Maciej Konrad Dudek[‡]

Stochastic demands, fixed costs and time-varying Solow residual

Abstract

In a general equilibrium model that contains the standard RBC model as a special case we provide a novel and yet very intuitive interpretation of the Solow residual. We argue in a simple framework with a micro-level uncertainty and fixed costs that movements in the measured value of the Solow residual can reflect endogenous evolution in the stock of knowledge on the status of individual market demands. We establish that transitory shocks can have persistent effects as they exacerbate informational imperfections. In addition, the Solow residual is shown to fluctuate even though the technological frontier is time invariant and factors are fully employed. Finally, we argue that movements in the measured value of the TFP can be caused by monetary disturbances.

Keywords: business cycles, demand uncertainty, Solow residual, fixed costs

JEL Classification: E32, D24, D51

[‡] Vistula University and INE PAN

1. Introduction

No firm has ever gone bankrupt for it has forgotten how to produce. However, numerous enterprises have been driven out of their markets by adverse shifts in demands. In this paper we take this simple observation seriously and illustrate how taste driven shifts in individual market demands can affect the effectiveness of factors allocation, the measured value of the Solow residual and finally how the shifts can impact aggregate activity.

A casual walk through a typical shopping mall can be quite informative and perhaps fascinating to an economist. In a relatively confined space we do observe nearly all phases that most products go through. At any point in time some tenants are forced to close their businesses while at the same time new ones, with some anxiety, open up theirs in anticipation of positive profits. Still others stand firmly and enjoy their seemingly secure flow of profits. While the experience of those who are driven out may appear as dramatic it reminds us that losing one's business is a part of the process. Moreover, it appears that in most cases the decision to cease operations is not an outcome of a sudden technological regress, but rather it reflects developments on the demand side as demands that previously existed simply expire.

It is customary, both for theoretical and practical reasons, in macroeconomics to posit that the aggregate production function takes the form:

$$Y = AK^{\alpha}L^{1-\alpha}. \tag{1}$$

Moreover, standard growth accounting exercises reveal that parameter A varies significantly even at a relatively high frequency. It turns out that A typically decreases during economic downturns and, in particular, it became lower during the Great Depression of 1930s and during the 1990/91 recession. This led some macroeconomists to a belief that exogenous volatility in A could stand at the root of the business cycle phenomenon. In fact it is widely believed that unexpected changes in the production possibility frontier can lead to model-based dynamics that resemble that observed in reality. Even if this view is correct it still calls for a sensible interpretation of the observed variation in A, as some authors, e.g. Conlisk (1989), Lagos (2006), Jaimovich & Rebelo (2006), note that the changes in A are not only unexpected, but also unexplained. In this paper we embark on the task to provide a novel rationalization of the movements in A in a general equilibrium model that contains the standard RBC model as a special case.

Our mechanism that drives changes in A is a very simple one and, we believe, a natural one. Specifically, we assert that the overall market outcome does not solely depend on the producers' ability to manufacture, i.e. the supply side of the market, but it also depends on the demand side of the market. In other words, we claim that apart from knowing how to produce, the technology aspect, it is imperative to know what to produce, i.e. producers must have a reasonable assessment of the demand side of the market. The underlying mechanism that we model reflects the experience of numerous economies. Specifically, one can imagine that the 1998 Russian collapse put an enormous strain on numerous businesses in Eastern Europe as those businesses lost a market for their products. Naturally, at the time Eastern European producers' physical ability to produce did not diminish as firms had access to their technologies and to abundant factor markets. However, the measured value of the Solow residual did fall at the time. Clearly, an adverse shift in demand did impact *A*. Similarly, in 1973, when the UK joined the EU, Australia's access to the British market was curbed negatively affecting the measured value of the total factor productivity. Again, it is hard to imagine that Australian production possibility frontier shifted at the time and, yet, the measured value of TFP must have fallen and remained lower until new markets for Australian products were found.

More formally we can note that GDP can be expressed as the sum of the values of all final goods purchased in a given period, i.e. as follows:

$$GDP \; = \; P_1Q_1 + .. + P_{i-1}Q_{i-1} + P_iQ_i + P_{i+1}Q_{i+1} + .. + P_nQ_n. \qquad (2)$$

Let us now imagine that the demand for good *i* suddenly disappears and its price becomes equal to zero. Naturally, in such a case the *GDP* assumes a new value given by:

$$GDP_{-i} \; = \; P_1Q_1 + .. + P_{i-1}Q_{i-1} + 0Q_i + P_{i+1}Q_{i+1} + .. + P_nQ_n, \qquad (3)$$

which is lower than the previous one. Clearly, the *GDP* has changed even though the actual quantities produced have remained unchanged. This simple example reminds us that even when the supply side is time invariant it may be the case that the measured value of aggregate activity fluctuates in response to demand shifts. Obviously, this simple illustrative example suggests that it may be worthwhile to explore the impact of the demand side disturbances on aggregate activity and on the measured value of the Solow residual in particular.

In our modeling approach we assume that individual market demands are stochastic. They evolve over time occasionally expiring and then possibly reappearing with some probability. In addition, we assume that the status of a given demand can only be identified when the production process is started and a sale attempt is made. Moreover, it is assumed that production entails in addition to standard variable costs a fixed cost. While the above assumptions may appear innocuous they lead to profound implications for aggregate activity and allow us to interpret the measured value of the Solow residual in a novel, possibly more appealing, manner. The mechanism that generates endogenous variability in the measured value of the Solow residual is a very simple one. Imagine that suddenly, possibly as a result of an adverse monetary shock, labor becomes more scarce and, thus, in equilibrium more expensive. Naturally, in such a case some firms rationally choose to suspend their activity and some continue their operations, but generate lower profits. The rational decision to suspend operation has two effects: it naturally reduces the present value of the flow of losses, but at the same time it precludes specific market demands from being observed. Inability to observe the demands in a given period imposes an additional burden on producers in the future periods. Note that by assumption demands can expire. Therefore, a given producer who rationally suspends production in a given period does not know whether the demand for her product expired or it continues to exist. Rational, via Bayes rule, beliefs revision implies that in the following period the producer deals with a riskier demand than it previously did. This, however, implies that should the producer resume operation, she will be more likely to misallocate resources. In other words, the producer will assign excessive amount of resources to projects that are not economically viable and will underfund projects that should be funded. This, however, impacts the productivities of the factors of production and naturally the measured value of the Solow residual.

In the substantive sense the paper captures a general theme that the quality of signals generated by economic variables is damaged during recessions. Therefore, recessions not only impose direct losses on the economy, but also negatively impact the informativeness of economic variables. The fact that damage inflicted by recessions goes beyond output loss has been explored in other contributions. Bernanke & Gertler (1989) and Gali *et al*. (2003) stress the role of capital market imperfections. The authors argue that damage is done through the impact on the financial hierarchy of access to capital, popularized by Fazzari *et al*. (1988), which relatively tightens against smaller businesses during recessions. Similarly, Brock & Evans (1989) show that small businesses are relatively more affected during recessions. Moreover, Greenwald & Stiglitz (1993) working on the role of imperfect capital markets, adverse selection, and imperfect information reach the conclusion that the recessions can negatively influence the economy. In addition, some authors, Bernanke *et al*. (1996), find that the composition of projects, a substantive point also explored in this paper, is affected during recessions.

Our results are presented in a number of sections. In the next section we outline the basic model. In Section 3 we define demand uncertainty – a key ingredient of the model. In Section 4 we present a solution for the equilibrium of the model. In Section 5 we discuss extensions. Finally, conclusions are presented in Section 6.

2. Model

The model's composition corresponds to the imperfectly competitive canon augmented with an additional state variable, distribution of project types, and the assumption of fixed costs. Functional forms are chosen to make our substantive points in the simplest and tractable framework. We want to emphasize that our model does contain the standard RBC model as a special case.

2.1. Consumers

There is a continuum of measure one of infinitely lived consumers who value consumption and leisure with preferences represented, following Kiyotaki[1] (1988), with the following utility function:

$$U(\{c_t\}_{t=1}^{t=\infty},\{l_t\}_{t=1}^{t=\infty}) = \sum_{t=1}^{\infty} \beta^{t-1} \log\left(c_t - \frac{\theta}{1+\eta} l_t^{1+\eta}\right), \tag{4}$$

where $\{c_t\}_{t=1}^{t=\infty}$ denotes the stream of consumption and $\{l_t\}_{t=1}^{t=\infty}$ denotes the stream of hours worked. Consumers receive labor income and a return on their capital holdings. Profit income in equilibrium equals zero.

Utility maximizing consumers take the paths of prices and wages as given and at each point in time chooses the number of hours worked l_t and the level of consumption c_t. The number of hours worked is given by:

$$l_t = \left(\frac{1}{\theta}\frac{w_t}{p_t}\right)^{\frac{1}{\eta}}. \tag{5}$$

In addition, to preserve complete analytic tractability along the intertemporal margin it is assumed that the rate of physical capital depreciation is equal to unity, i.e. in all periods we have $\delta = 1$.

---

[1] We choose to rely on this functional form to ensure analytic tractability while being able to allow for non-constant labor supply.

Under this simplifying assumption and the assumption of price taking behavior there exists an equilibrium path with a constant saving rate. We naturally realize that having chosen such specific values for a key parameter at best allows us to establish our results in a qualitative rather than strict quantitative case. Appendixes A and B provide sensitivity analyses with respect to our choice of the values of the parameters.

2.2. Producers

The process of production takes a number of steps. First capital and labor are combined to deliver an intermediate good referred to as the factor, then the factor is utilized in the process of production of a number of varieties of intermediate goods. Finally, the varieties are used in the process of production of the final good. The final good is used both for investment and consumption.

2.2.1. The final good

The final good is to resemble an aggregate consumption index. It in effect encompasses a number of intermediate goods. Specifically, we assume that there exists a fixed set of measure one of intermediate goods. Each intermediate good can be in either of two states in any given period. The good can be either demanded, i.e. used in the process of aggregation, or can be perceived as worthless, i.e. not required in the process of production of the final consumption good. Moreover, the process of aggregation takes the standard CES functional form and the process of production of the final consumption good can be summarized as follows:

$$Q_t = \left(\int_0^1 x_{i,t}^{\gamma} I_{i,t} di\right)^{\frac{1}{\gamma}}, \tag{6}$$

where $x_{i,t}$ denotes the amount of intermediate good i employed in the process of production and $I_{i,t}$ is the indicator function with $I_{i,t} = 1$ when the intermediate good i is demanded, valued by consumers, and $I_{i,t} = 0$ otherwise. The market for the final consumption good is perfectly competitive. Accordingly, the price of the final consumption good can be expressed as

$$p_t = \left(\int_0^1 p_{i,t}^{-\frac{1}{\sigma}} I_{i,t} di\right)^{-\sigma}, \tag{7}$$

where $\sigma = \frac{1-\gamma}{\gamma}$ and $p_{i,t}$ is the price of good i at time t. Naturally, in equilibrium whenever $I_{i,t} = 0$ then $p_{i,t} = 0$ as well.

The producers of the final consumption good take the prices of the intermediate goods as given, maximize profits, and in turn post demands for the intermediate goods. The inverse demands are given by:

$$p_{i,t} = \begin{cases} D_t^{1-\gamma} p_t^{\gamma} x_{i,t}^{\gamma-1} & \text{when} \quad I_{i,t} = 1 \\ 0 & \text{when} \quad I_{i,t} = 0 \end{cases}, \tag{8}$$

where D_t denotes the total nominal demand for the final consumption good.

Naturally, we view the final good as the abstract aggregate consumption good. In fact, we think of the intermediate goods as being of direct value to the consumers with the actual aggregate production function reflecting consumers' preferences over the intermediate goods.

2.2.2. The intermediate goods

The process of production of the intermediate goods reflects that presented in Matsuyama (1999). There are two major classes of intermediate goods. There is a class of goods of a continuum of measure n^c that are always demanded, i.e. $I_{i,t} = 1$ for all these goods. In addition, there is class of intermediate goods of measure $1 - n^c$, which are either demanded or not, i.e. $I_{i,t} \in \{0,1\}$. The production function is linear and identical for all intermediate goods. One unit of the factor produces a unit of an intermediate good, i.e.:

$$x_{i,t} = f_{i,t}. \tag{9}$$

As in Matsuyama (1999), we assume that intermediate goods that are always demanded are sold on perfectly competitive markets. Moreover, producers that face uncertain demands must pay a fixed cost F_{p_f}, where p_f denotes the price of the factor if they decide to produce. F can be perceived as the cost of gathering and processing information on the status of the demands. Alternatively, F could be interpreted as an agency cost in a more elaborate model with imperfect credit markets[2]. Note that it is assumed that producers that deliver goods that are always demanded do not pay any fixed cost as their demands are certain to exist.

There are a continuum of measure one of producers, behaving competitively, that produce intermediate goods with certain demands.

[2] Naturally, F could be a function of the expected return on the project. Assuming that would not alter the results. Similarly, F could be modeled as countercyclical as there are arguments that suggest that borrowing constraints are more stringent during recessions. Introducing that assumption would, however, only strengthen the results in the quantitative sense.

Accordingly, in equilibrium all producers do engage in production and the equilibrium price is equal to marginal cost, i.e.:

$$p_{i,t} = p_f \tag{10}$$

for each intermediate good with certain demand.

In addition, we assume that there are exactly two producers of each intermediate good with uncertain demand. Each period the producers can decide to engage in the process of production or can choose not to enter and stay idle. Should it occur that both producers opt to be active, the two producers are assumed to engage in price[3] competition and consequently both make negative expected profits of $-F_{p_f}$. In the other extreme case if none of them chooses to be present on the market the profits, the level of production and the price are all equal to zero. In the remaining scenario when only one of the producers enters and the other does not the one that enters pays the fixed cost F_{p_f} and enjoys the monopoly power but still is confronted with demand uncertainty.

Producers decide whether to be active or not simultaneously. Moreover, we assume that the producers are not aware of the actual state of nature, i.e. whether $I_{i,t} = 0$ or $I_{i,t} = 1$, before they make their decisions. They only rely on the rational assessment of the likelihoods of the two events. Furthermore, the uncertainty is not resolved until production is undertaken and a sale attempt is made. Assuming that the demand for a given good i exists with probability a_i and does not with probability $1 - a_i$, and that producers are expected profits maximizers, the equilibrium price of good i at time t is given by:

$$p_{i,t} = \begin{cases} \frac{1}{a_1} p_f & \text{when both enter and the demand exists} \\ 0 & \text{when both enter and the demand does not exist} \\ \frac{1}{\gamma a_1} p_f & \text{when only one enters and the demand exists} \\ 0 & \text{when only one enters and the demand does not exist} \end{cases} . \tag{11}$$

The two producers of the intermediate goods rationally foresee that if both enter then both make an expected loss of $-F_{p_f}$ if only one of them enters then the one that remains idle earns zero profits, and the one that enters earns

[3] We simply assume that in this case the two producers take simultaneously the expected demand as given. Furthermore, we assume that each one produces one half of the quantity consistent with the expected demand.

an expected profit equal to $(\sigma x_i^M - F)p_f$, x_i^M denotes the quantity produced by a monopolist who faces a demand that exists with probability a_i. Finally, if the two choose inactivity then the profits are equal to zero. As assumed the two producers decide on their level of activity simultaneously. The Nash equilibrium of the game between the two producers can be summarized as follows: both remain idle when $\sigma x_i^M - F < 0$ and both enter with probability b_{a_i} otherwise, where b_{a_i} satisfies:

$$\left(1 - b_{a_i}\right)\sigma x_i^M = F. \tag{12}$$

Naturally, in equilibrium b_{a_i} is never equal to one, but it can be equal to zero. Moreover, every period the expected profits earned by a producer are equal to zero. Consequently, by the law of large numbers the actual profits earned in this economy are equal to zero.

2.2.3. The factor

The production process for the factor relies on the standard Cobb-Douglas technology employing both capital and labor. Specifically, k units of capital and l units of labor yield:

$$f = k^{\alpha} l^{1-\alpha} \tag{13}$$

units of the factor. The factor is sold on perfectly competitive markets and, accordingly, its price is equal to marginal costs:

$$p_f = \left(\frac{r}{\alpha}\right)^{\alpha} \left(\frac{w}{1-\alpha}\right)^{1-\alpha}, \tag{14}$$

where r and w denote the rental price of capital and the wage.

3. Demand uncertainty

There are some goods with time invariant demands. Let us assume that the measure of those goods is equal to n_c. On the other hand there are markets in which demands evolve in a stochastic manner. We choose to model such cases by assuming that if the demand for a given intermediate good exists in a given period then it will continue to exist in the following period with probability q and will cease to exist with probability $1 - q$. Similarly, an expired demand will remain expired in the following period with probability q and will reappear with probability $1 - q$. In other words, we assume that individual demands follow a Markov process with the transition matrix given by:

$$\begin{array}{ccc} & + & 0 \\ + & q & 1-q. \\ 0 & 1-q & q \end{array} \tag{15}$$

Let $\omega = 2q - 1$ and observe that a positive demand observed at time t remains positive after T periods with probability $a_T = \frac{1}{2}(\omega^T + 1)$. Similarly, an expired demand at time t turns positive T periods later with probability $1 - a_T = \frac{1}{2}(1 - \omega^T)$. Naturally, whenever economic activity is undertaken and there is sale attempt made, the demand is observed and the actual state of nature can be inferred with certainty. On the other hand, whenever profit maximizing individuals rationally choose to suspend production there is no sale attempt made, and consequently demand is not observed and the actual state of nature remains unknown.

For clarity we refer to a market with positive demand with probability a as a project of quality a. Let n_a^t be the number of projects of quality a available at time t. Naturally, given the Markovian nature of the evolution of project types the overall number of projects is fixed and equal to $1 - n^c$, i.e.:

$$\int_0^1 n_a^t da = 1 - n^c. \tag{16}$$

Moreover, the set of admissible project types is given by, where again $\omega = 2q - 1$:

$$A = \{a : a = \tfrac{1}{2}(\omega^T + 1) \;\text{ or }\; a = \tfrac{1}{2}(1 - \omega^T),\; T = 1,2,\dots\}. \tag{17}$$

Let z_a^t denote the fraction of projects of type a suspended in period t. Assuming that agents use Bayesian updating when making inferences about the status of a given demand and invoking the law of large numbers, it is straightforward to establish that the distribution of project types satisfies the following laws of motion:

$$\begin{gathered} n_{a_1}^{t+1} = \sum_{i=1}^{\infty}\left(1 - z_{a_1}^t\right)a_i n_{a_1}^t + \sum_{i=1}^{\infty}\left(1 - z_{1-a_1}^t\right)(1 - a_i)n_{1-a_1}^t \\ n_{a_2}^{t+1} = z_{a_1}^t n_{a_1}^t \\ n_{a_3}^{t+1} = z_{a_2}^t n_{a_2}^t \end{gathered} \tag{18}$$

$$\dots$$
$$n_{1-a_3}^{t+1} = z_{1-a_2}^{t} n_{1-a_2}^{t}$$
$$n_{1-a_2}^{t+1} = z_{1-a_1}^{t} n_{1-a_1}^{t} \qquad .$$
$$n_{1-a_1}^{t+1} = \sum_{i=1}^{\infty}\left(1 - z_{a_1}^{t}\right)(1 - a_i) n_{a_1}^{t} + \sum_{i=1}^{\infty}\left(1 - z_{1-a_1}^{t}\right) a_i n_{1-a_1}^{t}$$

For a given sequence of $\{z_a^t\}_{a\in A}$, the system (18) is characterized by a fixed point property and the distribution of available projects types $\{n_a^t\}_{a\in A}$ converges to an ergodic distribution.

4. Equilibrium

There are two state variables in the model: physical capital and the distribution of project types $\{n_a^t\}_{a\in A}$. Nevertheless, the solution to the intertemporal problem given the very specific functional form of the utility function and the fact that the rate of physical capital depreciation is assumed to be equal to unity is straightforward. In particular, under the assumption of price taking behavior on the part of a representative consumer the fraction of output saved each period is constant and given by $s = \beta\alpha$. The solution prevails even in the presence of uncertainty and expected utility maximization.

The equilibrium within a given period is characterized by a number of reaction functions and market clearing condition. First of all, recall that both the amount of physical capital stock and the distribution of project types $\{n_a^t\}_{a\in A}$ are predetermined in a given period. Moreover, as the price of an intermediate good with certain demand is always equal to marginal cost and the efficiency in the final good producing sector requires that:

$$\left(\frac{x_{t,i}}{x_{t,j}}\right)^{\gamma-1} = \frac{p_{t,i}}{p_{t,j}}, \tag{19}$$

the actual quantities delivered are always the same irrespective of the specific good. Let x_t^c denote the quantity delivered by producers of an intermediate good of a given type with certain demand. Similarly, let $x_{t,a}^M$ be the quantity delivered by the producer of an intermediate good of type a. The demand for the good exists with probability a, when only one producer enters. In addition, let $x_{t,a}^C$ be the quantity delivered by the two producers of the intermediate good of type a when both producers enter. Noting that the producers of goods with risky demands must pay the fixed cost to produce, the overall demand for the factor can be expressed as:

$$f_t^D = n^c x^c + \int_{a\in A} n_a^t \left((b_a^t)^2 \left(x_{t,a}^C + 2F\right) + 2b_a^t (1 - b_a^t)\left(x_{t,a}^M + F\right)\right) da. \tag{20}$$

In equilibrium, the efficiency condition (19) and the indifference condition (12) must hold. In addition, the demand for the factor f_t^D given by (20) must be equal to the supply $k_t^\alpha l_t^{1-\alpha}$, i.e.:

$$k_t^\alpha l_t^{1-\alpha} = x^c \Phi_t, \tag{21}$$

where Φ_t denotes the following expression, where $\rho = \frac{1}{1-\gamma}$ and $g = \gamma^{\frac{\gamma}{1-\gamma}}$:

$$\Phi_t = n^c + \int_{a\in A} n_a^t a^\rho ((b_a^t)^2 + 2b_a^t (1 - b_a^t) g)\, da. \tag{22}$$

It is straightforward to show that the price level can be expressed as $p_t = \Phi_t^{-\rho} \frac{w_t}{1-\alpha}\left(\frac{l_t}{k_t}\right)^\alpha$. Moreover, as the quantity of labor supplied is given by (5), the equilibrium within a single period of time can be summarized with $B_1 = \left(\frac{1-\alpha}{\theta}\right)^{\frac{1}{\eta+\alpha}}$:

$$\begin{aligned} l_t &= B_1 \Phi_t^{\frac{\sigma}{\eta+\alpha}} k_t^{\frac{\alpha}{\eta+\alpha}} \\ y_t &= \Phi_t^\sigma k_t^\alpha l_t^{1-\alpha} \\ k_{t+1} &= \beta\alpha \Phi_t^\sigma k_t^\alpha l_t^{1-\alpha} \end{aligned} . \tag{23}$$

Moreover, in equilibrium as equations (21), (19), and (132) imply for any $a \in A$ such that $b_a^t > 0$ it must be, $B_2 = \frac{1}{F}(1-\gamma) g$:

$$B_2 k_t^\alpha l_t^{1-\alpha} (1 - b_a^t) a^\rho = \Phi_t. \tag{24}$$

Expression (24) defines implicitly, as Φ_t does depend on b_a^t's, the sequence of probabilities $\{b_a^t\}_{a\in A}$ at which producers enter. Finally, production in a given unit that faces a positive demand with probability a is suspended whenever none of the two producers enters and that occurs with probability $(1 - b_a^t)^2$, hence:

$$z_a^t = (1 - b_a^t)^2. \tag{25}$$

The description of the equilibrium within a single period of time is complete. The last relationship of (23) and (18) describe the evolution of the economy over time.

Model parameters do influence the evolution of the economy over time. However, there is a range of values for which the economy converges to a steady state. The approach path to the steady state can be oscillatory. Finally, multiple steady state equilibria are feasible. Appendixes A and B contain extensions of discussion of the equilibrium properties further. Naturally, we want to indicate that our results are only qualitative in nature and serve as an illustration as there is no particular scientific basis for our choice of the underlying parameters.

4.1. Dynamics

There are two state variables in the model: physical capital and informational capital embodied in the distribution of project types $\{n_a^t\}_{a \in A}$. Physical capital plays the traditional role in the model. It is a saving instrument and an input in the process of production. Informational capital captures the state of knowledge of economic agents about the state of nature of individual market demands. Naturally, physical capital is accumulated over time and is a result of rational decision making with the fraction $\beta\alpha$ of output saved each period. Informational capital, on the other hand, is created in fact as a by-product of economic activity, active firms reveal the status of demands and suspended units do not, and its evolution is summarized with the system of equations (18). As it turns out, a decision to suspend production leads to information loss and impacts negatively the shape of the future distribution of project types. Nevertheless, the decision is rational, i.e. consistent with the firm's value maximization at any point in time.

4.2. Long Lasting Effects of Transitory Shocks

For a wide parameter range the level of physical capital stock and the distribution of project types converge, respectively, to a steady state value and an ergodic distribution. Consequently, absent any changes in the fundamentals the economy remains in the steady state and only shocks can push the economy out of its long run equilibrium. At this stage the paper focuses on a very special form of shocks. In particular, we consider shocks to preferences on the leisure-consumption margin. Specifically, we observe that whenever θ changes, labor supply changes. A rise in θ decreases labor supply and makes the factor scarcer. This in turn discourages entry as the factor price is higher, and depresses activity even further. Clearly, a change in θ has a direct impact on output as it affects labor supply, and indirectly as it influences the entry margin. However, shifts in θ not only affect the current equilibrium values, but also impact the process of formation of both forms of capital. Specifically, as an increase in θ lowers output and as a fixed fraction of output $\beta\alpha$ is saved, the future level physical capital stock decreases as well. Moreover, as a positive innovation to θ reduces willingness of entry on the part of producers at the time of the shock, the number of observed demands is lower and there is less information revealed, and the shape of future distribution of project types changes as well. As a result the decisions to suspend operation of a greater number of units exacerbate uncertainty and lead to a fall in the informational capital stock embodied in $\{n_a^t\}_{a \in A}$. The fall in the informational capital stock implies a lower level of output in future periods as factor of production are utilized less efficiently. Figure 1 presents sample dynamics of output triggered by a 2% increase in θ (a negative labor supply shock.)

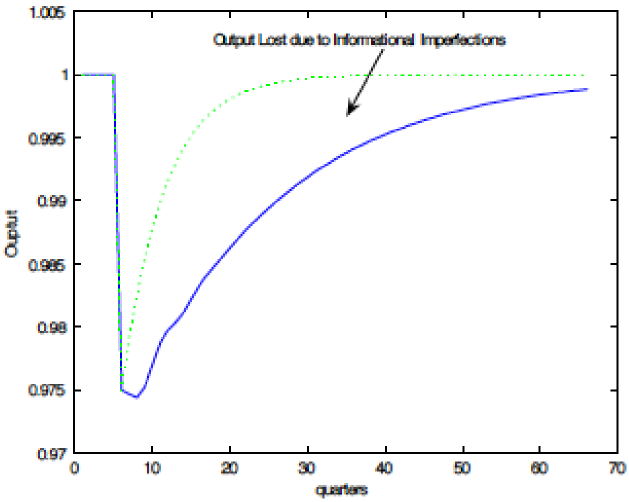


Figure 1. Output response to a negative labor supply shock.

Source: own computation.

Figure 2 presents the reaction of the key macro-variables to a one time 2% increase in θ. The response of the real wage is of particular interest as the real wage actually rises when the shock hits. This is not surprising because leisure is valued relatively more at the time of the shock, and then it falls and follows the path analogous to the remaining variables. The reason for the fall in the real wage after the return of θ to its original value is simple. The shock adversely affects the distribution of projects types and as the rewards to factors of production depend on the overall riskiness of the projects the real wage must decrease in line with the adverse change in the distribution of project types.

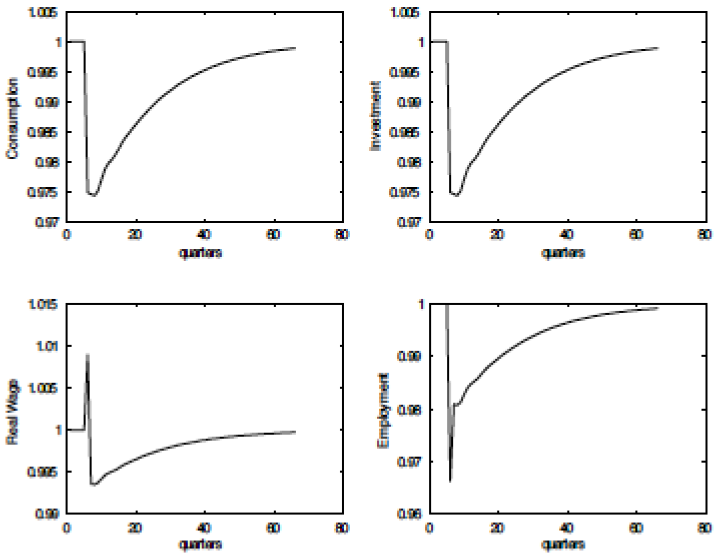


Figure 2. Response of key macroeconomic variables to a negative labor supply shock.

Source: own computation.

A rise in θ affects the economy both when the shock is present and when the value of θ returns to its normal value, as a contemporaneous rational decision to suspend production impacts negatively the future distribution of project types. Summarizing, the presence of informational capital enriches the dynamics. Moreover, the presence of informational capital introduces inertia to the economy. Thus, the model illustrates that even temporary disturbances can cause long lasting departures of output from the normal level. Naturally, in the model negative disturbances cause excessive output loss. On the other hand a positive innovation pushes output above its normal level for an extended period of time as well. Moreover, a positive innovation, if it occurs, leads to increased uncertainty resolution and makes the decision making process easier in the future periods and thus increases future output. In addition, given the imperfectly competitive structure of our model, a positive innovation actually brings output closer to the social, perfectly competitive, optimum. In summary, the presence of the additional state variable that captures agents' knowledge on the existence of specific demands enriches the dynamics and increases the variance of output with mean up to the first order unchanged.

4.3. Time-varying Solow residual

The overall number of projects is always constant. The number of markets with existing demands is always equal to $n^c + \frac{1}{2}(1 - n^c)$ and the number of markets with non-existent demands equals $\frac{1}{2}(1 - n^c)$. Moreover, existing technologies are time invariant. However, admittedly, economic agents are not equally informed on the actual status of individual market demands in all periods. Occasionally, economic agents face a riskier pool of projects and their decisions *ex post* turn out to be inefficient with some projects underutilized and other receiving excessive finance. Moreover, in all periods all factors of production are fully employed. At any point in time the level of output can be expressed as

$$y_t = \Phi_t^\sigma k_t^\alpha l_t^{1-\alpha}. \tag{26}$$

In equilibrium Φ_t depends on the distribution of project types and on the probabilities of entry by each of the types. These in turn depend on the actual amount of capital and labor in the economy. Consequently, the level of output can be expressed as a function[4] of the distribution of project types, capital, and labor available in the economy:

$$y_t = f(\{n_a^t\}_{a \in A}, k_t, l_t). \tag{27}$$

This functional form can be interpreted as a form of the aggregate production function. Obviously, the functional form obtained in this manner need not and in general does not resemble the functional form of the production at the micro-level. The production function at the micro-level is known in this model. It is a simple Cobb-Douglas production function represented by (13). Should we decide incorrectly to assume that the aggregate production function belongs to the same family of Cobb-Douglas functional forms, then noting that all three variables y_t, k_t, and l_t are observable, we will interpret Φ_t^σ as a measure of the total factor productivity. Naturally, in the traditional sense our interpretation will be 'flawed' as Φ_t in

[4] For some special parameter values the actual functional form can be obtained.

equilibrium does depend on k_t and l_t. Nevertheless, the interpretation as such will be consistent with the current operational methodological approach used in the Real Business Cycle theory and growth accounting. Informally, an inexperienced econometrician who attempts to fit the true micro-level production function into aggregate data is bound to pick up $\sigma \frac{\Delta\Phi_t}{\Phi_t}$ as a measure that reflects the Solow residual as approximately we have:

$$\frac{\Delta y_t}{y_t} = \sigma \frac{\Delta\Phi_t}{\Phi_t} + \alpha \frac{\Delta k_t}{k_t} + (1-\alpha)\frac{\Delta l_t}{l_t}. \tag{28}$$

Moreover, in equilibrium all variables y_t, k_t, l_t, and $\{n_a^t\}_{a \in A}$ do change and, consequently, the measured Solow residual varies as well. Figure 3 presents the actual co-dependency of equilibrium variables for a sequence of shocks to θ.

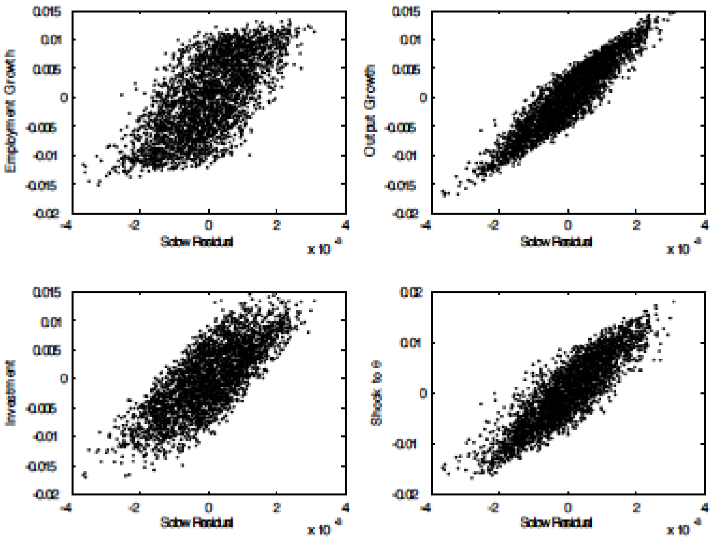


Figure 3. Correlation between key macroeconomic variables and the measured Solow residual.

Source: own computation.

As normally believed, output, employment and investment strongly respond to changes in the measured Solow residual. However, the relationship is spurious as the underlying shock lies elsewhere and does not influence the actual factor productivity. In this model shocks to preferences affect labor supply. Changes in labor supply for a given level of physical capital influence the scarcity of the factor. Variations in the scarcity of the factor impact the entry probabilities, which in turn influence the measured values of the Solow residual. Consequently, output, employment and investment all change in equilibrium in line with the measured value of the Solow residual despite the fact that the physical factor productivity is constant. Thus, the model presents a mechanism that generates the time-varying measured Solow residual with full factor employment and without technology shocks. Obviously, in the model the measured Solow residual does not indicate the change in the actual physical factor productivity as the factors are always fully employed and equally productive as the production possibility frontier is constant.

5. Extensions

The dynamics in the model is driven by shocks to preferences on the leisure-consumption margin. While shifts in tastes at the individual level do occur and assuming just that does not yield any controversy the paper makes in fact a stronger assumption. Specifically, we treat shocks to individual preferences as being perfectly correlated across individuals, i.e. we assume that the same type of shock affects all agents simultaneously. Clearly, there is no theoretical rationalization for perfect correlation across shocks. To deal with that issue we extend the model.

Recall that labor supply at any given point in time is given by:

$$l_t = \left(\frac{1}{\theta}\frac{w_t}{p_t}\right)^{\frac{1}{\eta}}. \tag{29}$$

Up to this point we have been relying on shifts in θ to induce variation in the amount of labor supplied. Naturally, as equation (29) indicates, labor supply changes as soon as the real wage changes. Under the assumption of full information the real wage could change only if some of the underlying parameters of the model change. Here, we decide to make a short cut[5] and assume that there is a timing issue within a single period of time. Specifically, we assume that the nominal wage w_t is observed whereas the price level p_t becomes known after the actual labor contract is signed. Accordingly, the actual labor contract must be signed given expectations about the price level and the actual amount of labor supplied, under yet another simplifying assumption of certainty equivalence behavior, takes the form:

[5] Formally speaking, we should embed the model into the Lucas's type framework and proceed with the fully rational exposition. We make the short cut to reduce the dimensionality of the model.

$$l_t = \left(\frac{1}{\theta}\frac{w_t}{p_t^e}\right)^{\frac{1}{\eta}}, \tag{30}$$

where p_t^e denotes the expected price level at t from the perspective of the beginning of period t. Similarly, the physical capital rental contract is signed conditional on expectations of the price level. To induce potential departures between the actual price level p_t and the expected price level p_t^e we follow Blanchard & Kiyotaki (1987) and introduce a monetary variable into the model with money in the utility being the source of money demand. Accordingly, the utility function assumes a new functional form and is expressed with:

$$U(\{c_t\}_{t=1}^{t=\infty}, \{l_t\}_{t=1}^{t=\infty}, \{m_t\}_{t=1}^{t=\infty}) = \sum_{t=1}^{\infty} \beta^{t-1} \log m_t \left(c_t - \frac{\theta}{1+\eta} l_t^{1+\eta}\right), \tag{31}$$

where m_t denotes the real value of money balances held by the consumer at t. The monetary authority injects with lump sum transfers money into the economy. The remainder of the model remains unchanged. The period t budget constraint takes the form:

$$c_t + m_t + k_{t+1} = \frac{w_t}{p_t} l_t + \left(1 - \delta + \frac{r_t}{p_t}\right) l_t + (1-\tau) m_{t-1} \frac{p_{t-1}}{p_t} + m_t^L, \tag{32}$$

where m_t^L denotes the real value of lump-sum monetary transfers at time t and τ denotes the tax on nominal cash holdings held on from the previous period. Recall, that is has been already assumed that $\delta = 1$. To simplify exposition further we assumed that $\tau = 1$, i.e. we assume that cash holdings are completely taxed away after one period. Finally, the lump sum transfers m_t^L are treated as given by a single consumer.

The extended version of the model under the assumptions of $\delta = 1$ and $\tau = 1$ remains fully tractable along the intertemporal margin. Specifically, it is straightforward, as under rational expectations, as of period t the expected error is zero, i.e. $E_t \frac{p_{t+1}}{p_{t+1}^e} = 1$ to show that the fraction of income saved in the form of physical capital each period is given by:

$$s_t = \alpha\beta \frac{p_t}{p_t^e}. \tag{33}$$

In addition, efficiency requires that:

$$\frac{M_t}{p_t} = c_t - \frac{\theta}{1+\eta} l_t^{1+\eta}, \tag{34}$$

where M_t denotes the nominal stock of money held at the end of period t. Moreover, in equilibrium it must be:

$$\begin{aligned} \theta l_t^{\eta} &= \frac{p_t}{p_t^e}\frac{w_t}{p_t} \\ \frac{w_t}{p_t} &= \Phi_t^{\sigma} k_t^{\alpha} l_t^{1-\alpha} \\ \Phi_t &= B_2(1-b_a^t)a^{\rho} k_t^{\alpha} l_t^{1-\alpha} \end{aligned} \quad . \tag{35}$$

To complete the model let us assume that the process governing the evolution of the monetary variable over time takes the form

$$M_t = (1-\tau)M_{t-1} + M_t^L, \tag{36}$$

where $M_t^L = (1+\lambda)(1+\nu_t)M_{t-1}$ is the lump sum transfer of nominal cash at time t. The parameter λ is known and constant throughout all periods and given that $\tau = 1$ reflects the average rate of money growth whereas ν_t is a mean-zero disturbance and is thought to represent shocks within the monetary transmission mechanism. The price expectations p_t^e held at the beginning of the period are rational in the following sense. Agents expect the price level to be equal to the value that would materialize if the shock ν_t was zero, i.e. agents simply expect the price to be equal to the value that would exist if the actual money stock was equal to its expected value. Given the specific price expectations the model can be solved for a given sequence of monetary shocks ν_t's.

Naturally, unlike in the previous section that dealt with shocks to θ it is very natural, within the present framework, to think of ν_t as of a common aggregate shock affecting all agents simultaneously. In fact the model is nearly, with the price expectation error affecting the saving ratio being the key difference, isomorphic to the version of the model presented in the previous section. Clearly, as the labor supply in equilibrium can be expressed as $\theta l_t^{\eta} = \frac{p_t}{p_t^e}\frac{w_t}{p_t}$, monetary shocks leading to discrepancies between p_t and p_t^e influence, for a given value of the real wage, the labor supply as if the shocks were due to unpredictable changes in the preference parameter θ. Specifically, a positive innovation to money stock generates a positive price surprise and leads to an increase in the quantity of labor supplied. Higher quantity of labor supplied increases the likelihood of entry as labor becomes cheaper. This increases output and leads to expansion. The actual price level is determined from the money demand equation (34). Obviously, monetary shocks are non-neutral and affect the equilibrium. This simple result must have been expected given the assumed informational lag within a single period of time. However, as noted earlier price expectation errors not only affect the actual quantity of labor supplied, but also influence the likelihoods of entry on the part of different producers. Specifically, the higher the quantity of labor supplied the lower the wage and the values of z_a^t's are lower. Increased entry on the part of producers changes the equilibrium value of Φ_t and consequently affect the measure value of the Solow residual. Figure 4 depicts the response of the Solow residual to a random draw of monetary shocks.

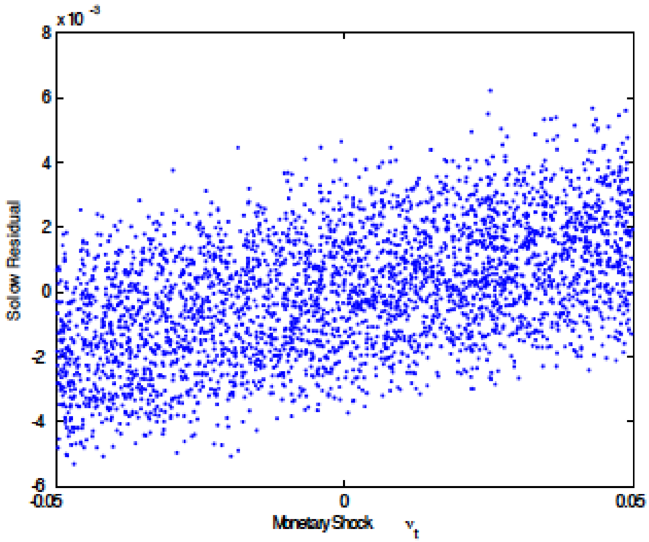


Figure 4. Response of the Solow residual to a monetary shock.

Source: own computation.

Naturally, the model as such is purely illustrative. Nevertheless, it shows that in an environment with fixed technology frontier the measured value of the Solow residual can respond to monetary shocks. We want to emphasize that factors are fully employed and that the actual number of goods that are demanded in a given period is always constant.

For completeness we note that the response of output to a monetary shock as well of the remaining key variables do correspond to output dynamics triggered by changes in θ as depicted in Figures 5 and 6.

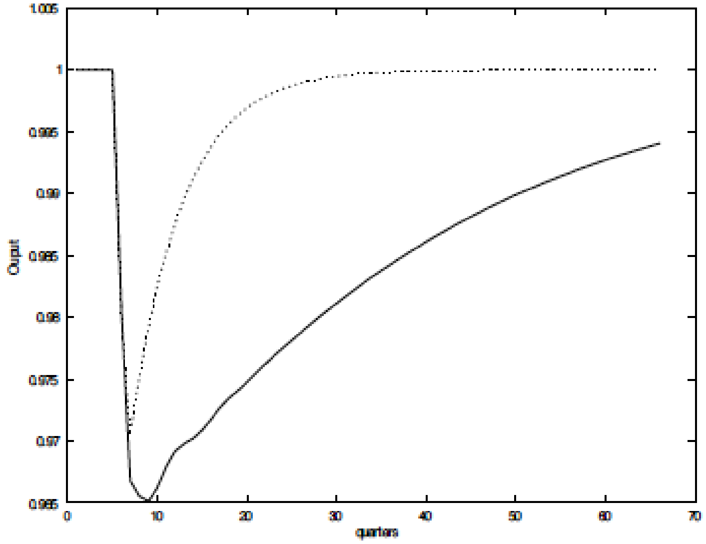


Figure 5. Response of output to a monetary shock.

Source: own computation.

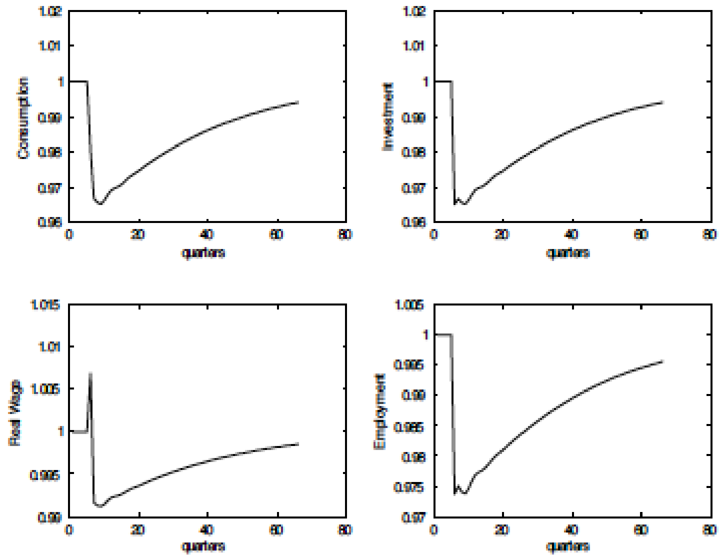


Figure 6. Response of key macroeconomic variables to monetary shocks.

Source: own computation.

Naturally, unexpected changes in money supply introduce inertia into the model. Specifically, a negative innovation can cause a long lasting fall in output. See Figure 7.

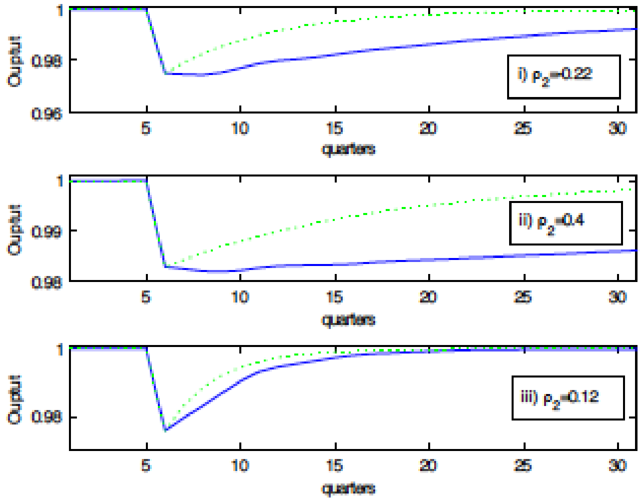


Figure 7. Response of output to monetary shocks.

Source: own computation.

6. Conclusions

The paper studies the impact of micro-level informational imperfections on aggregate variables under the assumption of fixed costs. It turns out that assuming non-zero fixed cost to produce allows the economy to respond to shocks along the extensive margin. Should a negative shock affect the economy, some producers may find it optimal to suspend production and refrain from economic activity. Naturally, this simple mechanism generates welfare losses when shocks are present. The paper goes beyond that basic observation and notes that a rational decision to suspend production precludes individual market demands from being observed. Consequently, if, as assumed in the paper, individual market demands follow a stochastic process, a decision to suspend production imposes informational burden on the economy as rational inferences regarding the status of an individual demand must be made without observing its current state. This implies that confronted with inferior information economic agents make on average worse decisions as they are more likely to misallocate resources and the negative effects of shocks can be long lasting even when the shocks themselves are just transitory.

In addition, we note that in principle the functional forms of the microlevel and the aggregate production functions need not coincide and in our paper they do not. Consequently, an attempt to measure total factor productivity with simple fit of the micro-level production function into aggregate data can lead to spurious results and identify changes in the productivity of factors even when the production frontier is time invariant and factors are fully employed. In particular, we show, following the current operational methodology, that output growth and the measured TFP growth can co-move even though there are no technology shocks. Moreover, we extend the model and show that monetary disturbances can be a source of fluctuations in the measured value of the Solow residual.

References

Acemoglu, D. (1993). Learning about others' actions and the investment accelerator, *The Economic Journal*, 103 (417), 318-328.

Barlevy, G. (2002). Sullying effects of recessions, *Review of Economic Studies*, 69 (1), 65-95.

Bernanke, B., Gertler, M. (1989). Agency costs, net worth, and business fluctuations, *American Economic Review*, 79 (1), 14-31.

Bernanke, B., Gertler, M., Gilchrist, S. (1996). The financial accelerator and the flight to quality, *The Review of Economics and Statistics*, 78 (1), 1-15.

Bernanke, B., Gertler, M., Gilchrist, S. (1999). *The financial accelerator in a quantitative business cycle framework*, in *Handbook of macroeconomics* (vol. 1), J. Taylor, M. Woodford (eds), North-Holland, 1341-1393.

Blanchard, O.-J., Summers, L. (1986). Hysteresis and the European unemployment problem, *NBER Macroeconomics Annual*, 1, 15-78.

Blanchard, O.-J., Kiyotaki, N. (1987). Monopolistic competition and the effects of aggregate demand, *American Economic Review*, 77 (4), 647-77.

Blanchard, O.-J. (2008) *The state of macro*, MIT, mimeo.

Blanchard, O.-J. (1993). Consumption and the recession of 1990-1991, *American Economic Review Papers and Proceedings*, 83 (2), 270-274.

Brock, W. A., Evans, D. S. (1989). Small business economics, *Small Business Economics*, 1 (1), 7-20.

Caballero, R. J., Hammour, M. (1994). On cleansing effects of recessions, *American Economic Review*, 84 (5), 1350-1368.

Caballero, R. J., Hammour, M. (1998). Macroeconomics of specificity, *Journal of Political Economy*, 106 (4), 724-76.

Caplin, A., Leahy, J. (1994). Business as usual, market crashes, and wisdom after the fact, *American Economic Review*, 84 (3), 548-565.

Caplin, A., Leahy, J. (1993). Sectoral shocks, learning and aggregate fluctuations, *Review of Economic Studies*, 60 (4), 777-794.

Conlisk, J. (1989). An aggregate model of technical change, *Quarterly Journal of Economics*, 104 (4), 787-821.

Chari, V. V., P. Kehoe, P., McGrattan, E. (2007). Business cycle accounting, *Econometrica*, 75 (3), 781-836.

Fisher, F. M. (1969). The existence of aggregate production functions, *Econometrica*, 37 (4), 553-577.

Galí, J., Gertler, M., López-Salido, J. D. (2003). Markups, gaps, and the welfare costs of business fluctuations, *Review of Economics and Statistics*, 89 (1), 44-59.

Galí, J. (1994). Monopolistic competition, business cycles, and the composition of aggregate demand, *Journal of Economic Theory*, 63 (1), 73-96.

Gertler, M. (1982). Imperfect information and wage inertia in the business cycle, *Journal of Political Economy*, 91 (5), 967-987.

Greenwald, B., Stiglitz, J. E. (1993). Financial market imperfections and business cycles, *Quarterly Journal of Economics*, 108 (1), 77-114.

Fazzari, S, Hubbard, G., Petersen, B. C. (1988), Financing constraints and corporate investment, *Brookings Papers on Economic Activity*, 1, 141-195.

Friedman, M., Schwartz, A. J. (1963). *A monetary history of the United States, 1867-1960*. Princeton: Princeton University Press.

Jaimovich, N., Rebelo, S. (2006). *Can news about the future drive the business cycle?*, NBER Working Paper No. 12537.

Jovanovic, B. (2006). Asymmetric cycles, *Review of Economic Studies*, 73 (1), 145-162.

Kiyotaki, N. (1988). Multiple expectational equilibria under monopolistic competition, *The Quarterly Journal of Economics*, 103 (4), 695-713.

Kydland, F. E., Prescott, E. C. (1982). Time to build and aggregate fluctuations, *Econometrica*, 50 (6), 1345-1370.

Lagos, R. (2006). A model of TFP, *Review of Economic Studies*, 73 (4), 983-1007.

Lucas Jr., R. E. (1987). *Models of business cycles*, Oxford: Basil Blackwell.

Lorenzoni, G. (2009). A theory of demand shocks, *American Economic Review*, 99 (5), 2050-2084.

Mankiw, G. N., Reis, R. (2006). *Sticky information in general equilibrium*, NBER Working Paper No. 12605.

Matsuyama, K. (1999). Growth through cycles, *Econometrica*, 67 (2), 335-347.
Ouyang, M. (2009). The scarring effect of recessions, *Journal of Monetary Economics*, 56 (2), 184-199.
Prescott, E. C. (1998). Lawrence R. Klein lecture 1997 – Needed: A theory of total factor productivity, *International Economic Review*, 39 (3), 525-551.
Pries, M. J. (2004). Persistence of employment fluctuations: A model of recurring job loss, *Review of Economic Studies*, 71 (1), 193-215.
Rigobon, R. (1997). *Learning by lending*, M.I.T., Ph.D. thesis.
Shleifer, A. (1986). Implementation cycles, *Journal of Political Economy*, 94 (6), 1163-1190.
Stiglitz, J. E. (1999). Toward a general theory of wage and price rigidities and economic fluctuations, *American Economic Review*, 89 (2), 75-80.
Stiglitz, J. E., Weiss, A. (1992). Asymmetric information in credit markets and its implications for macroeconomics, *Oxford Economic Papers*, 44 (4), 694-724.

Appendix A

The purpose of this appendix is to provide some discussion of the equilibrium properties depending on the parameter values. Observe that the distribution of project types $\{n_a^t\}_{a\in A}$ in principle does affect the equilibrium. Specifically, it turns out that both the ρ moment and the -ρ moment of the distribution of project types do affect the equilibrium. Accordingly, let $A' = \{a: b_a > 0\}$ and define:

$$\begin{aligned} \mu_0^t &= \int_{a\in A'} n_a^t a^0 da \\ \mu_\rho^t &= \int_{a\in A'} n_a^t a^\rho da \ . \\ \mu_{-\rho}^t &= \int_{a\in A'} n_a^t a^{-\rho} da \end{aligned} \tag{37}$$

Observe that equation (24) implies that the expression $\psi_t = (1 - b_a^t)a^\rho$ is identical for all $a \in A'$. Consequently, we can express Φ_t as:

$$\Phi_t = n^c + (1-2g)\mu_{-\rho}^t \psi_t^2 + 2(g-1)\mu_0^t \psi_t + \mu_\rho^t, \tag{38}$$

and in equilibrium the following expression obtains:

$$B k_t^{\rho_1} \psi_t = \Phi_t^{\rho_2}, \tag{39}$$

where $B = B_1 B_2 = \frac{1}{F}\left(\frac{1-\alpha}{\theta}\right)^{\frac{1-\alpha}{\eta+\alpha}}(1-\gamma)\gamma^{\frac{\gamma}{1-\gamma}}$, $g = \gamma^{\frac{\gamma}{1-\gamma}}$, $\rho_1 = \alpha\frac{1+\eta}{\alpha+\eta}$ and $\rho_2 = 1 - \frac{1-\gamma}{\gamma}\frac{1-\alpha}{\alpha+\eta}$. Observe that ψ_t never falls below zero and never exceeds q^ρ. Moreover, the monopolists problem has a non-degenerate solutions for $\gamma \in (0,1)$, i.e. $g \in (e^{-1},1)$. As a result Φ_t decreases for $\psi_t \in (0, q^\rho)$ when $\gamma < ½$ and can be either decreasing or have a local minimum for $\gamma > ½$ for $\psi_t \in (0,q^\rho)$. Note that irrespective of the sign of ρ_2 the higher the value of capital stock k_t, the lower the value of ψ_t and, consequently, the larger the values of entry probabilities. Similarly, the influence of changes in θ on the entry probabilities is unambiguous. On the other hand the impact on ψ_t of the informational statistics $\mu_{-\rho}^t$, μ_0^t, and μ_ρ^t is ambiguous and it does depend on the sign of ρ_2 and the sign of $(1 - 2g)$.

Observe that both functions $y = x^\rho$ and $y = x^{-\rho}$ are convex, where $\rho = \frac{1}{1-\gamma} > 1$. Any suspension of a project moves mass of the distribution of project types from the tails of the distribution of project types to the center.

Specifically, if at time t the fraction of suspended projects of type a increases by Δz_a then the number of projects of quality a_1 falls by the amount $a\Delta z_a n_a^t$, the number of projects of type $1 - a$ falls by the amount $(1 - a)\Delta z_a n_a^t$ and the number of projects of type $a' = aq + (1 - a)(1 - q)$ rises by the $\Delta z_a n_a^t$ amount. Naturally, as both functions $y = x^{\rho}$ and $y = x^{-\rho}$ are convex the ρ and $-\rho$ moments of the distribution of project types do fall. This changes the shape of Φ_t.

Observe that when ρ_2 is positive[6] at the margin, an increase in z_a^t leading to a simultaneous fall in μ_ρ^{t+1} and $\mu_{-\rho}^{t+1}$, and μ_0^{t+1} unaffected shifts the right hand side of (39) down makes ψ_t smaller, i.e. entry probabilities larger. In this case an increase in the riskiness of the projects leads to increased entry, conditional on physical capital stock being constant, and additional factor misuse and further output drop. Naturally, in this case more information is revealed, conditional on physical capital stock being fixed, and informational capital is built up at a faster rate. Higher level of informational embodied in $\{n_a^t\}_{a \in A}$ increases this time the ρ and $-\rho$ moments and discourages entry. In turn there is less information revealed. Consequently, informational capital is built up at a lower pace. The process continues and in this case the economy returns to its original state. However, the approach path can be oscillatory when physical capital stock is relatively unimportant in the process of production since informational capital can overshoot its long-run value on the approach path. The situation is different when ρ_2 is negative. In this case a marginal increase in z_a^t that lowers the values μ_ρ^{t+1} and $\mu_{-\rho}^{t+1}$, and leaves the value of μ_0^{t+1} unchanged, actually shifts the left hand side of (39) up, i.e. it rises the equilibrium value of ψ_t and makes the entry probabilities smaller additionally depressing informational capital formation. In this case the economy returns to its original position on a smooth approach path. Figure 8 presents a number of cases.

In this paper we focus on the latter case, i.e. we normally set the values of the underlying parameters in such a way so as to ensure that ρ_2 is negative. Consequently, in our model the higher the average risk associated with the projects the less likely the producers are to enter and smaller factor misuse. This assumption dampens the oscillations along the approach path, but does not necessarily imply that the actual welfare costs are smaller.

[6] The sign of $1-2g$ does not play an important role in the neighborhood of 0.

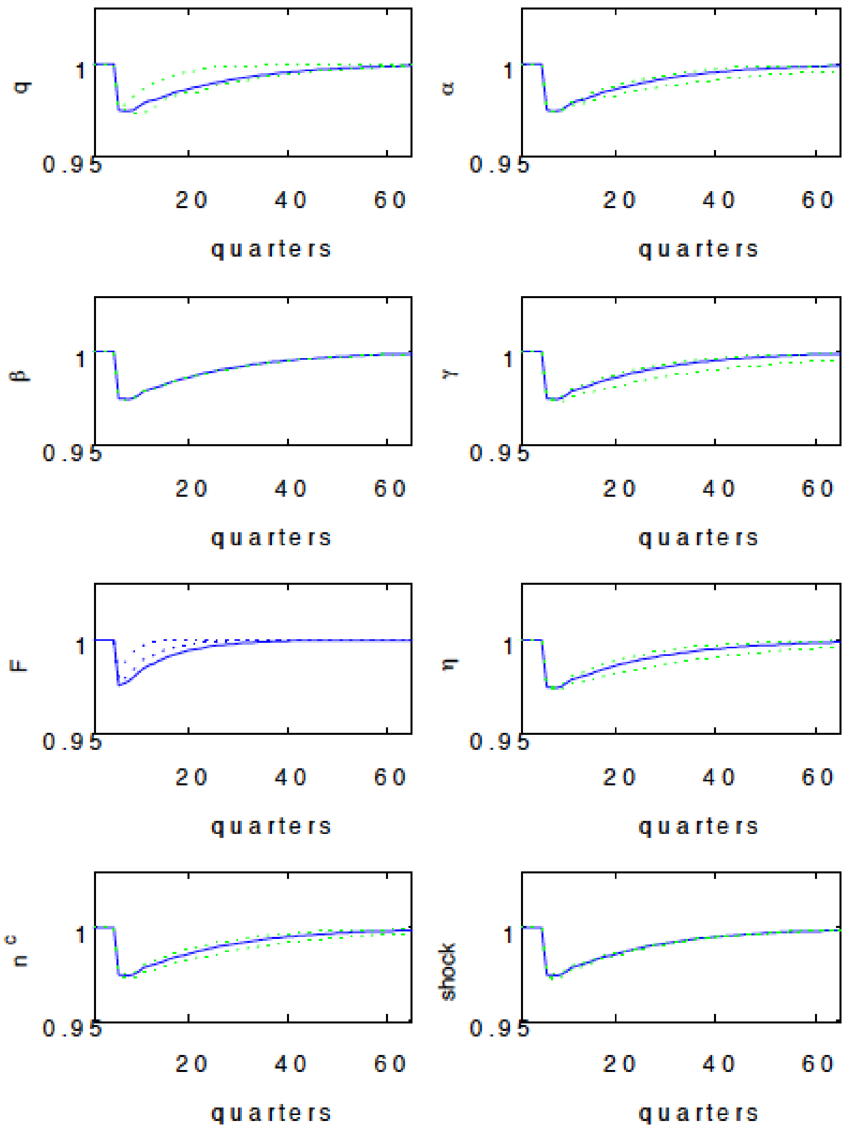


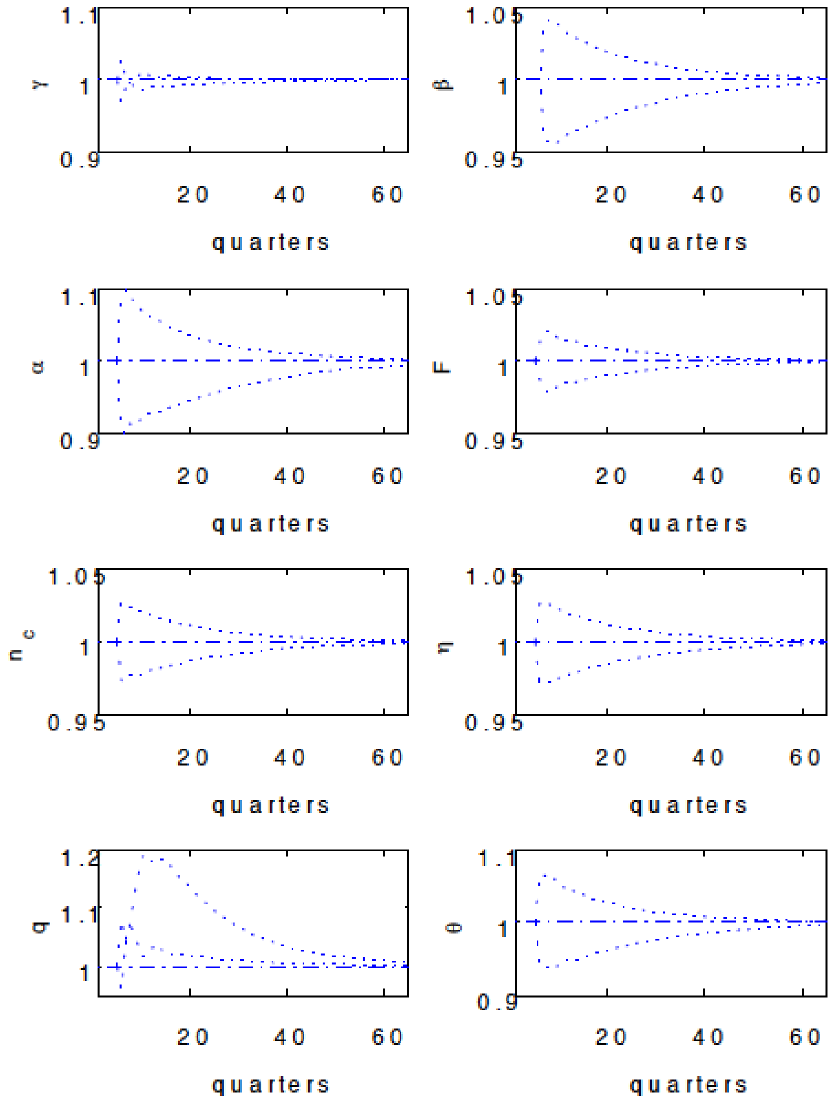
Figure 8. Time paths of the model parameters.

Source: own computation.

In summary, the model parameters do play a role for a very fundamental reason. Supply-side parameters such as α and η affect the relative importance of labor in the process of production and the labor supply. Real wage depends on the likelihood of entry. In particular, the higher the likelihood of entry the lower the real wage and the higher the labor supply, which makes entry additionally attractive. On the other hand the demand parameter γ defines the substitutability between intermediate goods. Consequently, it influences profits earned. In particular, additional entry can be welcome if new entrants create enough profits to generate additional demand for the existing firms. On the other hand it could be the case when the elasticity of substitution between intermediate goods is high that new entrants compete for the same demand and actually depress the value of per firm profits. Clearly, entry affects both the supply and the demand side and its overall impact on others depends on the parameter values. Consequently, changes in the ρ and the $-\rho$ moments of the distribution of project types can impact the entry probabilities in a number of ways. In this paper, we do assume that the parameters are such that the higher the riskiness of the projects the more reluctant the producers are to enter.

Appendix B

The purpose of this appendix it to present a number of sensitivity tests with respect to the key parameters of the model. The figure below presents the reaction of output to a one-time shock to θ for the reference value of the underlying parameter (the solid line), and a 5% increase and a 5% decrease in the value of the underlying parameter (the broken lines).



Source: own computation.