Sectoral Imbalance in Two-Sector Economy with Mobility Constraint and Firm Migration

Li, Xi Hao and Gallegati, Mauro

Department of Economics and Social Sciences (DiSES), Universita Politecnica delle Marche, Piazzale Martelli 8, 60121 Ancona, Italy.

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Mauro Gallegati*†   Xihao Li*‡

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Abstract

We consider a two-sector economy with a low-technology agriculture sector (sector A) and a high-technology manufacture sector (sector M). We investigate the scenario with mobility constraint that worker in sector A, when unemployed, has to afford the migration cost in order to move to sector M. By developing an agent-based two-sector model with computational simulation, we show that productivity growth localized at agriculture sector with mobility constraint leads to a decrease of agricultural market price, sectoral imbalance that workers are trapped unemployed in agriculture sector, and the overall economy experiencing economic downturn. In particular, localized productivity growth leads to both sectors bearing with high unemployment, low level of aggregate output, and low level of aggregate real wage income. Regarding remedy for the economic downturn under this scenario, we investigate the policy of firm migration such that agriculture firms can migrate to manufacture sector together with their employed workers. Agent-based study shows that this policy restores employment in both sectors, with a side effect of an increase of agricultural market price.

Keywords: two-sector model, agent-based economic modeling, productivity growth, sectoral imbalance, economic downturn, mobility constraint

JEL Classification: E17, E24, L52

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*Department of Economics and Social Sciences (DiSES), Università Politecnica delle Marche, Piazzale Martelli 8, 60121 Ancona, Italy.

†Email address: mauro.gallegati@gmail.com.

‡The author would like to thank Cathy Du, Gaia Li, and Sofia Li for invaluable support. Email address: xihao.li@gmail.com.

1 Introduction

Economic growth has been among targets of economic policy for developed and developing countries. Technical progress has been regarded as the main contributor to economic growth, e.g., see Solow (1957) among others. It has the belief that technical progress generates productivity growth, which leads to an overall better-off of the economy. Bearing with this mindset, policy makers, especially in developing countries such as China, are inclined to consider policies to promote technical progress and innovation in association with the target of economic growth.

Technical change, however, does not always guarantee a better-off of the economy. As Delli Gatti et al (2011, 2012) explain analytically with a two-sector framework, productivity growth localized in one sector with the presence of barriers to labor mobility leads to sectoral imbalances and economic downturn. By this tale, they relate the Great Depression with the localized technical progress in agriculture sector in the 1930's, and the recent Great Recession with the advancement of productivity in manufacture sector. Their works deliver the message that policies of promoting technical progress and innovation alone may not attain the overall better-off of the economy. They put forward the question on how to intervene by policy to keep the economy in tune at the time of sectoral imbalances induced by localized productivity growth. From methodological point of view, their works indicate that the interlinkage between sectors makes it difficult to identify the net effect of policy response by analytic models, as the economy emerges feedback loops to digest policy intervention, i.e., the response of one sector to policy influences the response of the other sector which comes back to impact the response of the original sector and so on.

The sophistication of two-sector economy and the limitation of analytic model on evaluating policy response lead us to consider embracing the technique of agent-based modeling (ABM), see e.g., Tesfatsion (2006) and Li (2014) for an introduction of ABM methodology. The application of ABM requires the effort to concretize two-sector economy from analytic models. By paying the cost of concretization, we may develop a computational platform for reproducing sectoral imbalance and economic downturn induced by localized productivity growth and quantitatively evaluating the effects of policy intervention.

In particular, our work concretizes the analytic framework of two-sector economy proposed by Delli Gatti et al (2011). We aim at developing an agent-based computational model for the economy of two sectors, sector A for agriculture sector that applies low production technology and sector M for manufacture sector that applies high production technology.

Our paper is organized as following. First, we review related literature in section 2. Then, we investigate in section 3 the benchmark scenario of free mobility such that, by affording a migration cost, labor force in sector A can move to sector M. We show by agent-based economic modeling and computational simulation that sector A market price decreases when sector A firms encounter idiosyncratic innovation shocks that lead to productivity growth. In this scenario, real wage incomes in both sectors increase, which implies a better-off of the overall economy.

Next, we investigate in section 4 the scenario of mobility constraint such that labor force in sector A has constraint to migrate to sector M. We observe a decrease of sector A market price when sector A firms experience idiosyncratic innovation shocks that lead to productivity growth, a phenomenon also observed under the scenario of free mobility. Different from the scenario of free mobility, the economy with mobility constraint shows that both sectors are trapped with high unemployment. Real wage incomes in both sectors drop down and remain in a level lower than that before innovation shocks. This implies, due to agricultural productivity growth, a worse-off of all workers in the economy. Our observations on the scenario of free mobility in section 3 and on the scenario of mobility constraint in section 4 are consistent with the analysis by Delli Gatti et al (2011), which convinces us to apply the agent-based computational platform on hand to evaluate the effect of policy intervention aiming at recovering the economy from the damage by sectoral imbalances and economic downturn under the scenario of mobility constraint.

Remedies against the economic damage by sectoral imbalances could be various. We consider in section 5 a simple policy of firm migration such that sector A firm has the chance to move to sector M, by fulfilling the obligation that it has to move its employed workers from sector A to sector M as well. We show that the firm migration policy recovers employment in both sectors, with the side effect of an increase in sector A market price. Section 6 concludes.

2 Literature Review

Our work is related to agent-based economic study and macroeconomic policy analysis. Existing economic research and literature have demonstrated the capability of agent-based economic modeling to handle sophisticated economic structures that include two-sector model. To name a few, Dawid et al (2013) depicts an agent-based macroeconomic model with labor market, credit market, and consumption. Riccetti et al (2014) handles an agent-based macroeconomic model with households, firms, and banks interacting in goods market, labor market, credit market, and deposit market. Quite a few ABM researches are concerned with two-sector model in particular, e.g., see Tesfatsion (2006) and Espíndola et al (2006).

For ABM policy analysis, one may see Tesfatsion and Judd (2006) for a review of earlier applications. Recent researches include but not limit to monetary policy studies and banking regulation in relation with financial crisis, e.g., see Teglio et al (2012), Delli Gatti and Desiderio (2014) and Grilli et al (2014); fiscal policy studies in relation with innovation, e.g., see Dosi et al (2013).

Different from existing ABM studies that mainly emphasize market equilibrium, our work contributes to ABM literature by providing a new case study of economic crisis in real sector under two-sector framework. Another contribution of our work is on macroeconomic policy analysis under economic downturn and crisis: we testify the firm migration policy under economic downturn ex post facto, which belongs to industrial policy in macroscopic level.

3 Two-Sector Economy with Free Mobility

Consider a two-sector economy of sector A and sector M with free mobility. Suppose it is under the discrete-time framework for period $t \in \{1, \ldots, T\}$. Firms are indexed by $i \in \{1, \ldots, I\}$, and households (labor forces) are indexed by $h \in \{1, \ldots, H\}$. Firms in each sector are assumed to produce output by using labor as the only input with a constant-returns-to-scale technology. Both sectors are competitive markets.

We denote variables in sector A and M with the superscript of A and M respectively. Denote I^A and I^M as the number of firms in sector A and M, H^A and H^M as the number of households (labor forces) in sector A and M respectively.

At the beginning of period t, firm $i \in \{1, \ldots, I\}$ starts with its productivity and net worth. Denote $\delta_{i,t}^A$ or $\delta_{i,t}^M$ for firm i's productivity at period t at sector A or sector M. Similarly, denote firm's net worth as $A_{i,t}^A$ or $A_{i,t}^M$.

We assume $\delta_{i,t}^A$ and $\delta_{i,t}^M$ are heterogeneous among firms, with its average value denoted by:

$$\overline{\delta_{i,t}^A} := \frac{1}{I^A} \sum_{i=1}^{I^A} \delta_{i,t}^A = a_t, \text{ and } \overline{\delta_{i,t}^M} := \frac{1}{I^M} \sum_{i=1}^{I^M} \delta_{i,t}^M = m_t$$

where a_t and m_t denote the average output per worker at sector A and M.

Manufacture product is considered as the numéraire good with its price to be unity, i.e.,

$$p_t^M = 1. \tag{1}$$

Under the condition of competitive market equilibrium, the manufacture wage per worker is determined by:

$$w_{i,t}^M = \delta_{i,t}^M \cdot p_t^M = \delta_{i,t}^M, \text{ for firm } i \text{ in sector M.} \tag{2}$$

In Delli Gatti et al (2011), labor force has free mobility to migrate from sector A to sector M, with the annualized value of the total cost of moving from sector A to sector M, denoted as: $f \cdot w_t^M$, where the parameter $0 < f < 1$ represents the migration cost as the proportion of manufacture wage per worker w_t^M charged by the representative firm in sector M. Our model is involved with heterogeneity of manufacture wage per worker $w_{i,t}^M$, upon that, we consider using the average manufacture wage per worker: $w_t^M = \overline{w_{i,t}^M}$, and the migration cost has the form: $f \cdot w_t^M = f \cdot \overline{w_{i,t}^M}$. In this sense, we regard migration cost as the worker's expected migration cost if it migrates from sector A to sector M and is randomly employed among firms in sector M with equal probability.

Sector A determines the agriculture wage per worker under the condition of market equilibrium and free mobility as:

$$w_t^A = (1 - f) \cdot \overline{w_{i,t}^M}. \tag{3}$$

This implies that, under the condition of market equilibrium with free mobility, the equilibrium agriculture wage per worker, w_t^A, is equal to the expected net wage income per worker if the worker migrates from sector A to sector M by paying the migration cost, i.e., $f \cdot \overline{w_{i,t}^M}$.

Firm decides its production by:

$$Q_{i,t}^A = (A_{i,t}^A)^\beta \text{ and } Q_{i,t}^M = (A_{i,t}^M)^\beta$$

where $\beta = 1$ is the parameter for constant-returns-to-scale technology.

It demands the labor input:

$$N_{i,t}^A = \frac{Q_{i,t}^A}{\delta_{i,t}^A} \text{ and } N_{i,t}^M = \frac{Q_{i,t}^M}{\delta_{i,t}^M}.$$

To allow labor force to migrate from sector A to sector M, we consider the procedure that sector A labor market matching is followed by labor force migration, then by sector M labor market matching.

Each household provides one unit of labor. Sector A labor market randomly matches firms for labor demand $N_{i,t}^A$ with households, under the accepted wage per worker $w_{i,t}^A = w_t^A$. If household is not matched in sector A, it bears the migration cost $f \cdot w_t^M$ and enters sector M labor market. Then, sector M labor market randomly matches firms for labor demand $N_{i,t}^M$ with households in sector M together with newly migrated households from sector A, under the accepted wage per worker $w_{i,t}^M$.

After labor market matching, firm i conducts production with its labor input:

$$Q_{i,t}^A = \delta_{i,t}^A \cdot N_{i,t}^A \text{ and } Q_{i,t}^M = \delta_{i,t}^M \cdot N_{i,t}^M.$$

Household h, if employed by firm i, realizes its labor income: $W_{h,t}^A = w_{i,t}^A$ or $W_{h,t}^M = w_{i,t}^M$. It has disposable income $Y_{h,t}^A$ and $Y_{h,t}^M$, which is the aggregation of its labor income and its deposit.

Household in sector A is assumed to spend a fixed portion c_A^A of its disposable income on its consumption of sector A goods, i.e., $c_A^A \cdot Y_{h,t}^A$, and a fixed portion c_A^M of its disposable income on its consumption of sector M goods, i.e., $c_A^M \cdot Y_{h,t}^A$, with the constraint $0 < c_A^A + c_A^M < 1$. The residual amount of disposable income goes to deposit as savings, with the portion $s_A = 1 - c_A^A - c_A^M$. Similarly, household in sector M is assumed to spend the portion c_M^A of its disposable income on sector A goods, i.e., $c_M^A \cdot Y_{h,t}^M$, and the portion c_M^M on sector M goods, i.e., $c_M^M \cdot Y_{h,t}^M$, with the constraint $0 < c_M^A + c_M^M < 1$. The portion of disposable income goes to savings as $s_M = 1 - c_M^A - c_M^M$.

Sector A goods market determines the market price p_t^A by:

$$p_t^A \cdot \sum_i^{I^A} Q_{i,t}^A = c_A^A \cdot \sum_h^{H^A} Y_{h,t}^A + c_M^A \cdot \sum_h^{H^M} Y_{h,t}^M. \tag{4}$$

By admitting the market price p_t^A, sector A goods market randomly allocates agriculture good for firms with supply $Q_{i,t}^A$ and for households with demand $\frac{c_A^A \cdot Y_{h,t}^A}{p_t^A}$ or $\frac{c_M^A \cdot Y_{h,t}^M}{p_t^A}$.

Sector M goods market accepts the market price $p_t^M = 1$, and allocates manufacture good for firms with supply $Q_{i,t}^M$ and for households with demand $c_A^M \cdot Y_{h,t}^A$ or $c_M^M \cdot Y_{h,t}^M$. The residual amount of manufacture goods goes to firm's inventory, which is regarded as investment I_t^M. Sector M goods market has the equilibrium by:

$$p_t^M \cdot \sum_i^{I^M} Q_{i,t}^M = c_A^M \cdot \sum_h^{H^A} Y_{h,t}^A + c_M^M \cdot \sum_h^{H^M} Y_{h,t}^M + I_t^M. \tag{5}$$

After sector A and sector M markets matching, firm i realizes its profit:

$$\Pi_{i,t}^A = p_t^A \cdot Q_{i,t}^A - w_{i,t}^A \cdot N_{i,t}^A \text{ and } \Pi_{i,t}^M = Q_{i,t}^M - w_{i,t}^M \cdot N_{i,t}^M$$

Then it updates its net worth:

$$A_{i,t+1}^A = A_{i,t}^A + \Pi_{i,t}^A \text{ and } A_{i,t+1}^M = A_{i,t}^M + \Pi_{i,t}^M.$$

Assume agriculture good is perishable such that it can not be transferred to next period, while manufacture good as inventory is transferred to next period, with a constant depreciation rate κ^M. After payments in goods markets, household h puts the remains of its disposable income into deposit, and transfers to next period.

At the end of period t, if firm has zero or negative net worth, i.e., $A_{i,t+1}^A \leq 0$ or $A_{i,t+1}^M \leq 0$, it exits the market with immediate replacement of new firm. If household obtains agriculture good less than the threshold amount for its survival, assumed to be one unit, it exits the market with the replacement of new household.

3.1 Agent-Based Simulation

We conduct the agent-based computational simulation for the two-sector economy with free mobility. The simulation is involved with 50 firms, 200 households, for $1,100$ periods with first 100 periods dropping out for initialization. We thus present the simulation result for $t = 1, \ldots, 1000$ periods.

Firms and households are randomly assigned to sector A or sector M. The simulation assumes household stays in its sector once assigned, the only possibility

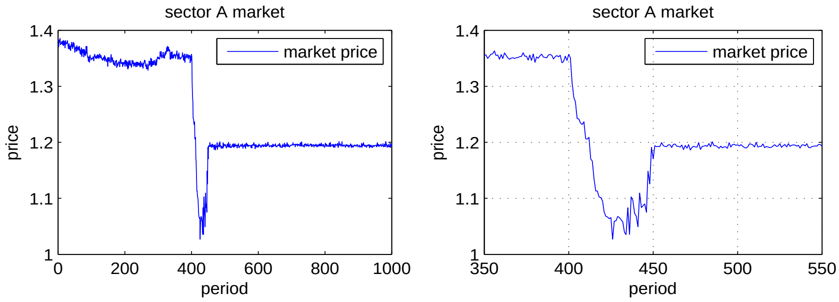

Figure 1: agricultural market price

to switch between sectors is by migration process. To have free mobility, even when household's deposit is not enough to pay the migration cost, it can move from sector A to sector M first, and pay the migration cost later by the end of period with its realized wage income. When exiting the economy, firms and households are replaced immediately by new entry firms and households within sectors, i.e., household exiting sector A is replaced immediately by new entry household entering sector A, and so on. Total labor supply in the economy is fixed, sector A and sector M adjust employment level to ensure full employment in both sectors.

It assumes household saves 5% of its income at each period as deposit that might be used to pay the migration cost. Household working in sector A spends 50% of its income on the consumption of agriculture goods while 45% of its income on manufacture goods. Alternatively, household working in sector M spends 45% of its income on the consumption of agriculture goods while 50% of its income on manufacture goods.

The simulation assumes an innovation shock hit at sector A for each period $t = 401, \ldots, 450$. Firms with equity level $A^A_{i,t} \in [\underline{A^I_t}, \overline{A^I_t}]$ is affected, generating 5% productivity growth. The lower bound $\underline{A^I_t}$ and the upper bound $\overline{A^I_t}$ are randomly chosen at each period $t = 401, \ldots, 450$.

3.2 Simulation Result

We observe the simulated two-sector economy experiences a decrease in agricultural market price after the agricultural productivity growth at period $t = 401, \ldots, 450$, see Figure 1. The average market price before agricultural productivity growth is $\overline{p^A}\,|_{t=1,\ldots,400} = 1.35$, while the average market price after productivity growth is $\overline{p^A}\,|_{t=451,\ldots,1000} = 1.19$, decreasing by 11.7%.

The simulated economy observes an increase in aggregate output in both sectors induced by agricultural productivity growth, see Figure 2. The average level of aggregate output in sector A before agricultural productivity growth is $\overline{Q^A}\,|_{t=1,\ldots,400} = 1204$, while that after productivity growth is $\overline{Q^A}\,|_{t=451,\ldots,1000} = 1681$, increasing by 39.62%. The average level of aggregate output in sector M before agricultural productivity growth is $\overline{Q^M}\,|_{t=1,\ldots,400} = 1628$, while that after productivity growth is $\overline{Q^M}\,|_{t=451,\ldots,1000} = 1974$, increasing by 21.25%.

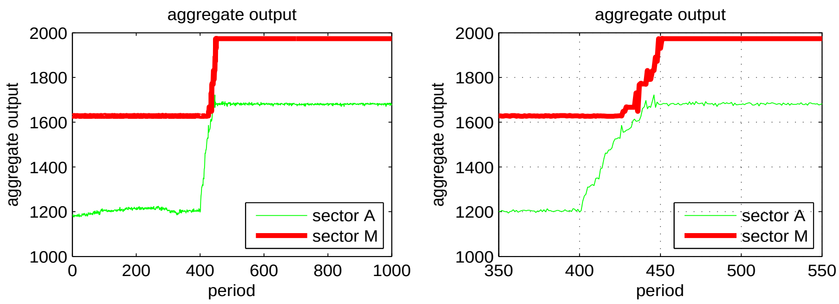

Figure 2: aggregate output

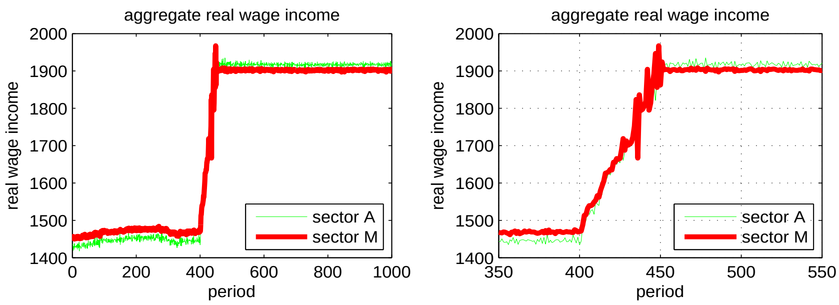

Figure 3: aggregate real wage income

Productivity growth in sector A leads to higher level of real wage income for households in both sectors, see Figure 3. The average level of aggregate real wage income for sector A workers before agricultural productivity growth is $\overline{W^A}\,|_{t=1,\ldots,400} = 1445$, while that after productivity growth is $\overline{W^A}\,|_{t=451,\ldots,1000} = 1917$, increasing by 32.66%. The average level of aggregate real wage income for sector M workers before agricultural productivity growth is $\overline{W^M}\,|_{t=1,\ldots,400} = 1468$, while that after productivity growth is $\overline{W^M}\,|_{t=451,\ldots,1000} = 1902$, increasing by 29.56%.

Both sectors remain full employment along time horizon, except that sector M for the time window of agricultural productivity growth records the highest unemployment rate 6.9%.

Agricultural productivity growth leads to household migrating from sector A to sector M, see Figure 4. The simulated economy observes 17 households migrate from sector A to sector M in total, which amounts to 14.17% of sector A workers.

In economic point of view, the simulated economy shows that agricultural productivity growth leads to household migration from sector A to sector M, and shrinks the size of labor force in sector A. Higher agricultural productivity increases output per worker, which compensates the impact of the shrinking labor force in sector A. The net effect is that aggregate output in sector A grows rapidly by 39.62%.

Agricultural productivity growth also leads to an increase of wage per worker in sector A, which compensates the shrinking of labor force in sector A. As a

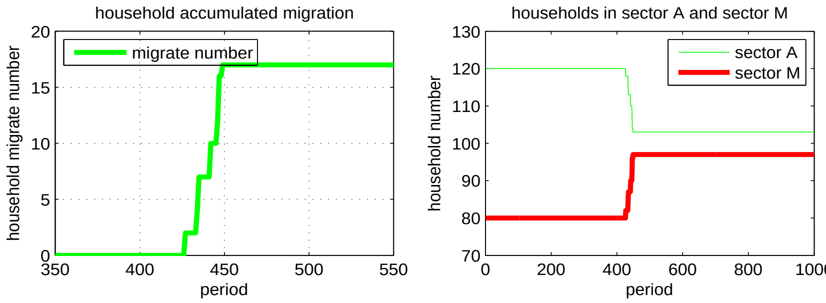

Figure 4: household migration

net effect, aggregate real wage income in sector A increases by 32.66%. The migration from sector A to sector M expands the labor force in sector M, and leads to higher aggregate real wage income in sector M, increasing by 29.56%. The increase of aggregate real wage income in both sectors implies that workers in both sectors are better-off, which is the first main finding from the simulated economy.

The increase of aggregate real wage income in both sectors leads to an increase of aggregate demand in both sectors, due to the fact that household spends fixed proportions of its income on sector A and sector M goods, the increase of aggregate demand in sector A is no greater than 32.66%, which is less than the percentage increase of aggregate output in sector A with 39.62%. Equation (4) thus implies that the simulated economy experiences a drop of sector A market price, which is the second main finding from the simulated economy.

These two main findings from the simulated economy, i.e., the decreasing of sector A market price and the better-off for workers in both sectors, are consistent with the analysis by Delli Gatti et al (2011).

4 Two-Sector Economy with Mobility Constraint

Two-sector economy with mobility constraint follows the same structure as that with free mobility, by two important variations. First, the scenario with mobility constraint assumes that the household has to complete the payment of the migration cost before it moves to sector M. It happens that the household cannot afford the migration cost and there exists some labor force ‘trapped’ in sector A labor market. In this case, sector A labor market is isolated from sector M labor market, and the agriculture wage per worker is determined by market clearing conditions in sector A market alone, i.e.,

$$w^A_{i,t} = \delta^A_{i,t} \cdot p^A_t$$

Since p^A_t is not yet determined by that time, we take a naive expectation to use the market price from previous period such that the agricultural wage is determined by:

$$w^A_{i,t} = \delta^A_{i,t} \cdot p^A_{t-1}. \tag{6}$$

Secondly, as proposed in Delli Gatti et al (2011), we generalize the model slightly to assume that workers in sector M have heterogeneous reservation wages, and they supply labor to those firms willing to pay a wage higher than their reservation wages. Sector M labor market adjusts to ensure full employment in the sense that everyone who wants a job at the current wage level can get one.

To implement this generalization, we assume that manufacturing output is no longer the numéraire good, its market price p_t^M is determined by market clearing condition:

$$p_t^M \cdot \sum_i^{I^M} Q_{i,t}^M = c_A^M \cdot \sum_h^{H^A} Y_{h,t}^A + c_M^M \cdot \sum_h^{H^M} Y_{h,t}^M. \tag{7}$$

Sector M firm decides its heterogeneous wage offering by taking a naive expectation on the market price, i.e.,

$$w_{i,t}^M = \delta_{i,t}^M \cdot p_{t-1}^M. \tag{8}$$

Thus, in the scenario of mobility constraint, Equation (4), (6), (7), and (8) determine wages and prices for sector A and sector M markets.

4.1 Agent-Based Simulation

We conduct the agent-based computational simulation for the two-sector economy with mobility constraint. The simulation is involved with 50 firms, 200 households, for $1,100$ periods with first 100 periods dropping out for initialization. It shares the same parameter sets and the same setup for agricultural productivity growth as the simulation for the scenario of free mobility. For a reason that will become clear in the later context, here we present the simulation result for $t = 1, \ldots, 600$ periods.

4.2 Simulation Result

We observe the simulated economy experiences a decrease in relative agricultural market price (relative to manufactural market price), denoted by $p^{A/M} := p^A/p^M$, after the agricultural productivity growth at period $t = 401, \ldots, 450$, see Figure 5. The average relative agricultural market price before agricultural productivity growth is $\overline{p^{A/M}}\,|_{t=1,\ldots,400} = 1.34$, while the average relative agricultural market price after productivity growth is $\overline{p^{A/M}}\,|_{t=451,\ldots,600} = 1.04$, decreasing by 22.39%.

The simulated economy observes a decrease in aggregate output in both sectors induced by agricultural productivity growth, see Figure 6. The average level of aggregate output in sector A before agricultural productivity growth is $\overline{Q^A}\,|_{t=1,\ldots,400} = 1185$, while that after productivity growth is $\overline{Q^A}\,|_{t=451,\ldots,600} = 1071$, decreasing by 9.62%. The average level of aggregate output in sector M before agricultural productivity growth is $\overline{Q^M}\,|_{t=1,\ldots,400} = 1585$, while that after productivity growth is $\overline{Q^M}\,|_{t=451,\ldots,600} = 1117$, decreasing by 29.53%.

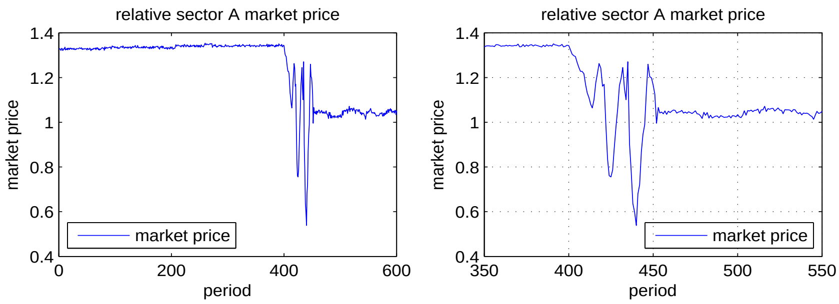

Figure 5: relative agricultural market price

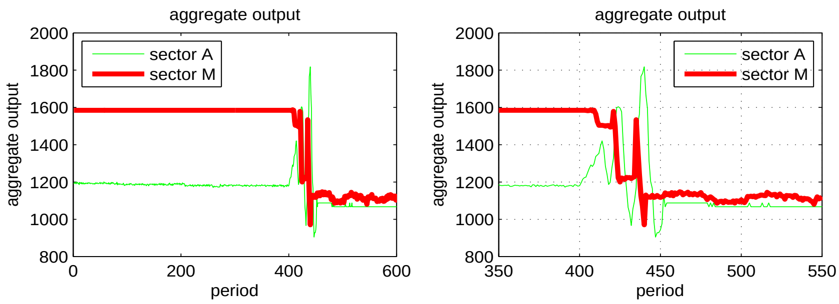

Figure 6: aggregate output

Agricultural productivity growth leads to lower level of aggregate real wage income for households in both sectors, see Figure 7. The average level of aggregate real wage income for sector A before agricultural productivity growth is $\overline{W^A}\,|_{t=1,\dots,400} = 1417$, while that after productivity growth is $\overline{W^A}\,|_{t=451,\dots,600} = 1149$, decreasing by 18.91%. The average level of aggregate real wage income for sector M workers before agricultural productivity growth is $\overline{W^M}\,|_{t=1,\dots,400} = 1439$, while that after productivity growth is $\overline{W^M}\,|_{t=451,\dots,600} = 1153$, decreasing by 19.87%.

Due to mobility constraint, the simulated economy observes no migration induced by agricultural productivity growth. Moreover, agricultural productivity growth leads to large unemployment in both sectors, see Figure 8. The unem-

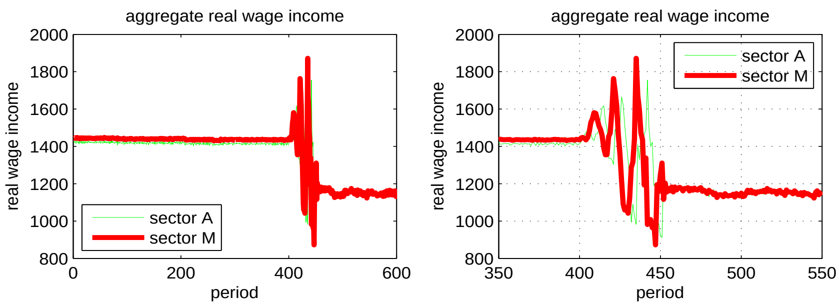

Figure 7: aggregate real wage income

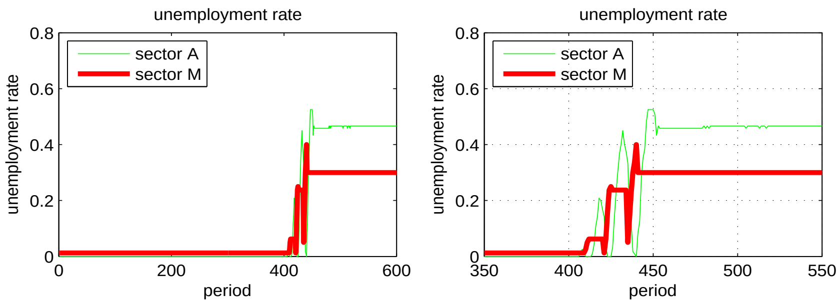

Figure 8: unemployment

ployment rate for sector A before agricultural productivity growth is 0.0%, while that after productivity growth is 46.5%. The unemployment rate for sector M before agricultural productivity growth is 1.25%, while that after productivity growth is 30%.

In economic point of view, the simulated economy with mobility constraint shows that agricultural productivity growth leads to labor force trapped in sector A with high unemployment rate 46.5%. Although agricultural productivity growth also leads to an increase of wage per worker in sector A, the compensation of large unemployment in sector A results in the net effect that aggregate real wage income in sector A decreases by 18.91%.

The decrease of aggregate real wage income in sector A has feedback effect: as household spends fixed proportions of its income on sector A and sector M goods, the decrease of aggregate real wage income in sector A results in a decrease of aggregate demand for goods in both sectors. This triggers production cut among firms with a decrease of aggregate output in both sectors, and a decrease of employment or an increase of unemployment in both sectors. Unemployment in both sectors lead to a further decrease of aggregate real wage income in both sectors, and so on. As a result, the simulate economy observes that aggregate real wage income in sector M decreases by 19.87%, aggregate output in sector A decreases by 9.62%, and aggregate output in sector M decreases by 29.53%.

Notice that aggregate real wage incomes in sector A and sector M decrease by 18.91% and 19.87% respectively, due to the fact that household spends fixed proportions of its income on sector A and sector M goods, the decrease of aggregate demand in both sectors is approximately with the range of 18% to 20%. Observing that aggregate output in sector A decreases by 9.62%, less than the percentage decrease of aggregate output in sector M with 29.53%, Equation (4) and (7) imply the decrease of agricultural market price relative to manufactural market price.

We have two main findings from the simulated economy with mobility constraint: the decrease of aggregate real wage income in both sectors implies workers in both sectors are worse-off, and the decrease of relative agricultural market price. These two findings are, once again, consistent with the analysis by Delli Gatti et al (2011). This consistency, together with the consistency that we obtain in the scenario of free mobility at section 3.2, convinces us to apply this agent-based simulation platform as computational testbed to testify the effect of policy intervention under economic downturn induced by localized productivity growth with mobility constraint.

5 Firm Migration Policy

Suppose in the scenario of mobility constraint, workers are trapped in agriculture sector induced by agricultural productivity growth, we propose the policy of firm migration as a remedy of the economy. In particular, this policy allows firm in sector A to move to sector M, by taking responsibility to move its employed workers from sector A to sector M as well.

5.1 Agent-Based Simulation

We conduct the agent-based computational simulation by implementing the firm migration policy into the existing two-sector economy with mobility constraint. Suppose that firm migration policy comes into effect from period $t = 601$. When either sector has unemployment rate higher than a policy target rate, assumed to be 7%, agriculture firm generating negative profit migrates to sector M. To simplify our analysis, we assume at most one firm migrating to sector M at each period. The newly migrated firm is endowed with equity that is sufficient for hiring the same amount of workers as it did in sector A.

5.2 Simulation Result

The simulated economy obtains 11 firms migration (44% of sector A firms), 84 households migration (70% of sector A workers).

We observe that firm migration leads to an increase of agricultural market price relative to manufactural market price in the simulated economy, see Figure 9. The average relative agricultural market price before firm migration is $\overline{p^{A/M}}\,|_{t=500,\ldots,600} = 1.04$, while that after firm migration is $\overline{p^{A/M}}\,|_{t=651,\ldots,1000} = 5.74$, increasing by 450%.

The simulated economy observes a decrease in aggregate output in sector A and an increase in aggregate output in sector M induced by firm migration, see Figure 10. The average level of aggregate output in sector A before firm migration is $\overline{Q^A}\,|_{t=500,\ldots,600} = 1068$, while that after firm migration is $\overline{Q^A}\,|_{t=651,\ldots,1000} = 569$, decreasing by 46.72%. The average level of aggregate output in sector M before firm migration is $\overline{Q^M}\,|_{t=500,\ldots,600} = 1116$, while the aggregate output after firm migration is $\overline{Q^M}\,|_{t=651,\ldots,1000} = 3268$, increasing by 192.83%.

Firm migration from sector A to sector M leads to lower level of real wage income for households in both sectors, see Figure 11. The average level of aggregate real wage income for sector A workers is $\overline{W^A}\,|_{t=500,\ldots,600} = 1147$ before firm migration, while that after firm migration is $\overline{W^A}\,|_{t=651,\ldots,1000} = 984$,

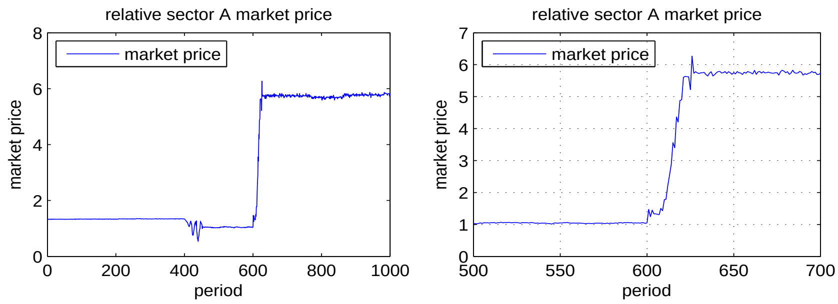

Figure 9: relative agricultural market price with firm migration

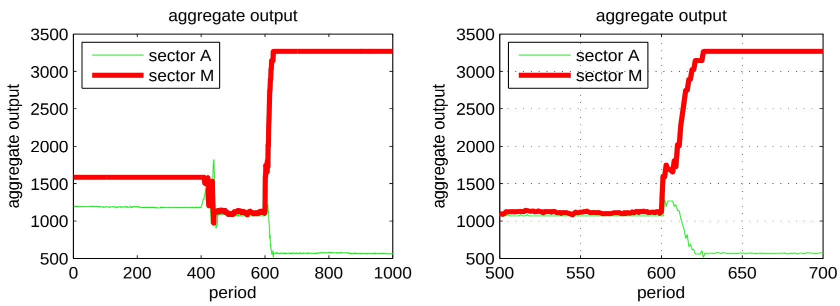

Figure 10: aggregate output with firm migration

decreasing by 14.21%. The average level of aggregate real wage income for sector M workers before firm migration is $\overline{W^M}|_{t=500,\ldots,600} = 1150$, while that after firm migration is $\overline{W^M}|_{t=651,\ldots,1000} = 1060$, decreasing by 7.83%.

Firm migration resolves high unemployment rate in both sectors, see Figure 12. The unemployment rate for sector A before firm migration is 46.5%, while that after firm migration is 0.0%, with zero unemployment. The unemployment rate for sector M before firm migration is 30%, while that after firm migration is 0.0%, with zero unemployment.

In economic point of view, firm migration policy has two effects. On one hand, by sector A firms migrating to sector M, 'trapped' labor force in sector A moves to sector M. On the other hand, when firms migrating to sector M, they

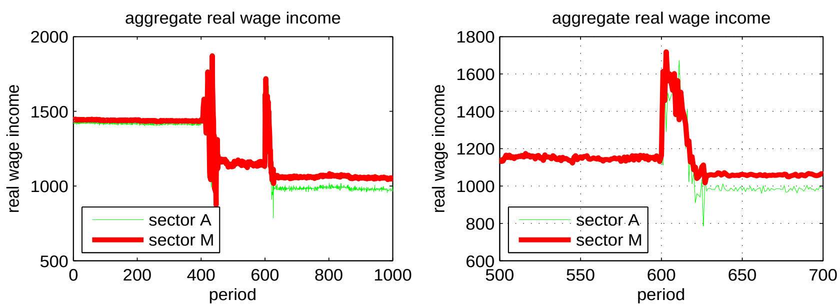

Figure 11: aggregate real wage income with firm migration

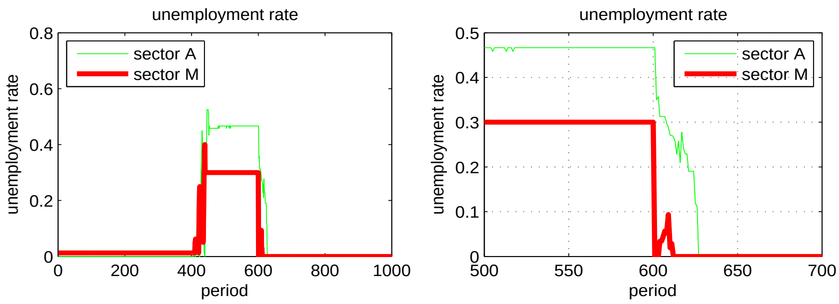

Figure 12: unemployment with firm migration

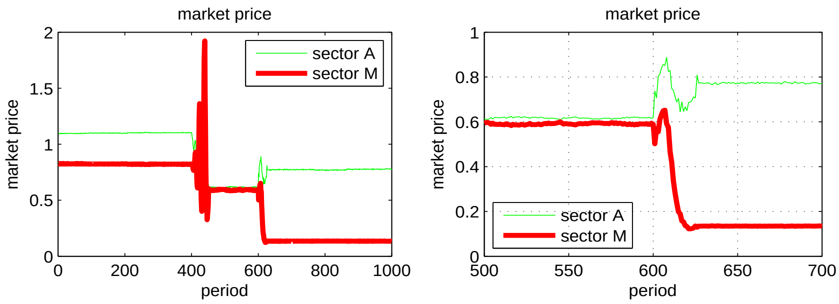

Figure 13: sector A and sector M market price

are endowed with sufficient equity to support their hiring the same amount of workers as they did in sector A. As wage per worker in sector M is higher than that in sector A, this infers an expansion of production base (firm's equity) in sector M while a contraction of production base in sector A. Thus, one may consider firm migration policy as a combination of the policy to migrate labor force from sector A to sector M with the macroscopic industrial policy that shrinks the agriculture sector and expands manufacture sector in the economy.

In particular, the simulated economy shows firm migration policy has the effect that restores full employment in both sectors. Sector A shrinks with a decrease of aggregate output by 46.72%, whereas sector M expands with an increase of aggregate output by 192.83%. The aggregate real wage incomes in sector A and sector M decrease by 14.21% and 7.83% respectively, due to the fact that household spends fixed proportions of its income on sector A and sector M goods, the decrease of aggregate demand in both sectors is approximately with the range of 7% to 15%. Equation (4) and (7) imply the increase of agricultural market price and the decrease of manufactural market price, which is verified by Figure 13. This leads to an increase of relative agricultural market price, which can be regarded as the side effect of employing firm migration policy.

6 Concluding Remark

We have developed the agent-based computational model which concretizes the analytic model of two-sector economy proposed by Delli Gatti et al (2011).

We have investigated the benchmark scenario of free mobility and have shown with computational simulation that localized productivity growth in agriculture sector leads to a better-off of the overall economy. When the economy encounters mobility constraint, we have shown that localized productivity growth in agriculture sector leads to a decrease of agricultural market price relative to manufactural market price, both sectors are trapped with high unemployment, aggregate output and real wage income in both sectors drop down and remain in a level lower than that before productivity growth, the economy experiences economic downturn or crisis. Our observations on the scenario of free mobility and on the scenario of mobility constraint are consistent with the analysis by Delli Gatti et al (2011). In other words, the agent-based two-sector model developed here performs equivalently to the analytic model proposed in Delli Gatti et al (2011). To some extent, this equivalence relieves us from the curse of 'degree-of-freedom' in agent-based economic study.

We have applied in our work the agent-based two-sector model as computational testbed to evaluate the effect of firm migration policy that aims at recovering the economy from the damage by sectoral imbalances under the scenario of mobility constraint. We admit the simplicity of firm migration policy, further experiments with alternative policies shall be included in the future research.

Productivity growth in our work is assumed to be driven by exogenous innovation shocks in agriculture sector. One extension of our work is to endogenize productivity growth, which is among our research agenda.

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