We name effects of relative prices of this kind as stimuli from the real sphere of the economy on the general level of prices.

On the other side, b represents stimuli on the price level from the monetary sphere of the economy because changes in p^{N} result from that of quantity of money in the circulation. It is widely accepted that monetary stimuli can change the monetary prices of all goods including the numeraire good and then change the general level of prices, as seen in (4.11) where $\varphi^{A}=0$ implies no stimuli coming from the real sphere to price level.

Finally, (4.13) shows certain combinations between changes in φ^A and b to ensure π^A=0: b must vary in an opposite direction of φ^A and reach a certain value to fully offset effects of a given change in φ^A on π^A if both φ^A and b are not equal to zero at the same time.

We illustrate $\pi^A(\varphi^A)$ with these combinations in Figure 4.1 where the graphs of $\pi^A(\varphi^A)$ go upwards based on (4.9). π^A=0 as long as neither of both stimuli happens. Also π^A=0 when both stimuli offset against each other completely. For example, b=b_k<0 will just lead to π^A=0 if φ^A=10% in Figure 4.1. $\pi^A \neq 0$ when only one stimulus works and the other one does not respond to offset its effects wholly. In particular, both stimuli may occur in the same direction and reinforce their effects. When e.g. φ^A=10% and b=b_j>0, we have $\pi^A=b_j+10\%(1+b_j)\lambda^A$ with $\pi^A>b_j$ and $\pi^A>10\%\lambda^A$, as shown at the Point B in Figure 4.1. If taking inflations in place of increases in price level, it is clear that there are positive relations between changes in both relative price and inflation. Only when the real sphere reaches an equilibrium at t+1 $\in$ **t** with migration equilibrium during (t, t+1) $\in$ **t**, that is, only when $\varphi^A_{t,t+1}(h^E_{t,t+1})=0$, does no relative price stimulus come to inflation. Otherwise, disequilibrium of the real economy will cause inflation even when b=0. Such the inflation can be understood as an appearance of the real disequilibrium through which it becomes observable. Meanwhile, such the inflation can also be seen as an adjustment of the price level to the real disequilibrium when adjustments of labor migration under given capital growth and its allocations cannot realize migration equilibrium and the relative price varies. However, the necessity of adjustments of this kind is often recognized only through inflations. The inflation forces the economy to reallocate capital and labor in favor of agriculture. Therefore, the real sphere, that is, investment allocation, labor migration and relative price, is relevant to the general level of prices and to macroeconomic fluctuations in the short run.

Figure 4.1 also shows the two stimuli for changes in π^A. The relative price stimulus can be expressed by movements of π^A along the curves $\pi^A(\varphi^A)$ in Figure 4.1, while the monetary one by up- or down-movements of the curves $\pi^A(\varphi^A)$ themselves. If there is a relative price stimulus with φ^A=10%, we still have π^A=0 as soon as b=b_k<0. But when no monetary stimuli take place and

$b=b_j=0$ as Point A indicates, inflation rate will reach $10\%\lambda^A$. However, π^A will be much higher if $b=b_i>0$ as Point B shows because two stimuli reinforce each other to push π^A in a single direction. In this case, the segment of Ob_i on the vertical axis measures main contributions of monetary stimulus to inflation and that of b_iC accounts mainly for the contribution of the relative price stimulus. The graphs show the steeper $\pi^A(\varphi^A)$ will become, the greater a positive b is, that is, a given $\varphi^A \neq 0$ will have stronger effects on π^A when b is positive.

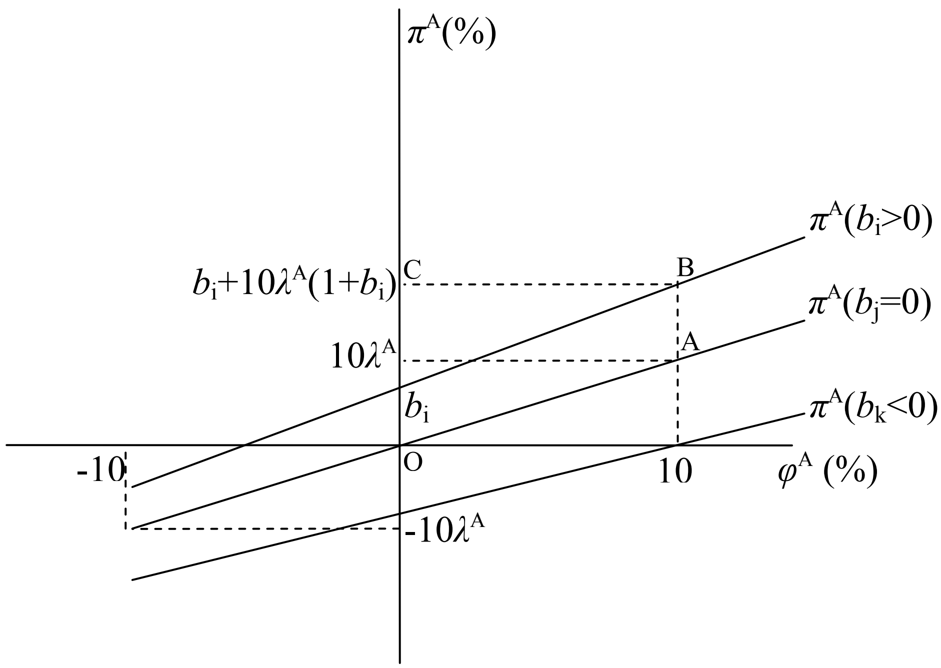

Figure 4.1 Growth Rates of Relative Price, Numeraire Good Price and the General Level of Prices

5. From Prices of Agricultural Products to Food Price within the CPI

The general level of price is useful in deflating the aggregate output of an economy between different time points. But, as mentioned at the beginning of this paper, the consumer's price index

(CPI) as another measure of inflation is used more widely in many economies all over the world, particularly in the developing ones. CPI is certainly far more tractable for statistics than the price level. However, there is something more for CPI from sociological and political viewpoints than from economic and statistical reasons. CPI measures the price changes of goods and services the consumer purchases and hence has immediate relevance with what the public thinks about on their economic well-being. Therefore, CPI is better than the price level to indicate the acceptance of inflation by the public opinions which will create pressure on policy maker to deal with inflation. In the short run, inflation often plays a role of a brake of booms. A reason for such a function of inflation is that the public is not ready to bear inflation. But it is the inflation measured with CPI, not with price level, that the public are concerning about most. Consequently, CPI works as a key signal of short-run macroeconomic performance to guide directions in which individual and public agents act. Furthermore, there are even only data on CPI available to both policy maker and the public in many developing countries which issue no information on the general level of prices. Therefore, we have to expend our analysis from the price level to CPI.

To analyze the relations between relative price of agricultural product and CPI we need several new assumptions regarding CPI as follows:

(1) Agricultural products consist of only what is destined to be processed to food for immediate consumption. In other words, all agricultural products must be processed by the food processing industry before being marketed to final consumption.

(2) All intermediate production and services from purchases of agricultural products at the door of the farms to sales of processed foods to final consumers are included in the food processing industry.

(3) Goods and services whose price information is collected in the framework of CPI can be divided into two groups of food and nonfood, denoted by superscripts of f and nf, respectively.

Let p^{f} and p^{nf} stand for monetary prices of food and nonfood, a^{f} and b^{nf} for their growth rates, and π for growth rate of CPI, respectively, the formula to calculate π during the phase $(\mathrm{t}, \mathrm{t}+1) \in \mathbf{t}$ can be written as follows:

(5.1) $\pi_{t,t+1}=\lambda_{t+1}a^{f}_{t,t+1}+(1-\lambda_{t+1})b^{nf}_{t,t+1}$

where

(5.2) $a^{f}_{t,t+1}=\dfrac{p^{f}_{t+1}-p^{f}_{t}}{p^{f}_{t}}$

(5.3) $b^{nf}_{t,t+1}=\dfrac{p^{nf}_{t+1}-p^{nf}_{t}}{p^{nf}_{t}}$

and $\lambda_{t+1}\in(0, 1)$ is the share of food expenditure in total consumption within the framework of the CPI at $t+1\in\mathbf{t}$. Let p^{c} denote relative price of food to nonfood when nonfood is the numeraire goods. We define p^{c}_{t} at $t\in\mathbf{t}$ and its growth rate during $(t, t+1)\in\mathbf{t}$, $\varphi_{t,t+1}$, as follows:

(5.4) $p^{c}_{t}=\dfrac{p^{f}_{t}}{p^{nf}_{t}}$

and [8]

(5.5) $$\varphi_{t,t+1}=\frac{p^{c}_{t+1}-p^{c}_{t}}{p^{c}_{t}}=\frac{\dfrac{p^{f}_{t+1}}{p^{nf}_{t+1}}}{\dfrac{p^{f}_{t}}{p^{nf}_{t}}}-1=\frac{p^{f}_{t+1}}{p^{f}_{t}}\,\frac{1}{\dfrac{p^{nf}_{t+1}}{p^{nf}_{t}}}-1$$

$$=\frac{1+a^{f}_{t,t+1}}{1+b^{nf}_{t,t+1}}-1$$

$$=\frac{a^{f}_{t,t+1}-b^{nf}_{t,t+1}}{1+b^{nf}_{t,t+1}}$$

(5.5) shows that $\varphi_{t,t+1}=0$ if and only if $a^{f}_{t,t+1}=b^{nf}_{t,t+1}$, that is, only when the prices of both product groups vary at equal speeds and no changes between growth rates of food and nonfood prices occur. Otherwise there will be $\varphi_{t,t+1}\neq 0$. Evaluate $a^{f}_{t,t+1}$ from (5.5) to get

(5.6) $a^{f}_{t,t+1}=b^{nf}_{t,t+1}+(1+b^{nf}_{t,t+1})\varphi_{t,t+1}$

Introduce (5.6) into (5.1) to replace $a^{f}_{t,t+1}$ and omit time subscripts when no confusions seem possible, we obtain: [9]

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[8] $\varphi_{t,t+1}=a^{f}_{t,t+1}-b^{nf}_{t,t+1}$ in continuous time case.

[9] $\pi=b^{nf}+\lambda\varphi$ in continuous time case.

$$(5.7)\quad \pi = \lambda[b^{nf} + (1+b^{nf})\varphi] + (1-\lambda)b^{nf}$$
$$= b^{nf} + (1+b^{nf})\lambda\varphi$$

We suppose that monetary stimuli have the equal effects on all goods and services contained in both the baskets for the general price level as well as CPI, therefore, we have

$$(5.8)\quad b^{nf} = b$$

b is clearly determined by monetary stimuli. Accordingly, these stimuli will not affect variations in φ. φ is subject only to stimuli originated from the real sphere. We assume there would be the same real forces affecting demand for und supply of both agricultural products and food. Therefore, changes in agricultural relative price may be one of the main factors determining changes in food relative price and φ may be a function of $\varphi^A(h)$, that is [10]

[10] (5.9) can be seen as a hypothesis that agricultural relative price is the main determinant of food relative price on the one hand. On the other, (5.9) may be explained and tested with data. In the practice, the Federal Reserve in the United States, for example, observes inflation among other indicators, by means of the measure named 'core inflation". This measure excludes categories of food and energy prices because of their high volatility most resulting from supply shocks. That means changes in food prices are not caused by the monetary policy essentially, which implies in turn that these changes should be ones that are relative to nonfood price. It is acknowledged that "these (*food and energy*) prices have substantial effects on the overall index", but "they often are quickly reversed and so do not require a monetary policy response." (Motley, 1997, italics is added by author of this paper). However, we may point out later that changes in food prices not only have substantial effects on CPI, but also require responses of the monetary authority in some developing countries. Another explanation is based on comparisons of food processing industry with petroleum processing one. In the former there are much more small- and middle-sized firms with low entry barriers, while only a few big or very big firms operate in the latter. Hence the food processing industry looks more like a competitive or a monopolistic competitive sector and its individual firms are price takers. But the latter is of oligopolistic competition and each of its only a few firms has apparent power in making price. Therefore, assumptions such as that capital and labor prices as well as profit margins are determined competitively apply more adequately to the former than to the latter. Technical and organizational innovations in food processing industry are profitable to firms who originate them, but are imitated and caught up with by other firms easily. Therefore, it is less possible for individual firms of food processing to make bigger margin over the costs, especially over costs of purchasing agricultural products. Competition may force individual food processing firms to be satisfied with transmitting changes of agricultural price to food price since a firm with higher-than-average food price will find to be defeated by other firms of the kind. Therefore, changes in food price relative to nonfood price may be a transmission of that in agricultural price relative to nonagricultural ones. See e.g. Gavin and Mandal (2002), Bauer, Haltom and Peterman (2004). .

(5.9) $\varphi=\varphi[\varphi^{A}(h)]$

Both φ and φ^{A} should vary in the same direction as follows

(5.10) $\frac{d\varphi}{d\varphi^{A}}>0$

Introduce (5.8) and (5.9) into (5.7), we get

(5.11) $\pi=b+(1+b)\lambda\varphi[\varphi^{A}(h)]$

$=\pi\{b, \varphi[\varphi^{A}(h)]\}$

While (5.9) links food relative price with migration of agricultural labor together, (5.11) makes the relations between migration and CPI inflation explicitly. But we consider only $\pi(\varphi)$ at the moment. Note $\pi(\varphi)$ is a linear function. Similar to the analysis of the general level of prices above, we obtain some properties of $\pi(\varphi)$ and even $b(\varphi)$

(5.12) $\frac{d\pi}{d\varphi}=(1+b)\lambda>0$

(5.13) $\frac{d\pi}{db}=1+\lambda\varphi>0$

(5.14) $\pi(\varphi=0)=b$

(5.15) $\pi(b=0)=\lambda\varphi$

(5.16) $b(\varphi, \pi=0)\rightarrow b=-\frac{\lambda\varphi}{1+\lambda\varphi}$

The equations of (5.12) to (5.16) have the same forms as that of (4.9) to (4.13) in the last section. Their meanings also are the same except the contents the variables represent. Hence we do not repeat them here. We even can reproduce Figure 4.1 as Figure 5.1 to illustrate relations between π on the one hand and φ and b on the other. A striking difference of Figure 5.1 from Figure 4.1 is that the graphs of $\pi(\varphi)$ go upwards much stepper than that of $\pi^{A}(\varphi^{A})$. It results from differences between the slopes of both graphs. Recall the slopes of $\pi(\varphi)$ and $\pi^{A}(\varphi^{A})$ are $(1+b)\lambda$ and $(1+b)\lambda^{A}$, respectively. λ and λ^{A} can be expressed intuitively as

$$\lambda=\frac{\text{Food Expenditure}}{\text{Total Consumption Expenditure}}$$

and

$$\lambda^{A} = \frac{\text{Agricultural Output}}{\text{Total Aggregate Output}}$$

where p^{nf} and p^{N} are normalized as units and are equal. It is evident that

$$(5.17) \quad \lambda > \lambda^{A}$$

since total consumption expenditure is surely smaller than total aggregate output on the one hand and food expenditure must exceed value of agricultural output on the other because expenditure on food composes not only this value but also the added value of the food processing industry to

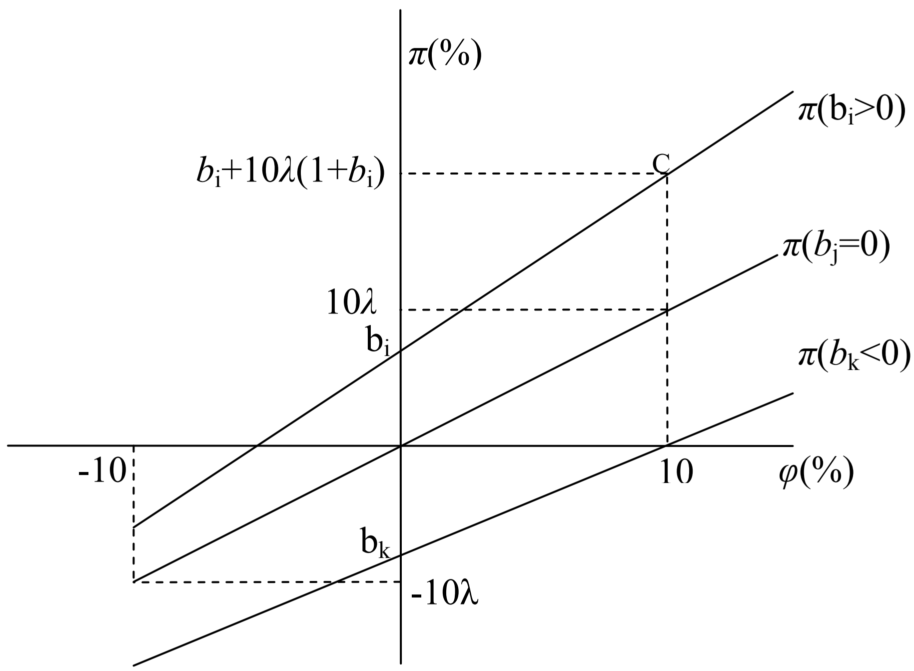

Figure 5.1 Relative Price of Food, Nonfood Price and CPI

agricultural product. Note that the total value of output of the food processing industry which also makes up the market supply of food surpasses the value of raw agricultural product delivered to the industry.[11] (5.17) points out that the effects of changes in food relative price on that of CPI

[11] Empirical values of λ/λ^{A} may lie in the range from 1.5 to 10 and may rise along with economic development.

should be much stronger than in the case between agricultural relative price and the general level of prices. Therefore, substitution of CPI for the price level as the key measure of inflation will substantially strengthen effects of relative agricultural price on inflation as soon as φ lies in the neighboring fields of φ^A. Consequently, migration of labor out of agriculture becomes even quantitatively relevant to the economy-wide inflation and further to short-run macroeconomic performance. In our model, labor migration now has effects on both economic growth and inflation at the same time. From its growth effects migration should be made speedy, that is, h should be greater along with a given investment. But its inflation effects limit its speed within a range accepted by the public and h cannot be too great. It is interactions of both the effects that set up the foundation of the mechanisms for migration equilibrium.

6. Limitation of Monetary Policy and Business Cycles

The economy with labor migration has to adjust itself if disequilibrium of migration prevails. Strong fluctuations or increases in relative price are both an appearance of and a remedy for the disequilibrium. Relative price increases may lead, but are not necessary to lead to economy-wide inflations measured with the general level of price or CPI, as (4.13) and (5.16) show respectively. Corresponding changes in prices of numeraire goods are sufficient to wholly offset stimuli of relative price on the price level or CPI and ensure that no inflations happen. This section will clarify why the adjustments of numeraire goods prices often fail and inflation becomes inescapable.

We begin with Equation (5.16) and Figure 5.1 where φ is assumed 10%.[12] Suppose $\lambda \geq 0.4$ in a typical developing economy with mass labor migration, then we have

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In China the average value for the period from 2000 to 2009 is estimated around 3 roughly if λ is measured by the Engel's coefficient and λ^A by ratio between agricultural and aggregate GDP, see CSY 2011, Table 2-2 and 10.2.

[12] φ exceeded the benchmark of 10% clearly in China in 2007 and 2008, as shown in Table 1.2.

$$(6.1)\quad b(\varphi, \pi{=}0) \rightarrow b_k = -\frac{\lambda\varphi}{1+\lambda\varphi} \approx -3.8\% < 0$$

for stability of CPI and the economy does not see inflation even though food relative price rises clearly.

However, b_k=-3.8% indicates a heavy fall in nonfood monetary prices. It implies that nonfood industries must be facing a difficult situation or even a recession since

(1) Their expected profits cannot be realized at strongly falling product prices.

(2) Wage rates of the nonfood industry have to increase along with the food price moving upwards. Otherwise the purchase power of the wage will decrease and labor forces transfer out. But increases of the wages will result in a severer fall of expected profits for the nonfood industries

(3) The nonfood industries have to reduce production if letting a part of labor forces go away at risen wage.

All these results hold true to the food processing industry as well because its firms can only transfer the increasing costs for purchasing agricultural products to their product prices since the industry is characteristic of low entry barriers and competitive monopoly. Therefore, all nonagricultural industries inclusive both food and nonfood ones suffer from same profit reductions. Only agricultural producers get advantages from the rising agricultural relative price. But agriculture contributes only a small part to aggregate output of the economy and the growth of its output cannot compensate for nonagricultural slowdown. Hence the economy goes with nonagriculture into a recession when agricultural relative price spikes and nonagricultural price falls correspondingly.

To avoid the recession of this kind, the economy will manage to prevent b from falling. Note b is the growth rate of monetary prices of nonagricultural products or nonfood and its changes depend on both relative price and monetary stimuli. What forces b to fall into the range of negative values along with the rise in φ is the insufficiency of money in the circulation as φ begins to rise. In fact, the constancy of money supplied to a given quantity of aggregate output is a presupposition for the possibility that increases in relative prices do not matter for the economy-wide inflation. But the presupposition must be relaxed when the contraction of production or recession of the economy is threatened from strong rises of relative prices. Back to the relations between agricultural relative price and the general level of prices and recall (4.2) to get the well-known equation of exchange: [13]

$$\text{(6.2)} \quad \mathrm{MV}=p^{\mathrm{N}}\mathrm{Y}$$
$$=p^{\mathrm{N}}(p\mathrm{Y}^{\mathrm{A}}+\mathrm{Y}^{\mathrm{N}})$$

where M and V stand for money supplied and its circulation velocity. We omit time notations for sake of simplicity. Let P represent the general level of prices. (6.2) shows that

$$\text{(6.3)} \quad p^{\mathrm{N}}=\mathrm{P}$$

if p does not change. Hence both numeraire good price and the price level are identical as long as the relative price remains unchanged. Then p^{N} or P will vary proportionally to that of MV given Y^{A} and Y^{N}. But p^{N} will separate from P if p changes. It can be demonstrated through (6.2) when the total monetary value of aggregate output do not vary, that is, MV=M*V* and thus P=P*. But p^{N} now must respond to changes in p in an opposite direction when Y^{A} and Y^{N} also are given. Rearrange (6.2) to get

$$\text{(6.4)} \quad p^{\mathrm{N}}=\frac{\mathrm{MV}}{p\mathrm{Y}^{\mathrm{A}}+\mathrm{Y}^{\mathrm{N}}}$$

and

$$\text{(6.5)} \quad \frac{\mathrm{d}p^{\mathrm{N}}}{\mathrm{d}p}=-\frac{\mathrm{MVY}^{\mathrm{A}}}{(p\mathrm{Y}^{\mathrm{A}}+\mathrm{Y}^{\mathrm{N}})^2}=-\frac{pp^{\mathrm{N}}\mathrm{MVY}^{\mathrm{A}}}{pp^{\mathrm{N}}(p\mathrm{Y}^{\mathrm{A}}+\mathrm{Y}^{\mathrm{N}})^2}=-\frac{p^{\mathrm{N}}p\mathrm{Y}^{\mathrm{A}}}{p(p\mathrm{Y}^{\mathrm{A}}+\mathrm{Y}^{\mathrm{N}})}$$
$$=-\lambda^{\mathrm{A}}\frac{p^{\mathrm{N}}}{p}$$

In facing the losses in profits and contraction of production resulting from increases in p,

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[13] (6.2) also exists in the Walras system with two commodities exchanged in a market. Let the *i*th commodity be the numeraire goods for the Walras system with n commodities and take its price, p^{i}, out, we get $\mathrm{MV}=p^{\mathrm{i}}[(p^1/p^{\mathrm{i}})q^1, \ldots, (p^{\mathrm{i-1}}/p^{\mathrm{i}})q^{\mathrm{i-1}}, q^{\mathrm{i}}, (p^{\mathrm{i+1}}/p^{\mathrm{i}})q^{\mathrm{i+1}}, \ldots, (p^{\mathrm{n}}/p^{\mathrm{i}})q^{\mathrm{n}})]$ where q denotes quantities exchanged.

nonagricultural firms and the monetary authority have to struggle to augment MV in order to alleviate falls of b or p^N. One of the means available to the nonagricultural firms is to improve efficiency of their capital, especially the operational part of capital. It means their capital has to flow more quickly than before, particularly since the firms get less sale revenues because of the rises in p. That many firms do so will make higher velocity of money in the circulation and V will rise. On the other side, firms suffering from deficits in funds after both p rose and p^N falls will demand more funds from outside. Hence the firms have to offer higher returns to the money market to mobilize money that usually flows slowly than the average. Therefore, V rises further, accompanying by increases in interest rate, r. Rises of V through both the channels evidently make a space not only for increases in p^N, but also for that in P. The nonagricultural firms take a breath while the economy-wide inflation appears. It is an inflation that appears through rational actions of economic agents in responses to increases in agricultural relative price, without any interventions initiated by the monetary authority. Inflations of this kind are also monetary phenomena, but not phenomena of monetary authority. By the inflation and rising interest rates, the disequilibrium of the real sphere of the economy has transmitted into monetary market. Shortage in supply happens not only in the labor and goods markets now, but also in monetary market. The economy booms, but the crisis looms because of falling profits of nonagricultural firms.

Although spontaneous actions of accelerating velocity of money circulation by private agents to dealing with a rising agricultural relative price can ease the pressure of falling p^N, their effects are often too weak to prevent nonagriculture from a recession since enhancement of circulation velocity of money is limited because flows of money take time on the one hand and money mobilized by higher interests for short run flows is quantitatively limited on the other. The monetary authority has to act since nonagricultural recessions imply economic slowdowns on the whole. That means more money will be issued into circulation and M increases. We look at its effects. Recall (6.2) and (4.5) and rewrite them into the equation of exchange as follows

(6.6) $\mathrm{MV}=\mathbf{Y}$

$= \mathbf{Y}^{*}(1+\pi)$

Let m^{M}, v and g stand for growth rates of M, V and $\mathbf{Y}^{*}$, representatively, and denote

(6.7) $m = m^{M} - g$

m is balance of growth rate of M minus that of $\mathbf{Y}^{*}$ and stands for “surplus money” issued over that for keeping money growth in line with real output growth if both V and relative price, p, remain unchanged. It is known that the Friedman rule of money supply (Friedman, 1960) requires

(6.8) m=0

In consideration of (6.7), we have relations between growth rates of (6.6)

(6.9) $m + v = \pi^{A}$

$= b + \lambda^{A}(1+b)\varphi^{A}$

If monetary authority follows Friedman rule and holds m=0, the interactions of economic agents to enhance efficiency of their money will result into v>0 and

(6.10) $v = \pi^{A} = b + \lambda^{A}(1+b)\varphi^{A} > 0$

where φ^{A}>0. Therefore, we have b>-[$\lambda^{A}\varphi^{A}/(1+\lambda^{A}\varphi^{A})$], that is, b does not need to fall to the level required for fully offsetting effects of rising φ^{A} on π^{A}. When more money is also issued and m>0, then we have

(6.11) $m + v = \pi^{A} > 0 \rightarrow b + \lambda^{A}(1+b^{A})\varphi^{A} > 0$

Through increases in m and v, b does not fall on the value of –[$(\lambda^{A}\varphi^{A})/(1+\lambda^{A}\varphi^{A})$] at all, but possibly rise even to b>0. Nonagriculture seems to get more revenues and could avoid reduction in profits while the economy as a whole seems to escape from a recession at the expense of inflation through monetary expansions. However, CPI inflation, triggered by the same relative price stimuli, is much stronger than inflation measured by price level as explained in the last section. We introduce (6.10) into (5.12) and obtain

(6.12) $\pi = b + (1+b)\lambda\varphi(\varphi^{A})$

and

(6.13) $\pi > \pi^{A}$

since $\lambda > \lambda^{A}$ and φ is assumed to lie in the neighboring fields of φ^{A}. The resulted public pressure will force the monetary authority to tighten its supply of money to limit CPI inflation within an accepted range, which could, however, bring the nonagriculture and the whole economy into a recession finally.[14] The disequilibrium brought about by the bias of nonagricultural investments with too much migration into nonagriculture requires adjustments of the real sphere of the economy. Falling pressure of nonagricultural price and the following inflation are only appearances of the real disequilibrium. Monetary maneuvers alone cannot substitute for adjustments of the real sphere. The economy has to slowdown and to invest more into agriculture to lead agricultural relative price to fall in order to restore equilibrium.[15]

7. Tests

7.1 Introduction

In this section we will use data from China to test some of the main implications of our model. China is the most populous country of the world and has witnessed massive migration of agricultural labor into nonagriculture for several decades. But China's the share of nonagricultural labor still amounts to 38% in 2010 (CSY 2011, Table 4-3) and it should manage to transfer its labor resources from agriculture to nonagriculture further in the future. Therefore, China is a typical nation remaining in the process of economic development with labor migration. On the other hand, China was a centrally commanded economy from 1949 to 1978. It has been

[14] It should be kept in mind that inflations caused by each of both increases in v or m cannot change φ^{A}. Hence inflation can ease the pressure of falling p^{N} on nonagricultural firms, but cannot change the situation of falling profits from which these firms are suffering. One of the functions the inflation has for nonagriculture may be that their wage rate rises more slowly than does food price, which slows the reduction of their profits. But the bias for nonagricultural investments already induced higher labor demand from nonagricultural firms and higher agricultural relative prices, the slower increases in nonagricultural wages cannot compensate for price falls of nonagricultural products and a contraction of nonagricultural production should be unavoidable.

[15] Two interesting examples may support our arguments. After price spike of pork and pork products in 2011, two big companies in China, the Wuhan Iron and Steel and the Shanxi Coking Coal Corporation, announced their plans to invest in pig husbandry and slaughter (News 1, 2012; News 2, 2012).

taking radical reforms to transfer itself into the market economy after 1978. Now the price mechanisms play an indispensable and essential role to allocate economic resources and products while labor and capital flow between sectors and areas on individual calculations largely freely. At the same time, China has built its statistical systems in line with the international standards and now publishes official statistical data regularly as well. Accordingly, we will take the years from 1978 to 2010, the newest year on which systematical data in China are available, as our investigation period.

As pointed out at the beginning of this paper, we have addresses relations between labor migration and agricultural and food relative price. After having shown their logical relations we are to check their empirical ones. The logic chain from intersectoral allocations of investments over labor migration to changes in general level of prices or CPI can be illustrated roughly as follows:

$$\Delta K \rightarrow \mu \rightarrow \theta \rightarrow h \rightarrow \varphi^{A} \rightarrow \pi^{A}\text{: Inflation}$$

or

$$\Delta K \rightarrow \mu \rightarrow \theta \rightarrow h \rightarrow \varphi^{A} \rightarrow \varphi \rightarrow \pi\text{: CPI Inflation}$$

It is very desirable to test if the whole chain is empirically relevant. However, the unavailability of the quantitative information on some of the variables limits our ambitions. For example, systematical data on μ and θ are not accessible on the one hand and cannot be estimated with other statistical materials reliably and consistently on the other. Furthermore, China issues neither integrated price indexes of agricultural and nonagricultural products nor statistics on the general level of prices so that computations of agricultural relative price and its growth rate, φ^{A}, according to (4.6) are not possible. Hence we are forced to test only a part of the chain. It is the relation between changes in both labor migration and food relative price, that is, the relations between h and φ within the CPI framework since dada on h are available and on φ may be estimated in an acceptable range consistently. The relation also is one of the key links of the chain since without it labor migration could not be made relevant to CPI inflation. In sum, we will test if (5.9) exists empirically or if the function of $\varphi=\varphi[\varphi^{A}(h)]=\varphi(h)$ has empirical contents.

7.2 Data

The data from China's labor and employment statistics can be immediately used to calculate labor shares (l) and their difference (h), defined by (2.1) and (2.2) respectively, clearly and consistently, but only yearly, because monthly or quarterly labor data are not accessible in China. Hence our tests must remain with yearly data although data of higher frequency are more adequate for tests of inflation-related hypotheses. As for the CPI, the annual data are available from 1978 and the monthly ones from 2001. All goods and services included in the basket for China's CPI are divided into eight groups. They are food; tobacco, liquor and articles for smoking and drinking; clothing; household facilities; health care and personal articles; transportation and communication; recreation, education and cultural articles, and residence.[16] We reclassify them into only two categories of food and nonfood where food corresponds to the same-named goods group and nonfood contains all other seven groups. The National Bureau of Statistics of China (NBS) delivers price index information on all those eight goods groups beside CPI. Therefore, data on growth rates of CPI and food monetary price, that is, on π and a, are immediately available.

To calculate growth rate of food relative price, φ, through (5.5), we still need data on growth rates of nonfood monetary price, b, which the NBS does not publish yet. To estimate b, we solve (5.1) for b to obtain:

$$(7.1) \qquad b=\frac{\pi - \lambda a}{1-\lambda}$$

where $\lambda \neq 1$. Introducing (7.1) into (5.5) to eliminate b, we get

$$(7.2) \qquad \varphi=\frac{a-\pi}{1+\pi-\lambda(1+a)}$$

[16] According to NBS, there are 600 to 700 representative commodities and services and 56,000 urban and 68,000 rural households selected for surveys for the CPI. The data of the representative goods will then be collected in eight goods groups as mentioned in the main texts. The weights of these good groups for the calculation of the CPI are determined according to the composition of the consumption expenditures of the surveyed households, see. e.g. CSY, 2008, p. 307.

where π-$\lambda(1+a)\neq$-1.[17] Apparently, data on λ are indispensable for the evaluations of both b and φ. However, the NBS does not issue information on any weights of the eight goods groups used for the CPI computation at all.[18] One of several possible methods to decode the weights with accessible statistics published by the NBS[19] is to resort to so called Engel's coefficients, denoted by $e\in(0, 1)$. Firstly, both λ and e have the same or very similar meanings in economics sense and statistical definitions as the ratio between food expenditure and total consumptive expenditure. Secondly, data on the both seem to be collected from the surveys of the same household samples in China.[20]

Unfortunately, the NBS publishes two sets of annual statistics on e for China's urban and rural households separately, but no the aggregated e for the whole country. Hence we have to estimate an aggregate e. Let superscripts r and u the rural and urban households, respectively, we first depict the time series of e^{r}_{t} and e^{u}_{t} data in Figure 7.1. It shows $e^{r}_{t}>e^{u}_{t}$ for every year under review. For a possible aggregate e_t, there must be

[17] This condition is same to that of $[(1+\pi)/(1+a)]\neq\lambda$. It is satisfied when $|\pi|\geq|a|$ since $\lambda\in(0, 1)$ and may not fulfilled when $|\pi|<|a|$.

[18] It is unclear why the NBS does not publish weight data it possesses. Even in the online debates on, after the NBS announced its adjustments of the weights in 2011, if the adjustments were made to artificially decrease CPI figures, the NBS did not explain why they kept the weigh data in secrecy. CPI weighs of the OECD member nations are made publicly by the OECD. Weights of the United States' CPI, for example, for 2009 are 9.8% for food and non-alcoholic beverages, 8.6% for energy and 83.6% for all items less food and energy within the CPI framework (OECD, 2012).

[19] A promising method to find out the weights for eight goods groups including λ is to solve eight simultaneous equations of $\pi_i=\lambda_i a^f_i+\lambda^{b1}{}_i b^1{}_i+\lambda^{b2}{}_i b^2{}_i+\lambda^{b3}{}_i b^3{}_i+\lambda^{b4}{}_i b^4{}_i+\lambda^{b5}{}_i b^5{}_i+\lambda^{b6}{}_i b^6{}_i+\lambda^{b7}{}_i b^7{}_i$, i=1, …, 8, where only λ's are unknowns. The NBS publishes data of π, a^f and b's on a monthly basis from 2001 on. With these monthly data within a single year the λ's of the year concerned should be evaluated from the equation system. The method was employed by the author of this paper, but failed because the results do not correspond to statistical definitions of λ's at all. For example, there are some λ's>1 and/or λ's<0. Sums of all λ's in many computations do not approach to 1. Reasons of the failure are unclear.

[20] For the compilation of data including the Engel's coefficients from private households, there are 56,000 urban and 68 000 rural households selected fur surveys (CSY 2008, p. 342). Both the figures are identical to what are for survey for CPI data may support our methods to make use of Engel's coefficients in the absence of CPI weights.

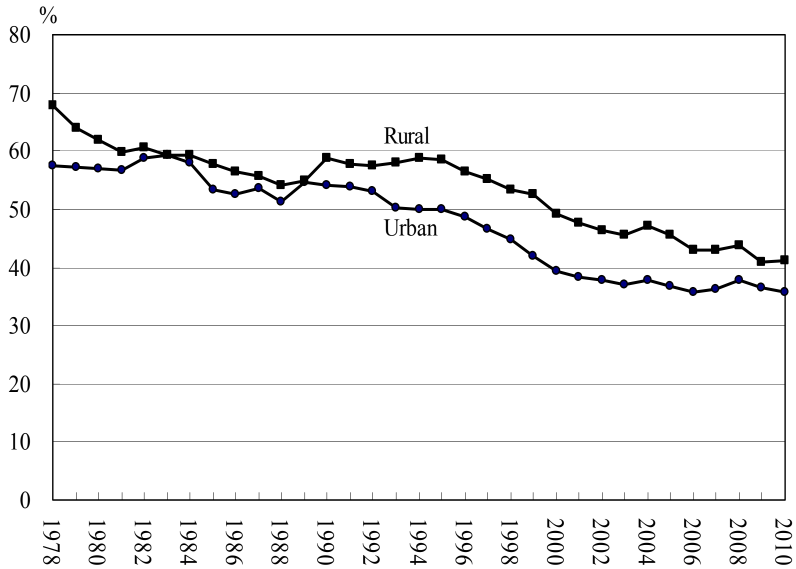

Figure 7.1 Rural and Urban Engel's Coefficients in China, 1978-2010

(7.3) $\quad e^{r}_{t} \geq e_{t} \geq e^{u}_{t}$

Since we do not know convincingly where e_t stands between e^{r}_{t} and e^{u}_{t} for every t, we shall use each of e^{r}_{t}, e^{u}_{t} and their average $e^{av}_{t}=(e^{r}_{t}+e^{u}_{t})/2$ as three quantitatively different representatives of e_t in place of λ_t for the estimations of b_t and φ_t through (7.1) and (7.2).[21]

Let b^{r}_{t} and b^{u}_{t} represent b_t calculated through (7.1) with e^{r}_{t} and e^{u}_{t}, respectively. We illustrate the estimated values of both b^{r}_{t} and b^{u}_{t} in Figure 7.2. The two graphs have several intersections, which means $b^{r}_{t}>b^{u}_{t}$ for some years and $b^{r}_{t}<b^{u}_{t}$ for others, although $e^{r}_{t}>e^{u}_{t}$ for each year during the period concerned. It can be explained with the derivative of (7.1):

(7.4) $$\left|\frac{\mathrm{d}b}{\mathrm{d}e}\right|=\frac{|\pi\text{-}a|}{(1-e)^{2}}$$

[21] The NBS issues information on price index of nonfood as a single group irregularly and scatteredly. For example it announced that annual growth rates of CPI, food and nonfood price would be 5.5%, 11.7% and 2.9% in May, 2011, respectively (NBS, 2011a). With these data we evaluate λ=40.91% for May, 2011 through (5.1). Data on China's Engel's coefficients for 2011 are not available yet. However, in consideration of Engel's coefficients of 2010, e^{r}_{2010}=41.1% and e^{u}_{2010}=35.7%, it is rational to estimate $e^{r}_{2010} \geq \lambda_{2010} \geq e^{u}_{2010}$ and (7.3) should be valid.

where e replaces λ. Value ranges of (db/de) clearly depend on that of (π-a) while the denominator is positive. The trends of both b^r_t and b^u_t are highly similar to each other for the whole period of 33 years as shown in Figure 7.2. Obviously, the graph of the true b_t must lie between these of b^r_t and b^u_t inclusive.

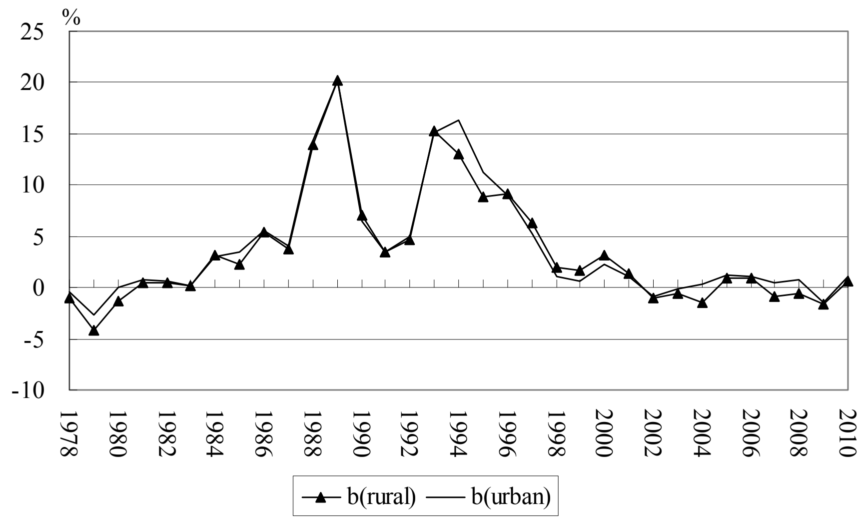

Figure 7.2 Two Estimations of Growth Rate of Nonfood Price in China, 1978-2010

We turn to look at the estimated values of φ which are depicted in Figure 7.3. It is to mention that there is

$$(7.5)\qquad |\frac{d\varphi}{de}|=|\frac{(a-\pi)(1+a)}{[1+\pi-e(1+a)]^2}|>0$$

from (7.2) after replacing e for λ there. Hence selections of e will affect values of estimated φ and in particular we have

$$(7.6)\qquad |\varphi^r_t| \geq |\varphi_t|, |\varphi^S_t| \geq |\varphi^u_t|$$

for every t because of $e^r_t > e^u_t$ in China, where φ^r_t and φ^u_t are computed with e^r_t and e^u_t, and φ_t stands for the true φ and φ^S_t for that calculated with the CPI-weights which are available to the NBS. As shown in Figure 7.3, φ^r_t fluctuates systematically more strongly than φ^u_t. It is also reasonable to assume that the graphs of both φ_t and φ^S_t must run between the two curves of φ^r_t and φ^u_t in Figure 7.3.

Figure 7.3 highlights the surprising magnitude of fluctuations in φ_t in the period of time under review.[22] φ^r_t and φ^u_t might exceed the absolute values of 5% in 16 and 13 of the total 33 years respectively, while their amplitudes should surpass 20 percentage points between -5% and 15%. The height of estimated φ is also reinforced by its comparison with of π. Figure 7.4 shows both ratios (φ^r/π) and (φ^u/π) could exceed the benchmark of 1 in 20 and 19 of total 33 years, respectively, and of 2 in 12 and 10 years. These figures should reveal the importance of φ^u for π.

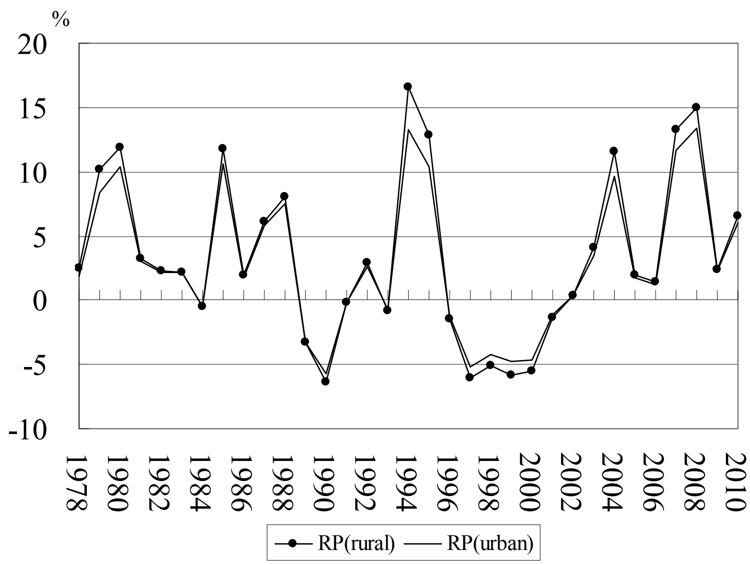

Figure 7.3 Two Estimations of Growth Rate of Food Relative Price

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[22] Our estimations of China's φ's during the period from 1978 to 2010 set up only a very rough range of possible values of φ^S_t. φ^S_t is important because the true φ_t is not observable and φ^S_t is the only representative of φ_t with systematic statistics of long range of time. We do not claim a close approximation of any of the time series of our estimated φ^r_t, φ^u_t and their average $\varphi^{av}_t=(\varphi^r_t+\varphi^u_t)/2$ to φ^S_t. The NBS (2011b) announced at the beginning of 2011 that it changed weights of the eight goods groups for the year 2011, in which λ was reduced 2.21 percentage point, that is, λ_{2011}-λ_{2010}=2.21%. But the NBS did not announce the values of both λ_{2011} and λ_{2010}. In addition, it hints that the weights inclusive λ would be fixed each five years from 2001 on. That means China would so far have only 3 sets of the weights for three five-year-periods of 2001 to 2005, 2006 to 2010 and 2011 to 2015, respectively. However, our estimations are based on a yearly weight.

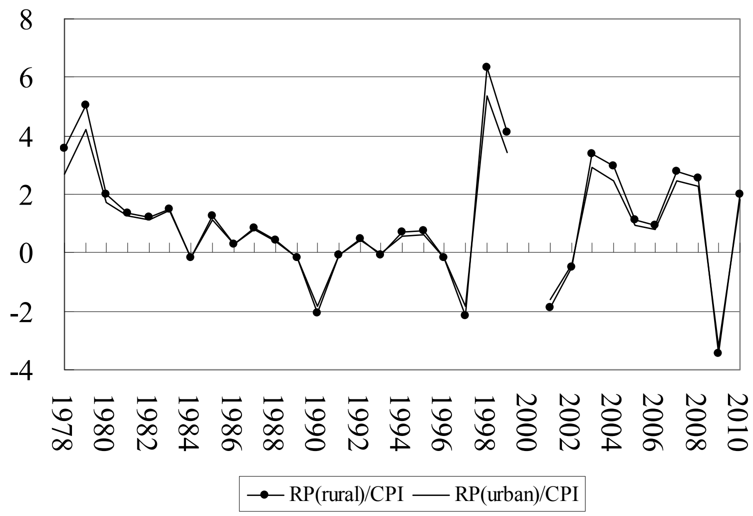

Figure 7.4 Ratios between Growth Rate of Food Relative Price and CPI

Note: (φ^r/π)=13.81 and (φ^u/π)=11.70 in 2000. They are not depicted because of their extremes.

The assuredness of the height of possible values of φ suffers doubtless from our estimation procedures with e in place of λ. In order to get a step freed from bias of our estimations, we calculate an approximation of φ through the difference of growth rate of food price minus that of CPI, that is, through a^f-π, whose values are already shown in Table 1.1 at the beginning of the present paper. Table 1.1 says convincingly that $(a^f_t-\pi_t)$ is far away from zero for the whole period we are investigating. The existence of $|a^f_t-\pi_t|>0$ implies there must be bigger $|\varphi_t|>|a^f_t-\pi_t|$. It can be demonstrated from the denominator of (7.2) [23]

$$1+\pi-\lambda(1+a^f) =1-\lambda+(\pi-\lambda a^f)$$
$$=1-\lambda+(1-\lambda)b = (1+b)(1-\lambda)$$
$$< (1+b)(1-b)$$

[23] In the continuous time case, $\varphi=a_t-b$. Since $b=[(\pi-\lambda a^f)/(1-\lambda)]$ from $\pi=\lambda a^f+(1-\lambda)b$, we have $\varphi=a^f-[(\pi-\lambda a^f)/(1-\lambda)]$ $=(a^f-\lambda a^f-\pi+\lambda a^f)/(1-\lambda)=[(a^f-\pi)/(1-\lambda)]>(a^f-\pi)$.

$=1\text{-}b^2<1$

since both $b \in (-1, 1)$ and $\lambda > b$ exist in China in the period concerned, no matter how big the biases in estimating b and λ by means of e may be. Hence we have

$$(7.7) \qquad |\varphi| = \left|\frac{a - \pi}{1+\pi - \lambda(1+a)}\right| > |a\text{-}\pi|$$

(7.7) also applies to minimum $|\varphi|=|\varphi^u|>|a^f\text{-}\pi|$. It points again that there must be the food relative price whose quantity is too big to be ignored in an analysis of CPI inflations in a developing country as China.

7.3 Tests

Let φ^{av} denotes φ calculated with $(e^r+e^u)/2$. In order to reduce biases of the following tests with the estimated φ's, we will regard φ^{av}, φ^r, φ^u and $(a^f\text{-}\pi)$ as dependent variables for separate tests because φ^S must be greater than $(a^f\text{-}\pi)$ and hence lie in the range defined by both φ^r and $(a^f\text{-}\pi)$ where $|\varphi^r|>|\varphi^{av}|>|\varphi^u|$. The program used for the tests is Eviews 6.0. In order to work with it, we rename and list all dependent and independent variables we select in Table 7.1.

Table 7.1 Variables and their Meanings

No	Variables	Meanings
	P1	φ^{av}
	P2	φ^r
	P3	φ^u
	P4	$a^f\text{-}\pi$
1	H	Migration rate
2	N	Growth rate of total amount of labor
3	LA	Growth rate of agricultural employment
4	Q	Growth rate of per capita grain output

5	ND	Rate of change in ratio of agriculturally utilized areas affected by natural disasters to the areas covered by that
6	G	Growth rate of per capita GDP in comparable prices
7	M	Growth rate of money in circulation
8	W	International food price index

Sources and computations of data on these 12 variables are given in Appendix II. N and especially LA are introduced into the tests for an examination if these two variables of total labor and its allocation can offset or strongly decrease effects of H on relative prices. Q may partly represent supply of agricultural products and ND the natural conditions influencing agricultural production and then supply. Both of Q and ND could have effects on food supply.[24] Demand for agricultural and food products is present with G, growth rate of per capita GDP since data on per capita household income for the whole China are not available. M is listed as an independent variable because it may impact on relative price when the injection of money into the economy has a sector-bias. W is taken into account based on the assumption that changes in global food prices may be transmitted into China. Although there is a fire-wall in China to cut off immediate co-movements between the national und international agricultural and food markets, both markets connect themselves through channels such as export and import of agricultural and food products. Variables such as unemployment rate which plays a key role in explaining inflation in the mainstream macroeconomics will not be considered since it contains in China only unemployed persons who possess the special rights of “city-residence”. Migrants out of agriculture or the rural areas who remain in the cities even when they become jobless after several years employment there will not be counted into unemployment. Hence unemployment rate defined in China is not adequate for economic analysis of inflation in China.

We first make the unit-root tests to see if the time series of the data are trend stationary

[24] Variables immediately refer to agricultural supply are usually used as explanatory ones for food price in empirical researches in the literature, see e.g. Zhang and Luo (2011) and Song (2011) on food monetary price fluctuations.

because only such data are qualified for a meaningful regression analysis. With the Augmented Dickey-Fuller Tests (ADF) we check the twelve data series selected and list the test results in Table 7.2. It shows that the original time series of all these variables pass the Durbin-Watson and ADF tests, respectively, and are trend-stationary at least with probability of 95%, hence can be used for regression analysis.

Table 7.2 Results of the Unit Root Test with ADF methods

Variable	No of Difference	(C, T, K)	DW Value	ADF Value	Results
P1	0	(0,0,0)	1.85	-3.05	I(0) ***
P2	0	(0,0,0)	1.84	-3.06	I(0) ***
P3	0	(0,0,0)	1.86	-3.05	I(0) ***
P4	0	(0,0,0)	1.86	-3.00	I(0) ***
H	0	(C,0,2)	2.18	-3.28	I(0) **
N	0	(C,T,0)	2.01	-5.92	I(0) ***
LA	0	(0,0,0)	1.99	-3.58	I(0) ***
Q	0	(0,0,0)	2.04	-5.58	I(0) ***
ND	0	(0,0,1)	1.82	-5.72	I(0) **
G	0	(C,0,3)	2.03	-3.70	I(0) ***
M	0	(C,0,0)	1.88	-3.30	I(0) ***
W	0	(0,0,0)	1.92	-4.58	I(0) ***

Note: (C, T, K) represents if ADF tests contain intercepts, trends and lags. *** and ** indicate that estimations are at the 1% and 5% significance level, respectively.

The regression equation for the test takes a linear form as follows:

$$\text{(7.8)}\quad P_i=C_i+k_{1,i}H+k_{2,i}H1+k_{3,i}N+k_{4,i}LA+k_{5,i}Q+k_{6,i}ND+k_{7,i}G+k_{8,i}M+k_{9,i}W+\varepsilon_i \qquad (i=1, 2, 3, 4)$$

where H1 stands for H_{t-1}, the first difference of H. The yearly data of H1 are from 1977 to 2009, while data of all other variables extend from 1978 to 2010. The one-period lag of H is taken into account for investigating more deeply if H has any effects on P_i. The regression results are depicted in Table 7.3. It shows that the adjusted correlation coefficients for all four dependent variables lie between 0.40 to 0.42, while all regressions pass DW and F tests. The probabilities of F-values which are smaller than 1% without exceptions indicate that at least some dependent variables are correlated with independent ones significantly.

Table 7.3 Results of the Regression Analysis with Nine Independent Variables

Dependent Variables	Adjusted R^2	DW value	F-value	Probability (F-value)
P1	0.4074	1.8874	3.445 ***	0.008
P2	0.4072	1.9144	3.442 ***	0.008
P3	0.4069	1.8620	3.439 ***	0.008
P4	0.4200	1.8703	3.575 ***	0.007

Note: *** indicate that estimations are at the 1% significance level.

We look at the independent variables shown in Table 7.4 and find only two of the nine variables are significantly correlated with independent variables. They are H1 and W. All other variables even do not pass t-tests at the 10% significance level. In particular, LA, as one of the main indicators of labor migration between agriculture and nonagriculture, seems too weak to be a competitor for the effects on food relative prices against H. The monetary variable does not work might not pose serious problems, while variables as per capita grain production, natural disaster, and per capita GDP which indicate the supply of and demand for agricultural and food products to some extents are not strong enough to have apparent effects on relative prices. ,

Table 7.4 Estimations of the Nine Independent Variables

	P1		P2		P3		P4	
	t-value	Prob.	t-value	Prob.	t-value	Prob.	t-value	Prob.
H	0.135208	0.8936	0.146135	0.8851	0.128634	0.8988	-0.498257	0.6230
H1	** 2.465510	0.0216	** 2.449217	0.0224	** 2.472269	0.0213	** 2.071504	0.0497
N	0.091408	0.9280	0.101582	0.9200	0.080101	0.9369	0.757813	0.4563
LA	-0.055921	0.9559	-0.072452	0.9429	-0.039373	0.9689	-0.732852	0.4711
Q	-1.252295	0.2230	-1.230795	0.2308	-1.269745	0.2169	-1.158231	0.2587
ND	-1.037023	0.3105	-1.016921	0.3198	-1.053882	0.3029	-1.224322	0.2332
G	0.161090	0.8734	0.083929	0.9338	0.228293	0.8214	0.439392	0.6645
M	0.905527	0.3746	0.959298	0.3474	0.856689	0.4005	0.951429	0.3513
W	*** 3.249919	0.0035	*** 3.232142	0.0037	*** 3.260339	0.0034	*** 3.295636	0.0032

Note: *** and ** indicate that estimations are at the 1% and 5% significance level, respectively.

We have to delete N, LA, Q, ND, G and M from (7.8) and form a new equation as follows:

(7.9) $P_i=C_i+k_{1,i}H1+k_{2,i}W+\varepsilon_i$ (i=1, 2, 3, 4)

for the further regression analysis. The estimations are shown in Table 7.5. The four new Adjusted R^2 for (7.9) are clearly greater than that for (7.8) with nine independent variables in Table 7.4, which implies that the deletion of the seven insignificant variables not only increases the explanatory extent of the remaining variables but also improves the quality of the regression equation itself. Both of H1 and W are significantly correlated with each of P's. In particular, estimations of H1 get apparent improvements since they pass the t-tests at the 1% significance level now, while only at the 5% one in the earlier regression analysis. At the same time, all four regression coefficients of H1 are much larger than the corresponding ones of W, meaning that migration of labor has much stronger effects on relative prices of all variants than do international food prices.

Table 7.5 Results of the Regression Analysis with Two Independent Variables

	P1		P2		P3		P4	
Adjusted R^2	0.449896		0.449596		0.449196		0.436489	
F-value	*** 14.08543		*** 14.06957		*** 14.04580		*** 13.39343	
Prob (F-value)	*** 0.000049		*** 0.000049		*** 0.000050		*** 0.000070	
Regression Coefficient								
H1	2.912124		3.165842		2.697136		1.427084	
W	0.228828		0.246459		0.213807		0.127736	
	t-value	Prob.	t-value	Prob.	t-value	Prob.	t-value	Prob.
H1	*** 3.562	*** 0.0013	*** 3.575	*** 0.0012	*** 3.543	*** 0.0013	*** 3.263	*** 0.0028
W	*** 3.179	*** 0.0034	*** 3.161	*** 0.0036	*** 3.190	*** 0.0033	*** 3.318	*** 0.0024

Note: *** indicates that estimations are at the 1% significance level.

Now we go to see the Granger causality between independent variables on the one hand and dependent ones on the other in Table 7.6. It shows that from all independent variables there are only H and G which seems to be the Granger causes of each of four P_i, while all P_i may be causes of Q but only P_1, P_2 and P_3 are causes of G. W, international food price, surprisingly is not the Granger cause of any P_i, although W may be correlated closely with P_i as shown in Table 7.4 and 7.5. Because all Granger causality tests are made with lag 1, that H is the Granger cause of P_i should be understood as H1 being P_i's Granger cause when H1 also correlates with P_i significantly.

Table 7.6 Granger Causality Tests with One-Period-Lag

	P1		P2		P3		P4	
	F-value	Prob	F-value	Prob	F-value	Prob	F-value	Prob
H → Pi	* ** 8.40641	*** 0.0071	* ** 8.38784	*** 0.0071	*** 8.38473	*** 0.0071	*** 6.68141	** 0.0150
Pi → H	1.37919	0.2498	1.44005	0.2398	1.32285	0.2595	1.54846	0.2233
N → Pi	1.7E-05	0.9967	0.00017	0.9896	1.6E-05	0.9969	0.02331	0.8797
Pi → N	0.46641	0.5001	0.42856	0.5179	0.50568	0.4827	0.77595	0.3856
LA → Pi	1.62579	0.2124	1.63121	0.2117	1.61398	0.2140	1.80900	0.1891
Pi → LA	0.82200	0.3721	0.79949	0.3786	0.84567	0.3654	1.36714	0.2518
Q → Pi	0.04525	0.8330	0.03099	0.8615	0.05963	0.8088	0.00029	0.9866
Pi → Q	** 3.01755	* 0.0930	** 3.12042	* 0.0878	** 2.92365	* 0.0980	** 3.24642	* 0.0820
ND → Pi	0.08951	0.7669	0.11077	0.7417	0.07250	0.7896	0.03782	0.8472
Pi → ND	* 2.11285	0.1568	* 2.11938	0.1562	* 2.09873	0.1581	** 2.85221	0.1020
G → Pi	*** 6.65609	** 0.0152	*** 6.75584	** 0.0145	*** 6.54985	** 0.0160	*** 7.10458	** 0.0124
Pi → G	** 2.70949	0.1105	** 2.62673	0.1159	** 2.77724	0.1064	* 2.16432	0.1520
M → Pi	0.74660	0.3946	0.76379	0.3893	0.73252	0.3991	0.74909	0.3939
Pi → M	1.40738	0.2451	1.41927	0.2432	1.39070	0.2479	1.15003	0.2924
W → Pi	0.12842	0.7227	0.11626	0.7356	0.14429	0.7068	0.23298	0.6329
Pi → W	0.47094	0.4980	0.48962	0.4897	0.45983	0.5031	0.50234	0.4841

Note: ***, ** and * indicates that estimations are at the 1%, 5% and 10% significance level

7.4 Conclusions

The regression analysis above may show that there could be statistical correlations between labor migration from agriculture to nonagriculture on the one hand and food relative price on the other in China from 1978 to 2010, and that changes in migration could lead to that of relative price. However, it must be modified since, among other things, (1) Our estimated data on relative prices may not correspond to what are found from calculations with the data on food expenditure weights possessed by the Chinese authority. Therefore, our regression results have to be revised seriously or even given up fully if China makes the data on the weights and nonfood price available to the public. (2) Supplies of agricultural product and of food are certainly two different things. In our regression analysis there are only variables representing some aspects of agricultural supply. We may need to find variables with data series immediately for food supply. (3) An aggregate household disposal income should be a better variable representing factors affecting food demands than GDP since only a part of GDP is allocated for household consumption. It is to hope that the logic of effects of migration on CPI inflation put forward by this paper, and also the regression analysis made above, can contribute to more attention paid by policy maker in the developing countries inclusive China to relative price with the publication of relevant statistics.

Appendix I Computations of A, B, C, Q, R, S, T, τ, u, υ and v

1. Computation of A

It is known from (2.8), (2.9) and (2.10) that

$$\text{(A1)}\quad \mathrm{A}=\frac{\partial p^{\mathrm{L}}}{\partial l^{\mathrm{L}}}$$

$$=-\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}+(1-l)\mathrm{L}^2\frac{1}{(f^{\mathrm{A}})^2}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-l)\mathrm{L}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}+(1-l)\mathrm{L}^2\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}^2f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})^2}$$

$$=\mathrm{L}\frac{1}{f^{\mathrm{A}}}\{-\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}+(1-l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-l)\mathrm{L}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}+(1-l)\mathrm{L}\frac{\mathrm{d}^2f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})^2}\frac{l}{l}\frac{\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}}{\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}}\}$$

$$=\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[-1+e_{\mathrm{L}}^{\mathrm{A}}+(1-l)\frac{1}{l}e_{\mathrm{L,MPL}}^{\mathrm{N}}]$$

$$=-\frac{1}{l}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]<0$$

A<0 because all terms at the right-hand side of the last equation sign are positive if the first minus sign is not taken into account, and $l\neq 0$, $f^{\mathrm{A}}\neq 0$..

2. Computation of B

It is known from (2.8), (2.9) and (2.11) that

$$\text{(A2)}\quad \mathrm{B}=\frac{\partial p^{\mathrm{L}}}{\partial \theta^{\mathrm{L}}}$$

$$=(1-l)\mathrm{KL}\frac{1}{(f^{\mathrm{A}})^2}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-\theta)\mathrm{K}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}+(1-l)\mathrm{KL}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}^2f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})\mathrm{d}(\theta\mathrm{K})}$$

$$=(1-l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\{\mathrm{K}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-\theta)\mathrm{K}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}\frac{1-\theta}{1-\theta}+\mathrm{K}\frac{\mathrm{d}^2f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})\mathrm{d}(\theta\mathrm{K})}\frac{\theta}{\theta}\frac{\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}}{\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}}\}$$

$$=(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}[\frac{1}{1\text{-}\theta}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}e_{\mathrm{K}}^{\mathrm{A}}+\frac{1}{\theta}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}e_{\mathrm{K,MPL}}^{\mathrm{N}}]$$

$$=\frac{1}{\theta(1\text{-}\theta)}(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}]>0$$

B>0 because all terms at the right-hand side of the last equation sign are positive and $\theta\neq 0$, $\theta\neq 1$, $f^{\mathrm{A}}\neq 0$.

3. Computation of C

It is known from (2.8), (2.9) and (2.12) that

$$\text{(A3)}\quad \mathrm{C}=\frac{\partial p^{\mathrm{L}}}{\partial \mathrm{K}}$$

$$=\text{-}(1\text{-}\theta)(1\text{-}l)\mathrm{L}\frac{1}{(f^{\mathrm{A}})^{2}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1\text{-}\theta)\mathrm{K}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}+\theta(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}^{2}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})\mathrm{d}(\theta\mathrm{K})}$$

$$=(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\{\theta\frac{\mathrm{d}^{2}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})\mathrm{d}(\theta\mathrm{K})}\text{-}(1\text{-}\theta)\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1\text{-}\theta)\mathrm{K}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}\}$$

$$=(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\{\theta\frac{\mathrm{d}^{2}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})\mathrm{d}(\theta\mathrm{K})}\frac{\mathrm{K}}{\mathrm{K}}\frac{\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}}{\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}}\text{-}(1\text{-}\theta)\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1\text{-}\theta)\mathrm{K}]}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}\frac{\mathrm{K}}{\mathrm{K}}\}$$

$$=(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}[\frac{1}{\mathrm{K}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}e_{\mathrm{K,MPL}}^{\mathrm{N}}\text{-}\frac{1}{\mathrm{K}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}e_{\mathrm{K}}^{\mathrm{A}}]$$

$$=(1\text{-}l)\frac{1}{\mathrm{K}}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[e_{\mathrm{K,MPL}}^{\mathrm{N}}\text{-}e_{\mathrm{K}}^{\mathrm{A}}]$$

C is clearly definable because all terms at the right-hand side of the last equation sign are definable and $\mathrm{K}\neq 0$, $f^{\mathrm{A}}\neq 0$.

4. Computation of Q

It is known from (2.14), (2.18) and (2.19) that

$$\text{(A4)}\quad \mathrm{Q}=\frac{\partial p^{\mathrm{G}}}{\partial \gamma}$$

$$=\frac{f^{\mathrm{N}}}{f^{\mathrm{A}}}>0$$

Q>0 because $f^{\mathrm{A}}>0$, $f^{\mathrm{N}}>0$ and $f^{\mathrm{A}}\neq 0$.

5. Computation of R

It is known from (2.14), (2.18) and (2.20) that

$$\text{(A5)}\quad \mathrm{R}=\frac{\partial p^{\mathrm{G}}}{\partial l^{\mathrm{G}}}$$

$$=\gamma \mathrm{L}\frac{1}{(f^{\mathrm{A}})^2}f^{\mathrm{N}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1\text{-}l)\mathrm{L}]}+\gamma \mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}$$

$$=\gamma\frac{1}{f^{\mathrm{A}}}\{\mathrm{L}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1\text{-}l)\mathrm{L}]}\frac{1-l}{1-l}+\mathrm{L}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}\frac{l}{l}\frac{f^{\mathrm{N}}}{f^{\mathrm{N}}}\}$$

$$=\gamma\frac{1}{f^{\mathrm{A}}}[\frac{1}{1-l}f^{\mathrm{N}}e_{\mathrm{L}}^{\mathrm{A}}+\frac{1}{l}f^{\mathrm{N}}e_{\mathrm{L}}^{\mathrm{N}}]$$

$$=\gamma\frac{1}{l(1-l)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[l\,e_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)\,e_{\mathrm{L}}^{\mathrm{N}}]>0$$

R>0 because all terms at the right-hand side of the last equation sign are positive and $l\neq 0$, $l\neq 1$, $f^{\mathrm{A}}\neq 0$.

6. Computation of S

It is known from (2.14), (2.18) and (2.21) that

$$\text{(A6)}\quad \mathrm{S}=\frac{\partial p^{\mathrm{G}}}{\partial \theta^{\mathrm{G}}}$$

$$=\gamma\frac{\mathrm{K}f^{\mathrm{N}}}{(f^{\mathrm{A}})^2}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-\theta)\mathrm{K}]}+\gamma\frac{\mathrm{K}}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(\theta\mathrm{K})}$$

$$=\gamma\frac{1}{f^{\mathrm{A}}}\{\mathrm{K}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-\theta)\mathrm{K}]}\frac{1\text{-}\theta}{1\text{-}\theta}+\mathrm{K}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(\theta\mathrm{K})}\frac{\theta}{\theta}\frac{f^{\mathrm{N}}}{f^{\mathrm{N}}}\}$$

$$=\gamma\frac{1}{f^{\mathrm{A}}}(\frac{1}{1\text{-}\theta}f^{\mathrm{N}}e_{\mathrm{K}}^{\mathrm{A}}+\frac{1}{\theta}f^{\mathrm{N}}e_{\mathrm{K}}^{\mathrm{N}})$$

$$=\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}]>0$$

S>0 because all terms at the right-hand side of the last equation sign are positive and $\theta\neq0$, $\theta\neq1$, $f^{\mathrm{A}}\neq0$.

7. Computation of T

It is known from (2.14), (2.18) and (2.22) that

$$\text{(A7)}\quad \mathrm{T}=\frac{\partial p^{\mathrm{G}}}{\partial\mathrm{K}}$$

$$=\text{-}\gamma(1\text{-}\theta)\frac{f^{\mathrm{N}}}{(f^{\mathrm{A}})^2}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-\theta)\mathrm{K}]}+\gamma\theta\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(\theta\mathrm{K})}$$

$$=\gamma\frac{1}{f^{\mathrm{A}}}\{(1\text{-}\theta)\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{\mathrm{d}f^{\mathrm{A}}}{\mathrm{d}[(1-\theta)\mathrm{K}]}\frac{\mathrm{K}}{\mathrm{K}}+\theta\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(\theta\mathrm{K})}\frac{\mathrm{K}}{\mathrm{K}}\frac{f^{\mathrm{N}}}{f^{\mathrm{N}}}\}$$

$$=\gamma\frac{1}{f^{\mathrm{A}}}(\frac{1}{\mathrm{K}}f^{\mathrm{N}}e_{\mathrm{K}}^{\mathrm{N}}-\frac{1}{\mathrm{K}}f^{\mathrm{N}}e_{\mathrm{K}}^{\mathrm{A}})$$

$$=\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}(e_{\mathrm{K}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})$$

T is clearly definable because all terms at the right-hand side of the last equation sign are definable and $\mathrm{K}\neq0$, $f^{\mathrm{A}}\neq0$.

8. Computation of τ

It is known from (2.27) that

$$\text{(A8)}\quad \tau\frac{1}{\gamma}=\frac{\mathrm{AQ}}{\mathrm{BR}-\mathrm{AS}}$$

$$=\frac{\mathrm{Q}}{\frac{\mathrm{B}}{\mathrm{A}}\mathrm{R}-\mathrm{S}}<0$$

Considering B/A first:

(A9)

$$\frac{\mathrm{B}}{\mathrm{A}}=\{\frac{1}{\theta(1\text{-}\theta)}(1\text{-}l)\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}]\}/\{-\frac{1}{l}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[l(1-e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]\}$$

$$=-\{\frac{1}{\theta(1\text{-}\theta)}(1\text{-}l)[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}]\}/\{\frac{1}{l}[l(1-e_{\mathrm{L}}^{\mathrm{A}})\text{-}(1\text{-}l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]\}$$

$$=-\frac{l(1\text{-}l)}{\theta(1\text{-}\theta)}\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

Hence

$$\text{(A10)}\quad \frac{\mathrm{B}}{\mathrm{A}}\mathrm{R}\text{-}\mathrm{S}=(-\frac{l(1-l)}{\theta(1\text{-}\theta)}\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}})\{\gamma\frac{1}{l(1-l)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[l e_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)e_{\mathrm{L}}^{\mathrm{N}}]\}$$

$$-\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}]$$

$$=-\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}[l e_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)e_{\mathrm{L}}^{\mathrm{N}}]$$

$$-\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}]$$

$$=-\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\{\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}[l e_{\mathrm{L}}^{\mathrm{A}}+(1\text{-}l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}]\}$$

$$=-\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}][l e_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}][(l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

$$=-\gamma\frac{1}{\theta(1\text{-}\theta)}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\mathrm{X}$$

Note

$$\mathrm{X}=\frac{[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}][l e_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1\text{-}\theta)e_{\mathrm{K}}^{\mathrm{N}}][(l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}>0$$

since all terms in the numerator and denominator are positive.

Therefore,

$$\text{(A11)}\quad \tau\frac{1}{\gamma}=\frac{\mathrm{Q}}{\frac{\mathrm{B}}{\mathrm{A}}\mathrm{R}-\mathrm{S}}$$

$$=(\frac{1}{f^{A}}f^{N})/[-\gamma\frac{1}{\theta(1-\theta)}\frac{1}{f^{A}}f^{N}X]$$

$$=-1/[\gamma\frac{1}{\theta(1-\theta)}X]$$

$$=-\frac{1}{\gamma}\theta(1-\theta)\frac{1}{X}$$

and

$$\text{(A12)}\quad \tau=-\theta(1-\theta)\frac{1}{X}$$

$$=-\theta(1-\theta)\frac{l(1-e_{L}^{A})-(1-l)e_{L,MPL}^{N}}{[\theta e_{K}^{A}+(1-\theta)e_{K,MPL}^{N}][le_{L}^{A}+(1-l)e_{L}^{N}]+[\theta e_{K}^{A}+(1-\theta)e_{K}^{N}][l(1-e_{L}^{A})-(1-l)e_{L,MPL}^{N}]}<0$$

$\tau<0$ because $\theta>0$, $\theta<1$ and $X>0$.

9. Computation of u

It is known from (2.29) that

$$\text{(A13)}\quad u=\frac{AT-CR}{BR-AS}=\frac{T-\frac{CR}{A}}{\frac{B}{A}R-S}$$

We first look at CR in the numerator of (A13)

$$\text{(A14)}\quad CR=[(1-l)\frac{1}{K}L\frac{1}{f^{A}}\frac{df^{N}}{d(lL)}(e_{K,MPL}^{N}-e_{K}^{A})]\{\gamma\frac{1}{l(1-l)}\frac{1}{f^{A}}f^{N}[le_{L}^{A}+(1-l)e_{L}^{N}]\}$$

$$=\gamma\frac{1}{l}\frac{1}{K}L\frac{1}{f^{A}}\frac{1}{f^{A}}f^{N}\frac{df^{N}}{d(lL)}(e_{K,MPL}^{N}-e_{K}^{A})[le_{L}^{A}+(1-l)e_{L}^{N}]$$

and

$$\text{(A15)}\quad \frac{CR}{A}=\{\gamma\frac{1}{l}\frac{1}{K}L\frac{1}{f^{A}}\frac{1}{f^{A}}f^{N}\frac{df^{N}}{d(lL)}(e_{K,MPL}^{N}-e_{K}^{A})[le_{L}^{A}+(1-l)e_{L}^{N}]\}$$

$$/\{-\frac{1}{l}L\frac{1}{f^{A}}\frac{df^{N}}{d(lL)}[l(1-e_{L}^{A})-(1-l)e_{L,MPL}^{N}]\}$$

$$=-\gamma\frac{1}{K}\frac{1}{f^{A}}f^{N}\frac{(e_{K,MPL}^{N}-e_{K}^{A})[le_{L}^{A}+(1-l)e_{L}^{N}]}{l(1-e_{L}^{A})-(1-l)e_{L,MPL}^{N}}$$

hence

$$\text{(A16)}\quad \mathrm{T}-\frac{\mathrm{CR}}{\mathrm{A}}=\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}(e_{\mathrm{K}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})-\{-\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{(e_{\mathrm{K,MPL}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[le_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}\}$$

$$=\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\frac{(e_{\mathrm{K}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]+(e_{\mathrm{K,MPL}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[le_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

$$=\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\mathrm{Z}$$

Note

$$\mathrm{Z}=\frac{(e_{\mathrm{K}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]+(e_{\mathrm{K,MPL}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[le_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

is definable because all terms in its numerator and denominator are definable and its denominator is positive.

From (A11) we get

$$\text{(A17)}\quad \frac{\mathrm{B}}{\mathrm{A}}\mathrm{R}-\mathrm{S}=\gamma\mathrm{Q}\frac{1}{\tau}$$

$$=\gamma\frac{1}{\tau}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}$$

therefore

$$\text{(A18)}\quad u=\frac{\mathrm{T}-\frac{\mathrm{CR}}{\mathrm{A}}}{\frac{\mathrm{B}}{\mathrm{A}}\mathrm{R}-\mathrm{S}}$$

$$=(\mathrm{T}-\frac{\mathrm{CR}}{\mathrm{A}})/(\gamma\frac{1}{\tau}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}})$$

$$=(\gamma\frac{1}{\mathrm{K}}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}}\mathrm{Z})/(\gamma\frac{1}{\tau}\frac{1}{f^{\mathrm{A}}}f^{\mathrm{N}})$$

$$=\tau\frac{1}{\mathrm{K}}\mathrm{Z}$$

$$=\tau\frac{1}{\mathrm{K}}\frac{(e_{\mathrm{K}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]+(e_{\mathrm{K,MPL}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}})[le_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

u is clearly definable because τ and Z are definable and K≠0.

10. Computation of υ

It is known from (2.32) that

. (A19) υ=-$\tau\frac{\mathrm{B}}{\mathrm{A}}$

Introducing (A9) and (A12) into (A.19) to get

$$\upsilon=-\{-\theta(1-\theta)\frac{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}{[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}][le_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K}}^{\mathrm{N}}][l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}\}$$

$$\{-\frac{l(1-l)}{\theta(1-\theta)}\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}\}$$

$$=-\frac{l(1-l)[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}]}{[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}][le_{\mathrm{L}}^{\mathrm{A}}+(1-l)e_{\mathrm{L}}^{\mathrm{N}}]+[\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K}}^{\mathrm{N}}][l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]}$$

$$<0$$

$\upsilon<0$ since all terms in the numerator and denominator at the right-hand side of the last equation sign are positive.

11. Computation of v

It is known from (2.32) that

$$\text{(A20)}\quad v=-\frac{1}{\mathrm{A}}(u\mathrm{B}+\mathrm{C})$$

$$=-(u\frac{\mathrm{B}}{\mathrm{A}}+\frac{\mathrm{C}}{\mathrm{A}})$$

We know from (A9) and (A18) that

$$\text{(A21)}\quad u\frac{\mathrm{B}}{\mathrm{A}}=u[-\frac{l(1-l)}{\theta(1-\theta)}\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}]$$

$$=-u\frac{l(1-l)}{\theta(1-\theta)}\frac{\theta e_{\mathrm{K}}^{\mathrm{A}}+(1-\theta)e_{\mathrm{K,MPL}}^{\mathrm{N}}}{l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}}$$

and from (A1) and (A3) that

$$\text{(A22)}\quad \frac{\mathrm{C}}{\mathrm{A}}=\{(1-l)\frac{1}{\mathrm{K}}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[e_{\mathrm{K,MPL}}^{\mathrm{N}}-e_{\mathrm{K}}^{\mathrm{A}}]\}/\{-\frac{1}{l}\mathrm{L}\frac{1}{f^{\mathrm{A}}}\frac{\mathrm{d}f^{\mathrm{N}}}{\mathrm{d}(l\mathrm{L})}[l(1-e_{\mathrm{L}}^{\mathrm{A}})-(1-l)e_{\mathrm{L,MPL}}^{\mathrm{N}}]$$

$$= -l(1\text{-}l)\frac{1}{\mathrm{K}}\ \frac{e^{\mathrm{N}}_{\mathrm{K,MPL}} - e^{\mathrm{A}}_{\mathrm{K}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}}$$

Hence

$$\text{(A23)}\quad u\frac{\mathrm{B}}{\mathrm{A}} + \frac{\mathrm{C}}{\mathrm{A}} = -u\frac{\theta e^{\mathrm{A}}_{\mathrm{K}} + (1\text{-}\theta)e^{\mathrm{N}}_{\mathrm{K,MPL}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}} - l(1\text{-}l)\frac{1}{\mathrm{K}}\ \frac{e^{\mathrm{N}}_{\mathrm{K,MPL}} - e^{\mathrm{A}}_{\mathrm{K}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}}$$

$$= -\ l(1\text{-}l)[\ u\frac{1}{\theta(1\text{-}\theta)}\ \frac{\mathrm{K}}{\mathrm{K}}\ \frac{\theta e^{\mathrm{A}}_{\mathrm{K}} + (1\text{-}\theta)e^{\mathrm{N}}_{\mathrm{K,MPL}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}} + \frac{\theta(1\text{-}\theta)}{\theta(1\text{-}\theta)}\ \frac{1}{\mathrm{K}}\ \frac{e^{\mathrm{N}}_{\mathrm{K,MPL}} - e^{\mathrm{A}}_{\mathrm{K}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}}\ ]$$

$$= -\frac{l(1\text{-}l)}{\theta(1\text{-}\theta)}\ \frac{1}{\mathrm{K}}\ [u\mathrm{K}\frac{\theta e^{\mathrm{A}}_{\mathrm{K}} + (1\text{-}\theta)e^{\mathrm{N}}_{\mathrm{K,MPL}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}} + \theta(1\text{-}\theta)\ \frac{e^{\mathrm{N}}_{\mathrm{K,MPL}} - e^{\mathrm{A}}_{\mathrm{K}}}{l(1 - e^{\mathrm{A}}_{\mathrm{L}}) - (1 - l)e^{\mathrm{N}}_{\mathrm{L,MPL}}}\ ]$$

$$= -\frac{l(1\text{-}l)}{\theta(1\text{-}\theta)}\ \frac{1}{\mathrm{K}}\ \frac{u\mathrm{K}[\theta e^{\mathrm{A}}_{\mathrm{K}} + (1\text{-}\theta)e^{\mathrm{N}}_{\mathrm{K,MPL}}] + \theta(1\text{-}\theta)[e^{\mathrm{N}}_{\mathrm{K,MPL}} \text{-} e^{\mathrm{A}}_{\mathrm{K}}]}{l(1\text{-}e^{\mathrm{A}}_{\mathrm{L}})\text{-}(1\text{-}l)e^{\mathrm{N}}_{\mathrm{L,MPL}}}$$

Therefore,

$$\text{(A24)}\quad v = -(u\frac{\mathrm{B}}{\mathrm{A}} + \frac{\mathrm{C}}{\mathrm{A}})$$

$$= \frac{l(1\text{-}l)}{\theta(1\text{-}\theta)}\ \frac{1}{\mathrm{K}}\ \frac{u\mathrm{K}[\theta e^{\mathrm{A}}_{\mathrm{K}} + (1\text{-}\theta)e^{\mathrm{N}}_{\mathrm{K,MPL}}] + \theta(1\text{-}\theta)[e^{\mathrm{N}}_{\mathrm{K,MPL}} \text{-} e^{\mathrm{A}}_{\mathrm{K}}]}{l(1\text{-}e^{\mathrm{A}}_{\mathrm{L}})\text{-}(1\text{-}l)e^{\mathrm{N}}_{\mathrm{L,MPL}}}.$$

v is clearly definable because $\theta \neq 0$, $\theta \neq 1$, $\mathrm{K} \neq 0$, $[l(1 - e^{\mathrm{A}}_{\mathrm{L}})\text{-}(1\text{-}l)\, e^{\mathrm{N}}_{\mathrm{L,MPL}}] \neq 0$ and u is definable.

Appendix II Data Explanations

Data on π, also for computations of b and φ

π: growth rate of CPI. Data on CPI for 1978-1984: retail price index, NBS, 2010, Table 1-21; for 1985-2007: CPI, NBS, 2010, Table 1-21; for 2008-2010: CPI, CSY 2011, Table 9-1.

Data on a^f, also for computations of b and φ

a^f: growth rate of food price index. Data on food price index for 1978-1992: food price index within retail price index, CSY1993; for 1993: food price index within retail price index, CSY, 1994; for 1994-2010: food price index within CPI, CSY, different years from 1995 to 2011.

Data on e^r and e^u as weights of food expenditure for computations of b and φ

e^r and e^u: Engel's coefficients of rural and urban households. NBS, 2010, Table 1-23; CSY 2011, Table 10-2. There is no e^u for the year 1979 in the sources. We estimate that $e^u_{1979}=(e^u_{1978}+ e^u_{1980})/2$.

Data on L, L^N and L^A: total, nonagricultural and agricultural labor, for computations of h or H, H1, N and L^A: NBS, 2010, Table 1-4; CSY 2011, Table 4-3.

Data for computations of Q, growth rate of per capita grain production:

Per capita grain production = (Total grain production/Total population)

Data on total grain production: NBS, 2010, Table 1-32; CSY 2011, Table 13-2.

Data on total population: NBS, 2010, Table 1-3; CSY 2011, Table 3-1.

Data for computations of ND, change in ratio of disaster areas affected to areas covered.

ND= the ratio_t -the ratio_{t-1}

Data on the ratio: NBS, 2010, Table 1-33; CSY 2011, Table 13-25.

Data for computations of G, growth rate of per capita GDP:

Data on GDP per capita at constant price: NBS, 2010, Table 1-8; CSY 2011, Table 2-4.

Data for computations of M, growth rate of money in circulation:

Data on money in circulation for 1977-1989: sum of deposits in financial institutions and cash in circulation, NBS, 2010, Table 1-57; for 1990: M2, NBS, 2010, Table 1-57; for 1991-2010: growth rate of M2, CSY2011, Table 19-4. There is no M for the year 1993 in the sources. We estimate that $M_{1993}=(M_{1992}+ M_{1994})/2$.

Data for computations of W, growth rate of international food price index

Data on international food price index: for 1977-1991, wholesale price, price of the year 1995=100: International Financial Statistics (IFS), Yearbook 2001; for 1991-1996, market price index, price of the year 1995=100: IFS, Yearbook 2003; for 1996-2007, market price index, price of the year 2000 =100: IFS, Yearbook 2008; for 2007-2009, market price index, price of the year 2005 =100: IFS, monthly, November 2011.

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