Economic Fluctuations and the Role of Monetary Policy: An Investigation of an Agent-based Model

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Abstract— **The merit of ABM comes directly from removing set of unreal assumptions that are commonly assumed in standard models. Not only can ABM regenerates macroeconomics regularities at the same level as the traditional models without introducing any exogenous process but also displays the ability to capture microeconomics dynamics. Simulation results conform to standard monetary economics theory—expansionary monetary policy can be used as a stabilization tool and leave no permanent impacts to real variables. When an economy experiences growth, an increase in money supply is required to stabilize price level, otherwise, severe deflation is expected as well as high fluctuations in unemployment level. Simple monetary policy can be used to stabilize such fluctuations and would reduced economy-wide default risk, which may have positive economic impacts in the long run. Provided that agents do not hold assets in this model setup, the study supports Friedman's K-percent rule as it performs the best in term of output improvement. The asymmetric effects of monetary policy are found in number of aspects: impact to GDP, impact duration, and impact to unemployment level. Less flexibility in downward price adjustment is the reason behind such asymmetric responses.**

Keywords; Agent-based modeling, complex adaptive systems, monetary policy, endogenous business cycles, economic fluctuations, asymmetric effects of monetary policy, money supply

I. INTRODUCTION

Conventional economic models often rely on extremely unreal set of assumptions from representative agent with perfect foresight to Walrasian's auctioneer-who before any buying and selling takes place in any markets, asks both buyers and sellers the price and the quantity both willing to buy and sell, then simultaneously adjusts the excess supply and demand through price mechanism until all markets are in equilibrium.

In reality, the economy is populated with individuals who may have different preferences and may act differently in response to the same situation. Also, agents are interrelated by a nexus of contractual and delivering arrangements. When one breaches or fails to fulfill the obligation, it can easily cascade through the whole interrelated system, potentially triggering coordination failures on a grand scale. Simultaneous optimization of representative agent as a standard practice of micro-founded framework may not display this matter well enough, sequential decisions of individual agents is more suitable in this regard. Moreover, deliberately choose one agent to represent the whole population of individuals and make inference to aggregates may result in fallacy of composition[1].

As the name suggests, an Agent-based model, henceforth referred to as ABM, focuses mainly on agents and their characteristics. How agents interact? How agents form decision rules and preform the actions accordingly? When we allow agents to interact, process and accumulate information, the model or the economy will evolve overtime resulted in complex and adaptive system. ABM combines many elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming.

ABM can account for what other traditional models have ignored- the very crucial element of the real world economy- agent's heterogeneity, problem relating to heterogeneity and sequential decisions of agents. Instead of focusing on the steady state of the economy and introduce some exogenous elements to trigger the fluctuation, ABM produces fluctuations and other

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[1] See kirman (1992)

economic regularities that internally emerge from the model.

To investigate the pattern of fluctuations, I have developed a simple baseline model proposed by Lengnick (2011) by adding capital input and growth from R&D, which is under the class endogenous growth model. The results of the simulation can match what the conventional model offers and can be looked at as an alternative approach to study economy. Upon investigation, macroeconomics regularities can be reproduced as emergences[2]. Global regularities such as employment fluctuation, growth rates, income distribution are the results of repeated interaction of large number of heterogeneous micro agents. In turns, these regularities feed back another round of information to the determination of agent interaction and their micro behaviors. The loops then emphasize to the emergences of such regularities.

With capital inputs introduced to the model, the results are in support of Solow-Swan growth model. The system will converge to the balance growth path, which is zero in the case of no population growth and the only force that drives investment in capital is reinvestment from depreciation. When the economy experience growth from R&D, increasing money supply is required to support price level, otherwise, serve deflation is expected as well as high fluctuation in price and unemployment level. Simple monetary policy can be used to stabilize such fluctuations and may have positive impact in the long run from its ability to counter high fluctuations. Given that agents do not hold assets, the study supports Friedman's K% rule as it performs the best in overall welfare improvement.

At full employment, increasing money supply may have temporary effect on real output due to the excess capacity and existing inventory in the economy, reducing output gap in New-Keynesian's terminology. The effect, however, is asymmetric between expansionary and contractionary policy.

II. MODEL

A. Model Conceptualization

The economy is populated with households ($h = 1,2,...H$), consumption-goods firms ($f = 1,2,...F_1$),

and capital firms ($f = 1,2,...F_2$), who interact over a discreet time span and decisions of each type of agent is sequential. Agents are bounded rational and limited with information and follow relatively basic behavioral rules. This is the extended version of the Legnick (2011) model aiming to incorporate capital into the economy. Unlike conventional model, capital is not saving, it has to be produced and the use of capital is market driven. Capital can be looked at as intermediate goods called machines, which is produced by capital firms. The way economy utilizes machines is identical labor utilization. Both types of firms engage in exchange market of capital. Capital firms set price in the same way as consumption goods firms- marked up rule. Both type of firms share the same labor force, hence, they set wage the same way. Since there is only one type of labor, capital is perfectly substitutable to labor. However, capital or machines require a certain number of labors to operate it. Capital in short run is a fixed cost, once firms decide to acquire capital, it takes time to liquidate it, and this will create excess capacity in the economy. Consumption goods firms may be restricted in acquiring more capital if they have not got enough labor to operate.

Market structure of capital goods is slightly different from consumption goods. Consumption goods firms and capital firms are all connected, which implied that firms regardless of their type process more information about the economy compared to households and often search for the best possible offers. Nonetheless, this does not mean that consumption firms will always fulfill their demand- market restriction is still in place.

To prevent long run advantages in its cost of input, simulation framework randomizes the order in which the firms will produce during each period. Technology growth in this model is endogenous. Firms preform R&D to obtain higher level of managerial technology or factor augmenting (Hicks-neutral). To simplify the model, only consumption goods firm can preform R&D. Each firm may have different level of technology proxies by size of the firms measured by sales and profit.

The interacting structure of the consumption goods trading in this model is described as follow, which I follow Matthias Lengnick (2011).

1. Each household has trading relationships with a subset of all firms in the economy but is not limited in employment decision. In a certain period of time, household can only buy goods from firms that it has trading connection with. Households can have

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[2] In such systems stable phenomena or relationships can occur on the macro level that can impossibly be deduced directly to micro decisions. These phenomena have came to be called "emergent" in the literature since they are endogenously emerging from micro interactions instead of being assumed on the micro level from the outset and then simply set equal (or summed up) to the macro level.

demand constrain in short run when all firms that it has connection with cannot satisfy its demand.

2. Firms are not limited to this type of interaction structure- goods and labors can be sold to or hire from all households in the economy.

3. Trading network can be re-established after a period of time. Households may search for better price offers and the most expensive offered firm will be removed from the network or a firm that cannot satisfy their demand.

4. Household can visit any firms in the economy they wish; however, not knowing about firm vacancy position status and only a fraction of firms β_n in the economy can be visited in each decision time. If all firms that unemployed households visit do not offer a position, they will stay unemployed until the next decision period. Once employment relationship between firms and households is established, trading connection between employer and worker is established as well, if not exist before.

With this kind of interacting structure, information is limited locally and only available through search effort. Also, this structure represents the friction in the economy allowing some rooms for policy intervention.

Timing of decisions are described as follows. Major decisions take places at the beginning and at the end of the month. Production and market activity happen during the day.

SEQUENCE OF EVENTS

1. Capital Firms and consumption firms preform adaptive demand expectation and obtain production inputs as per plan. Wage/price are set.

2. Employed and unemployed households search for open positions offered from firms they visit and decide whether to accept the offer based on their reservation rate and firm's vacancy status. They continue to visits firms until the number of firms visited reach the level of their efforts.

3. Given price and quantity criteria, households update their trading connection.

4. Households compute their demands on consumption based on their wealth and distributed equally on a daily basis.

These events above occur at the beginning of the month 5,6 will be repeated until the end of the period.

5. Firms produce goods (consumption goods, machines)

6. Households execute their planned demand.

7. Firms pay their wage bills to workers and distribute share of their profit to shareholders. [3]

8. Households adjust their reservation rate.

B. *Model in details*

i) *Consumption-goods firms*

Demand expectation evolve overtime according to

$$d_{f,t}^e = (1 + \phi_i)d_{f,t-1} \text{ if } S_{f,t-1} \geq \gamma_{se} f_{g,t,t-1} \qquad (1)$$

$$d_{f,t}^e = (1 - \phi_i)d_{f,t-1} \text{ if } S_{f,t-1} < \gamma_{sr} f_{g,t-1} \quad (2)$$

where $\phi_i \sim u\,(0, \sigma_\phi)$

$$f_{g,t} = Z_{g,t}(\lambda l_{f,t} + \lambda_k k_{f,t}) \qquad (3)$$

where $\lambda > 0$

Inventory evolves according to

$$i_t = i_{t-1} + f_{g,t} \qquad (4)$$

where $\lambda_k > \lambda > 0$ and $Z_{g,t} \geq 1$ is technology level .

$Z_{g,t} = 1$ when restrict economy form growth

Following Gaffeo (2008),

$$Z_g = Z_{g,t-1} + \epsilon_{f,t}$$

where $\epsilon_{f,t}$ is random exponential with mean υ_z

$$\upsilon_z = \frac{\delta_{f,t} \pi_{t-1}}{(p_{f,t-1}) Y_{t-1}} \qquad (5)$$

where $\delta_{f,t} \sim \bar{\delta}_f + U(0, \sigma_{\delta_f})$ Or retained-earning of firms scaled down by nominal sales; however, this is just a proxy technology improvement where firms do not have to actually pay to obtain R&D. This is to rule out the possibility of firms' bankruptcy.

By assuming this form of production function, it is implicitly assumed that capital stock and labor are perfectly substitutable. Firm with zero capital can operate a production as well as firm with zero labor and only

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[3] The fraction of shares is assumed to be proportional to the level of wealth of each household (Habor, 2008), Legnick (2011).

utilize capital. However, this type of production function is widely used in ABM literatures (Chan, 2008). This kind of production function will not give the economy a total shift to capital usage with no labor input. Due to the fact that, there is a price on capital and its functions as an adjustment mechanism of the optimal ratio of the economy and is normally more costly compared to labor. Nonetheless, minor modification is made on this by putting some restrictions on the level of labor each firm needs to supply their production process.

Essentially, firm will considers the below equation to choose the best alternative.

$$\max\left(\frac{\lambda_k}{p_{k1}\delta_{k1}\tilde{l}}, \frac{\lambda_k}{p_{k2}\delta_{k2}\tilde{l}}, \dots, \frac{\lambda_k}{p_{ki}\delta_{ki}\tilde{l}}, \frac{\lambda_l}{w_f}\right) \quad (6)$$

The above equation is analogous to optimizing behavior of choosing the mixture of capital and labor by comparing $\frac{MP_k}{P_k}$ and $\frac{MP_L}{W}$. The solution, however, with the given production function, it is always a corner solution.

$\tilde{l}$ is the amount of labor required to maneuver the technology according to the specs capital firms give. $\tilde{l} = 1$ if $\tilde{\tilde{l}}_f > \tilde{l}$

where $\tilde{\tilde{l}}_f = l_f - \sum \tilde{l}_f$ or the left over labor that is not operating the machine.

However, a firm may not be able to get the best offer since a firm may not be able to finance the machine. That is, another condition has to be met

$$w_f \geq p_{ki} * k_i + \tilde{l}_k * w_f \quad (7)$$

Firms can only expand their production by acquiring more capital if and only if they are operating at their full capacity, otherwise, they will expand their production by hiring more labor. Even if they decided to increase their capital level, if constrained by labor by the newly acquired machines, positions needed to be offered.

Wage will be adjusted according to past experience of fulfilling the offered position. If the firm has free-position opened, it will consider increasing the wage rate. If, otherwise, all position has been filled with workers for past δ periods, wage rate will be decrease.

$$w_t = w_{t-1}(1 \pm \mu_w) \quad (8)$$

where $\mu \sim U(0, \sigma_w)$

Pricing will be set according to the marked up rules and will adjust corresponding to the last period sales and their unsold inventory.

$$p_{f,t} = p_{f,t-1}(1 + \mu) \text{ if } S_{f,t-1} \geq \gamma_{pi}\lambda f_{g,t-1} \quad (9)$$

where $\mu_p \sim U(0, \sigma_p)$

$$p_{f,t} = p_{f,t-1}(1 - \mu) \text{ if } S_{f,t-1} < \gamma_{pd}\lambda f_{g,t-1} \quad (10)$$

where $\mu_p \sim U(0, \sigma_p)$

Price will rise as long as it does not exceed the $\overline{p}_f$ and decrease as long as the $\underline{p}_f$ is not reached.

$$\overline{p}_{f,t} = \overline{\phi}_f mc_{f,t} \quad (11)$$

$$\underline{p}_{f,t} = \underline{\phi}_f mc_{f,t} \quad (12)$$

ii) Capital firms

The production function of each capital-producing firm is

$$K_{f,t} = \lambda l_{f,t} \quad (14)$$

Capital firms share the same technology as consumption goods firms. Decision on expanding or reducing capacity is identical to consumption-goods firm.

Price is set according to the marked up rules but less restrictive with the margin. Since, capital firms share the same homogeneous labor force as consumption goods firms and know the property of their machine, capital firms can also account the productivity of the machines and average cost of labor into their price setting mechanism.

$$\overline{p}_{k,t} = \overline{\phi}_f(mc_{k,t} + f(\lambda_k, \lambda, \overline{w}_{t-1})) \quad (15)$$

$$\underline{p}_{k,t} = \underline{\phi}_f(mc_{k,t} + f(\lambda_k, \lambda, \overline{w}_{t-1})) \quad (16)$$

Capital goods is produced throughout the month but is sold only at the beginning of the period whereas goods are produced and sold throughout the month.

iii) Capital market structures

Under the assumption that firms are likely to know and process more information about the economy, I assume that capital goods market has some kind of mechanism that will randomly pick an order of consumption-goods firms to buy capital product from capital producing firm where the best offer will be the first in the list.

The first in the buyer list will be able to acquire all the amount of capital it needs to fill their production plan if the first sellers cannot supply or the amount the second in the list will take the bids and the third if the second has not got enough and so on. If none of capital firms provide enough capital, the buyer will take all available leaving the next bidder with nothing. Thus has to rely on labor only. Sellers do not know which order they are in the list only the inventory left in each period, but know how

much they can sell and how much unsold inventory they have, which will be fed back to another round if decision. This kind of structure is commonly practiced in ABM literatures (Chan,2008 Salle- Yıldızoğlu - Sénégas ,2012). Some papers may apply different interaction process for example Dosi and Napoleno (2012) have a capital producing firm advertise their machine to consumption goods firm and get paid in advanced before delivering- to make sure they can finance their production.

iv)   Households

Households plan their monthly consumption at the beginning of the month based on their current wealth and information about price they face (their trading connection). Assuming that real planed consumption expenditure increases with real liquidity at a decreasing rate4

$$c_{h,t} = \left(\frac{M_{h,t}}{\overline{P}_{h,t}}\right)^{\alpha} \text{ if } \frac{M_{h,t}}{\overline{P}_{h,t}} > 1 \qquad (17)$$

$$c_{h,t} = \frac{M_{h,t}}{\overline{P}_{h,t}} \qquad \text{if } \frac{M_{h,t}}{\overline{P}_{h,t}} < 1 \qquad (18)$$

$M_{h,t}$ represents current level of wealth of households

$\overline{P}_{h,t}$ represents current average price level that households face from their trading connection

α parameter satisfying (0,1)

If the firm he visited can supply his daily demand and he has enough liquidity to purchase $m_{h,t} > p_{f,t} c_{h,t}^d$, transaction is executed. Household's liquidity will be transferred to his trade-partner. If otherwise, households have insufficient liquidity to purchase goods from this firm, highest possible amount will be purchased $\frac{m_{h,t}}{p_{f,t}}$ .If the visited firm cannot supply the daily demand of households, the transaction will perform at highest possible amount i_f that a firm can offer. Intensity level of job searching depends of employment status of households. Unemployed household will put an effort of β_u. Employed households who received wage below their reservation will search for new position with an effort of β_b, otherwise β_e. And $\beta_e < \beta_u, \beta_b$. Households would consider revising (lowering) their reservation rate by $\delta_w\%$ if they were unemployed for a curtained period. Once agree to works, the reservation rate is adjusted to the new wage rate they receive. Households will update their trading-network by comparing both price and quantity (if they face demand constraint from the most recent period) of the in-network firms to off-network firms. The highest offers will be compared to a randomly picked offer form off-network firms and the least supplied firm (if they are demand constraint) will be compared to quantity offer form a randomly picked off-network firm.

III.   SIMULATION RESULTS

At this stage, I have no attempt to calibrate the model to match empirical data. All possible numerical values and sensible parameters are allowed, those parameters that degenerating dynamical path by visual inspection are ruled out.[5]

TABLE1: PARAMETERS VALUE

Parameter		Parameter	Value
σ_{ϕ}	0.2	λ	3
σ_p	0.2	λ_k	4
σ_w	0.02	$\tilde{l}$	2
σ_{δ_f}	0.8	δ_k	0.1
γ_{se}	0.9	$\bar{\delta}_f$	0.2
γ_{sr}	0.8	β_e	1
γ_{pi}	0.9	β_b	1
γ_{pd}	0.8	β_u	4
$\bar{\phi}_f$	1.15	$\delta_{w\%}$	Current reservation wage
ϕ_f	1	α	0.9
β_n	10		

General properties of the model are insensitive to different number of agents if the ratio of agent's type remains the same. This emphasizes the fact, which representative agent framework has failed to address, that heterogeneity of agents is one of the causes of coordination failure and, as the results, business cycles.
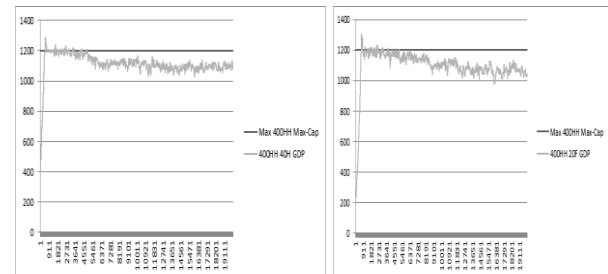

Figure 1. Maximum capacity (potential GDP) is the same between these two setups. However, from visual inspection, the case with 400HH and 20F (right figure) shows higher fluctuation in output

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[4] Following Lengnick (2011) and fundamental psychological law of Keynes (1936)

[5] For example, firms are restricted not to marked-up their price more than some percentage since this will degenerating stable GDP, unemployment.

A. Macroeconomics Regularities

One way to judge the performance of ABM is by its ability to reproduce aggregate empirical laws of the economy without having to resort to any exogenous shock process. Also, the model should be able to display, as a general feature, the ability to self-organize and to display risk of severe recession from coordination failure without recurring to negative aggregate shocks.[6]

Not only can the model regenerates general macroeconomics regularities but also able to capture some microeconomics dynamics. As shown (see Fig. 2 (bottom)), even if the labor input and consumption goods are homogenous, consistent with empirical findings, price and wage do not necessary follow the law of one price. Right-skewed firm's size distribution is also detected- the size is measured by number of workers.

The results from the simulation are also in line with Solow-Swan growth model. Capital accumulation can cause economy to grow, however, the use of capital will converge to some certain optimal level- and the only investment in capital is reinvestment on capital depreciation (see Fig. 2). The economy will converge to balance growth path with the driven factor of population growth and technology factor. Since the population growth in zero in this case, the balance growth path grows at rate of zero if no technology improvement is introduced. Unlike in traditional Solow-Swan theoretical model, capital inputs are not directly derived from household saving; the model explicitly introduces capital-producing firms with marked-up margin in price-setting behavior. By, adding this market factor, the simulation finds volatility in reinvestment on capital input as well. Also, when capital input is introduced into the baseline model proposed by Lengnick (2011), the economy experience higher fluctuation and bigger output gap (compare Fig. 1 and Fig. 2). Because capital input represents consumption firm's fixed cost, once acquired, there is no resell market to liquidate during economic recession. Therefore, adjustment on labor input is amplified.

B. Monetary policy

Monetary policy, in this study, is addressed in a simple form of increasing money supply directly injected to households' nominal wealth. However, such policy will only have temporary impact to economy, price mechanism will absorb the effect.
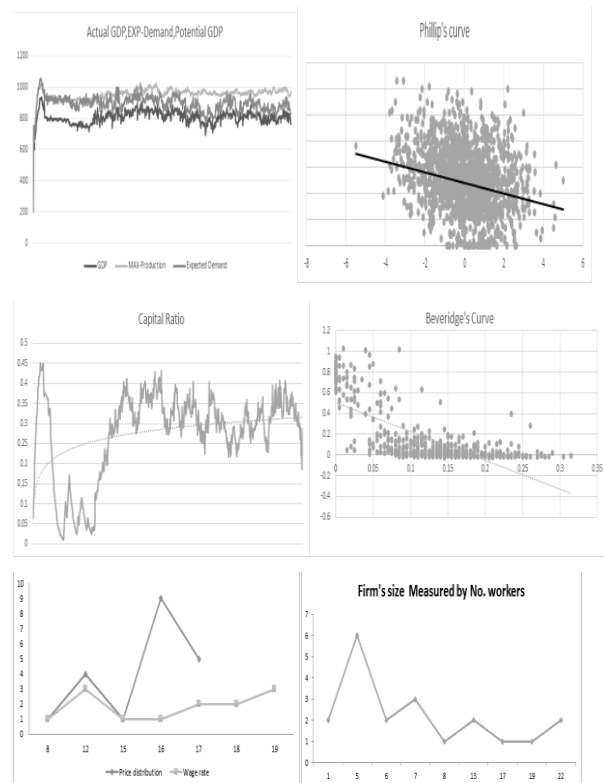

Figure 2. Ability of ABM to reproduce stylized facts without intrducing any exogeneous process.

To visually illustrate this, the extreme case is presented below, with 40% increase in money supply.
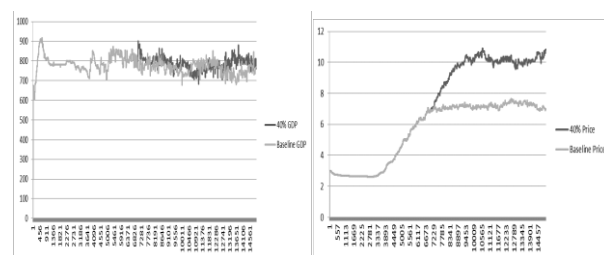

Figure 3. Case of injecting money supply by 40%

As shown, even with enormous amount of money injected into the economy, there is, however, no effect to real output and price will works out to offset the shock. Nonetheless, the opposite may not hold, negative shock, at this amount, may catastrophically damage the economy that will never be brought back with price mechanism.

The mechanism behind the effectiveness of monetary policy in this model come from the nature of

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[6] Gaffeo (2008) ,Lengnick (2011)

agent's heterogeneity, sequential decision making and forgoing the conventional assumption of Walrasian's auctioneer along with marketing clearing mechanism. Injecting wealth directly into households may seems like cheating and forcing the economy to improve. To clarify, it is the nominal wealth that increases and eventually price will spike up and dries out the money delusion. But because the sequential decision making, it take some periods of time before all firms increase their price and adjust their production. And that is the window of opportunity for the monetary policy to be effective in short run.

1) Monetary policy to counter deflation from increasing in productivity parameter.

An investigation of the model shows that, without any policy interventions, a sudden supply shift can cause unemployment level to shoots and fluctuates at an unsatisfying level.

Three cases are presented in this section.

1. Baseline model without increasing money supply

2. Increasing money supply at average of 2% yearly

3. Increasing money supply equals to percentage change of productivity parameter

The simulation runs for 50000 periods, which is equivalent to over 1667 major decision periods (where firms plan their production, set price and households search for a job) or about 138 years. The simulation burns in for 5000 days to make sure all the effect from initial endowment dries out. The key indicator in this regards is to see if price level is stable. Then technology improvement is introduced and different monetary policies are imposed.

Because of the sharply increase in technology level, which is specific to this model, increasing money supply by 2% yearly is considered a very mild policy. Yet, it is clear that it has successfully stabilized both price level and unemployment level-- although may not be able to support price level at the level before the jump of economic growth.

TABLE2: SIMULATION RESULTS ON MONEY SUPPLY CONTROLS

	Price level	Unemployment	Real wage	Firms' loss *	Output
Baseline	Severe Deflation	Highly fluctuate	Growing / Fluctuate	About 20% of firms experience loss	Baseline
2% Money supply increase	Stable	Stable	Growing / stable	About 10%	Cleary better than baseline
Money supply increase = Technology level change	Stable higher in level compare to 2%	Stable	Growing / stable	About 10%	Better than baseline

Only in short-run, no firms accumulates long-term loss. Profit level is directly related to ability to preform R&D.

The speed of adjustment is even better than the case of increasing money supply at the equal rate of growing technology. (see Fig. 4 top right) At the beginning of the economy growth, price level in the case of 2% policy drops down very fast, yet is fairly stable afterward. In the case of M = Z or increasing money supply equal to percentage change in technology takes longer time to get back to the stable path.

Both MP rules, however, preforms equally well in stabilizing unemployment level (Fig.4 top left).

The stabilization property comes from the fact that MP pours liquidity into the economy at the time it needs the most. When technology improves, firm's capacity will increase given the same input level. Thus, either price or labors, or both will be reduced giving the economy long period of deflationary and high unemployment rate. When MP is imposed, households will have more liquidity, thus, more goods are bought and sold. Hence firms will not have to adjust their production

by laying off their workers. And with fixed K% rules, firms with adaptive demand expectation will have higher chance of getting the demand expectation right and plan their production accordingly compared to the uncertainty of M%=Z% rules.

Moreover, there is the second effect of pouring 2% nominal money into the system that is price level is stable. In another words, nominal money flooded in earlier become more valuable giving another round of positive effect to loop in the system over and over again.

Noted that, I have given a proof earlier that expansionary monetary policy in this simple form has no positive impact to long-term output level. At best, it can have temporary effect on the real output no greater than the maximum capacity of the supply side, aka at potential GDP level, and the effects will, later on, be diluted by the increase of price level. The story is difference in endogenous growth model. In term of long-run growth (see Fig. 5), the economy with money injected into is a

clear better off. This effect comes directly from the benefit of sizing down the volatility in business cycles. R&D is directly associated with profit level of firms, with less economy-wide default risk (see Fig. 4 bottom right). Chances are firms will become more successful in research and development, hence higher growth and overall improvement in overall output. (see Fig. 5). As the simulation results show price level is just arbitrary and is a meaningless measure of economic performance, it does not have to be supported in order to increase overall performance of the economy. The real danger needed to keep eyes on is the fluctuation in price level which can undermines the economy in the long run. Increasing money supply at the level of technology change may help price to sustain at the higher level but no other economic performance in comparison to the k% rule.
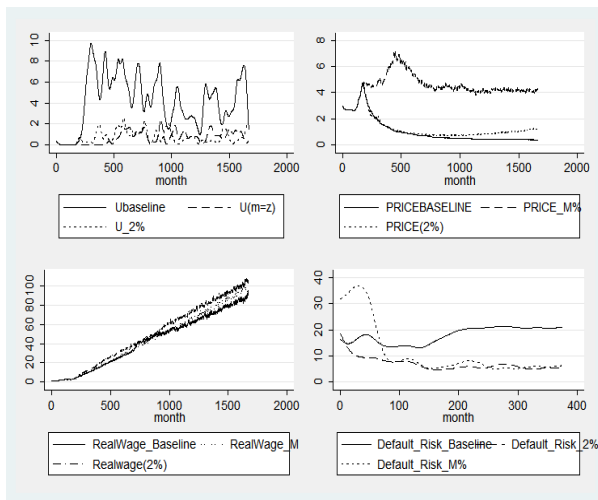
Figure 4. Unemployment, price level, real wage and economy-wide default risk of each case
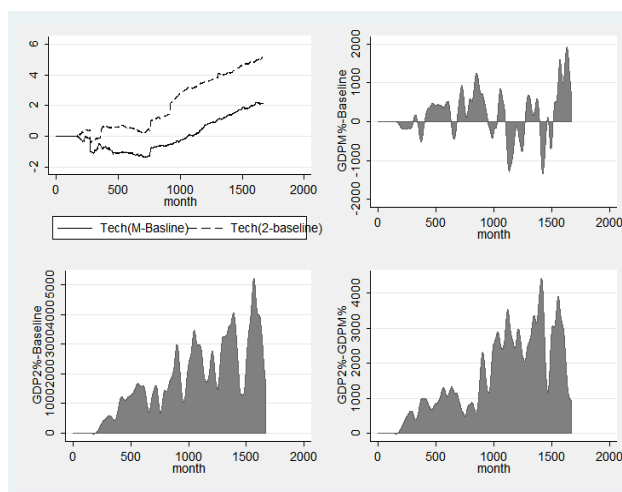
Figure 5. Difference in technology level and overall performance on output of each policy

Nevertheless, the above analysis is specific to the model, where there is no asset market, thus, deflationary does not really affect agent's wealth, which can be another story when allowing agents to hold asset, of which its price is directly linked to agent's wealth.

2) *Asymmetric effects in short run monetary policy.*

Empirical studies have shown that expansionary monetary policy and contractionary monetary policy have asymmetric effect especially at full employment. Yet, conventional structural model can only investigate the effects only at neighborhood of steady state and is limited to some degree of approximation. This section intends to address the point that ABM has the capability to capture a highly non-linear structure and can test policy effects at any stage of the economy.

Upon investigation, baseline growth model has persistently high unemployment rate, which may not suit the purpose of this section. Also, models with automatic stabilizer (k% rule, M%=Z% rule) have done their job well to suppress the volatility; hence, experimenting on contractionary policy is simply lifting off the only tool that used to stabilize the fluctuation, which certainly will cause grater negative impact. That being the case, the best candidate to be used in this experiment is the model that excludes growth. As shown in Fig. 3 expansionary monetary policy in this simple form has no real effect in the long run if productivity parameter remains unchanged, eventually price will inflate up to balance out such policy. In short run, however, injecting nominal wealth can have some influences to real output (which is the reason why monetary policy works as a stabilizer in the first place) and the effects are asymmetric between expansionary and contractionary policies.
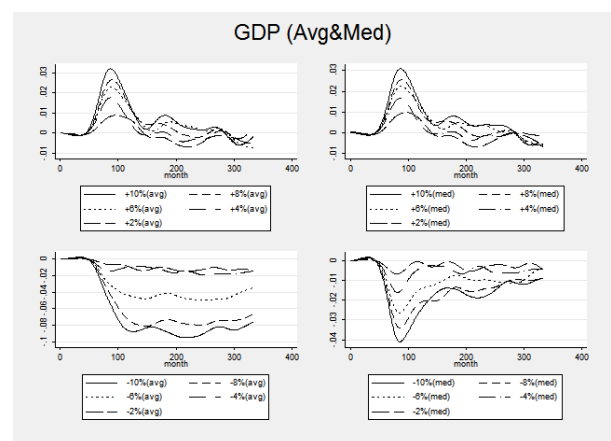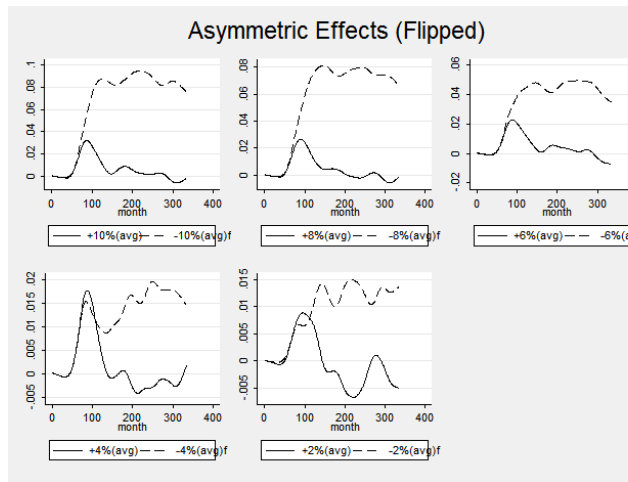

Figure 6.

Figure 7. GDP response to shocks (by mean)

Figure 9. Unemployment level (mean)

Figure 10. Unemployment level (median)

In this section, one time monetary shock is introduced to the economy from 2% to 10% both signs. The simulation runs for 100 times each case to make sure the analysis is not case specific and all the anomaly is eliminated. Since ABM is not a conventional general equilibrium model where the equilibrium path are predetermined with market clearing mechanism, interpretations of Fig.6 to Fig 11 should have a big remark on. It is not conventional impulse-response graph, although the concept is the same. Mean and median difference to baseline of each cases and each variables are collected. HP-filter is applied to remove the cyclical components and the trends of each cases are plotted against time variable to see the dynamic effects of monetary policy. The results of negative shocks on output are flipped (red lines) to illustrate the asymmetric responses. (Fig.7 – Fig.8)
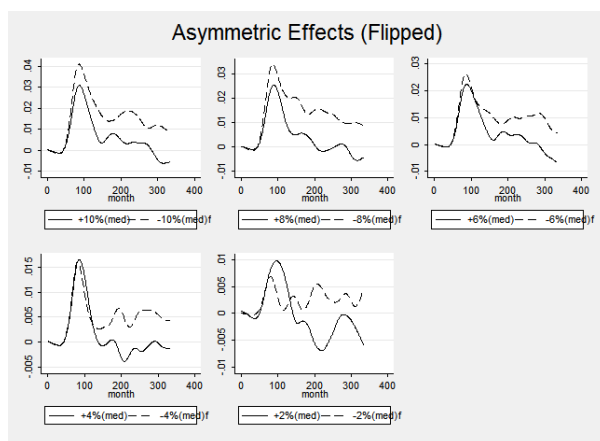

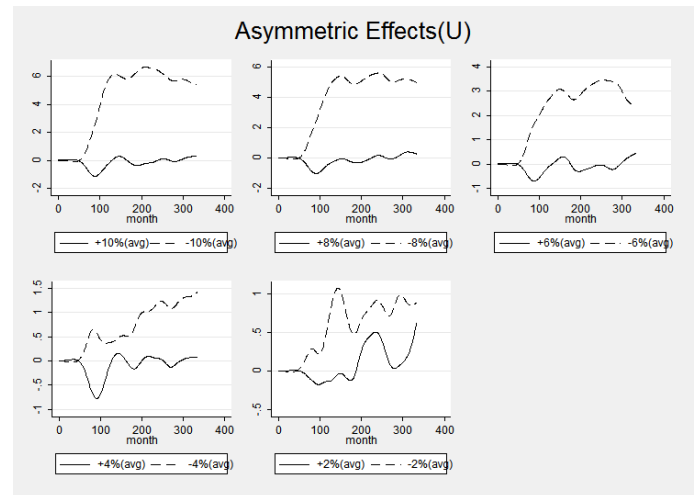Figure 8. GDP response to shocks (by median)
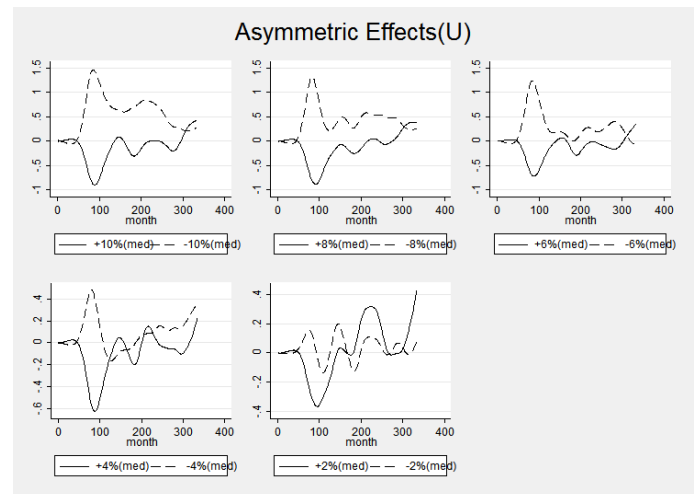
By visual inspection, mean and median can produce significance differences in outcomes especially on negative shocks. The stronger the negative shocks, the longer it takes for the economy to recover, and there is a possibility of not being able to recover from the shock if the shock is too high. (Fig. 7).

The matter of picking the best statistical representative line either by mean or median is not a subject of this paper, which I will leave it to a further study. Nonetheless, asymmetric effects can be detected in all cases on both magnitude and duration of impacts as illustrated in Fig 6 – Fig.10

The results are very clear that monetary policy addressed in this from of injecting liquidity can have asymmetric effects on output and unemployment level. Moreover, pushing-the-string type of asymmetric can be detected. No matter how hard you push on the string +6%,

+8% or +10%, it would not do much the effect, on the contrary the harder you pull (contractionary) there is no limit on the impact. The difference of impact is computed and is shown in Fig.12. The impact of 2% positive shock to baseline is about 1% increase in GDP-- the biggest difference in impact of all cases tested in this study.

The culprit of asymmetric responses lies in Fig. 11. Price is less flexible in downward adjustment.
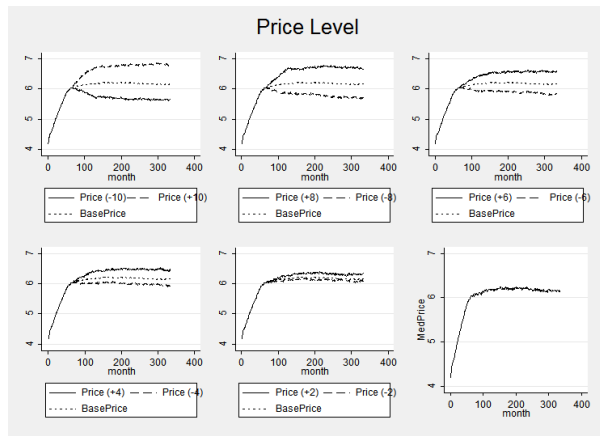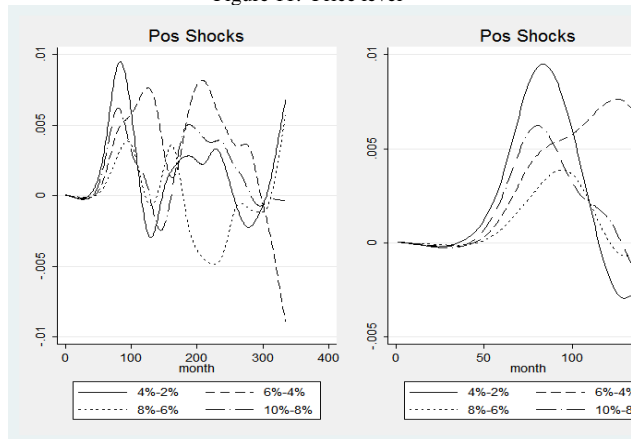

Figure 11. Price level

Figure 12. Effectiveness of each positive shock

The economy will not only take longer time adjusting the price downward (mean) but also the absolute level can be less (both mean and median in the less aggressive shocks). For expansionary policy, price will adjust about the same level as the size of shocks imposed into the economy(in percentage change)— for contractionary policy, however, price lacks the flexibility to adjust that much. When measured mean, price may drop further to dilute the negative effect (-8%,-10%), but it would take longer time and with the simulation periods of this paper and price level is not supported.

This comes from simple and straight-forward firms' adaptive behavioral rules of which are set in a very intuitive way. If the unsold inventory is too high, firm faces two choices—firing some workers or reducing the price. However, firms will not set the price below their cost and experience losses. If the price meet lower bar, firms will not reduce the price any further (Equation (11) (12)). As the results, production needs to be reduced by reducing the production size or firing workers giving the economy persistent periods of recession. The effect then intensifies with lower demand from households' side both from downward price rigidity that limits the price dilution effect to shock (absolute wealth is not brought back to the same level before the shock) and unemployment which lower the income of households. Not to mention that part of households income comes from shares of firm's profit.

There are number of literatures supporting this line argument that less flexibility in downward price adjustment is one of the causes of asymmetric responses in monetary policy. Nonetheless, most models are constructed in a partial equilibrium context and when extended to general equilibrium model the effects often cancel out when non-linear structures have been removed from linear approximation—since the exact solutions are practically unobtainable.

In ABM, the ability to display such asymmetric effects is deeply rooted from the benefit of using less restrictive set of assumptions. With sequential decision making and removing market clearing mechanism of Walrasian's auctioneer enables the model to preserve a highly non-linear structure and is free from limiting the model to find the predetermined equilibrium path. Hence, price setting scheme like equations (11) (12) can be incorporated in a full structural model at minimal computational cost.

IV. CONCLUSION

The merit of ABM comes directly from removing set of strong and restrictive assumptions that are commonly assumed in standard models. Not only can ABM regenerates macroeconomics regularities at the same level as the traditional models without introducing any exogenous process but also displays ability to capture microeconomics dynamics. Monetary policy addressed in this paper is a simple form of money supply control. The results conform to standard monetary economics theory. Monetary policy can be effectively used as stabilization tools and has no long-run impacts to real aggregate

variables. However, when an economy experiences growth from increasing in productivity parameter from research and development, not only fluctuation in price and unemployment level, resulted from increasing in productivity can be reduced, but also long run positive impacts can be observed from its ability to suppress economy-wide default risks which gives firms higher chances of success in R&D. Friedman K% rule performs better in term of overall improvement in output compared to M%=Z% rule as introduced in this paper. Nevertheless, both give the economy a better off. The mechanism behind the policy effectiveness lies in the nature of adaptive behavior of heterogeneous agents, which often cause coordination failures preventing the economy to achieve the potential GDP level and monetary policy can help fill the gap in the short run. The study reports asymmetric effects in monetary policy between expansionary and contractionary. Negative policy shocks give stronger impacts to the economy compared to expansionary policy and the effects tend to last longer as well. The source of asymmetric response addressed in this paper lies in the nature of downward price rigidity. Price tends to move downward in the case of negative shocks less than when equal amount of shocks with positive sign is imposed to the system. When price mechanism is the only tool to dilute the impact of policy shocks, hence, the negative impact can be much higher and last longer.

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