

Capital Reallocation, Productivity and Expectation-Driven Business Cycles*

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Abstract

In this paper, we show that news on future technological improvement can trigger an immediate economic expansion in a model with heterogenous productive efficiency. The key element in our model is financial friction on allocating capital from less productive to more productive projects. The arrival of good news on future technology reduces such frictions and generates significant increase in current total factor productivity via capital reallocation. This triggers an immediate increase in output, consumption, investment and hours worked.

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1 Introduction

What drives business cycles? In the Real Business Cycle (RBC hereafter) models, business cycles are triggered by TFP (Total Factor Productivity) shocks: an *unexpected* shift to TFP leads to a positive comovement of output, consumption, investment and hours worked. Recent evidence by Beaudry and Portier (2006a), in contrast, shows that news shocks containing information on future TFP changes are potentially an important source of business cycles. An important finding in their paper is that an *anticipated* change in future TFP leads to a boom in output, consumption, investment and hours worked before the actual productivity increase is realized. Moreover, TFP, as measured by Solow Residual, rises rapidly in response to a favorable news shock. This finding has invoked a growing number of studies on "expectation-driven business cycles" (EDBC hereafter), which contrast the standard "technology-driven" story in the RBC literature.

This paper shows that these two approaches can be reconciled in a simple framework with financial frictions on capital allocation across heterogeneous productive projects: good news about future technological opportunities lead to an increase in the current TFP, which triggers an immediate economic expansion. The idea is based on the following observations. More productive projects deserve larger inputs and thus are more likely to be financially constrained.¹ When there is an anticipated improvement in future technology, project value tends to increase and the financial constraint is relaxed accordingly. This triggers a reallocation of capital from less productive projects to more productive projects. The efficiency gains created by the reallocation show up in the aggregate economy as an upward shift to current TFP, and lead current output, consumption, investment, and hours worked to comove positively.

Our work builds on the microeconomic evidence on productivity, the importance of reallocation for aggregate productivity changes, and the roles of capital reallocation in business cycles. First, there exists persistent heterogeneity in productivity at firm level. As surveyed by Bartelsman and Doms (2000), micro studies have consistently found that there is sizable dispersion in plant-level productivity within narrowly defined U.S. manufacturing industries. The ratio of average TFP for plants in the ninth decile of the productivity distribution relative to the average in the second decile was about 2 to 1 in 1972 and about 2.75 to 1 in 1987. Moreover, more than one-third of the plants remain in the same productivity quantile after five years (see Bartelsman and Dhrymes, 1998), indicating that productivity gaps among plants are quite persistent.

Furthermore, it has been found that resource reallocation plays a central role in the aggregate productivity growth. According to Baily, Hulten and Campbell (1992) and Foster,

¹Barlevy (2003) finds that empirically firms with higher output per worker tend to borrow more (after controlling for net worth), suggesting that they are more vulnerable to credit constraints.

Haltiwanger and Krizan (1998), the increasing output shares of high productivity plants and the decreasing output shares of low productivity plants contribute positively to aggregate productivity growth in all the 23 examined manufacturing industries. Furthermore, as found by Foster, Haltiwanger and Krizan (2002), over the 1990s virtually all of the productivity growth in the U.S. retail trade sector, which lies at the heart of many recent technological advances such as E-commerce and advanced inventory control, is accounted for by more productive establishments displacing much less productive establishments.²

More recent evidence shows that reallocation of productive capital across firms through merger and acquisition and partial-firm asset sales is procyclical while the benefit of reallocation, measured by cross-sectional dispersion of productivity of capital is countercyclical. For example, Eisfeldt and Rampini (2006) find that between 1.4% and 5.5% of the capital stock turns over each year, depending on the measure of the capital stock. Moreover, the correlation of standard deviation of productivity dispersion with output is around -0.4.³ The convergence of productivity across firms during the boom period indicates that capital reallocation at firm level might play an important role in the aggregate productivity fluctuations. Similarly, Maksimovic and Phillips (2001) find that less productive firms tend to be sold as prospects of the aggregate economy improve. This suggests that the frictions impeding reallocation are considerably countercyclical.⁴

Based on the above observations, we introduce financial frictions on capital reallocation as the key model ingredient. In our model, project sizes are subject to financial constraints due to the limited enforcement of debt payment. Particularly, the financial constraint binds for more productive projects, which offer more incentive to default the debt contract.⁵ This creates a gap of marginal productivity of capital between different types of projects, and therefore, the potential benefit of reallocating capital from less productive to more productive projects. Correspondingly, good news induce capital to flow from less productive projects to more productive ones, as they relax the financial constraint on the latter by increasing the

²On the productivity-enhancing role at the firm level, Maksimovic and Phillips (2001) find that when both the purchased and existing assets are taken into account, the change in productivity (measured by TFP) from the year prior to the asset sale or merger to the end of the second year after the transaction is significantly positive for partial-firm assets sales. In addition, gain in productivity for purchased plants is positive related to the initial difference in productivity between the buying firm and the purchased firm.

³This negative correlation is robust to adjustment of capital utilization.

⁴Moreover, as argued by Jovanovic and Rousseau (2006), four of the five major merger waves since 1890s were a part of the needed reallocation that occurred during the two bursts of general-purposed technologies - electricity and internal combustion, and information technology. In particular, the recent economic boom in the late 1990s is characterized by both an anticipation of “New Economy” led by breakthrough in IT technology, and historically high merger activities.

⁵See Barlevy (2003) for more discussion on this type of moral hazard problems and the opposite “cleansing effect”.

projects' future profits and thus the associated collateral value.⁶

We calibrate our model to match the long-run features of U.S. data. Our numerical results show that following an anticipated future technological improvement, the magnitude of the initial increase in TFP, which is purely driven by resource reallocation, is about one third that of the TFP increase when technology improvement is materialized. This efficiency gain leads aggregate output, consumption, investment, and hours worked to comove positively together. The business cycle statistics in our model, moreover, are close to the U.S. data.

Our work is closely related to Jermann and Quadrini (2006a), which show that in a model with financial frictions due to the limited enforcement of debt, mere prospect of high future productivity growth can generate sizable gain in current labor productivity. In their paper, however, financial frictions are imposed on the investment of new capital goods, instead of allocating existing capital across plants with different productive efficiencies. As a result, when the constraint on investment is relaxed due to an anticipated future technologic improvement, capital and labor will shift from consumption goods production to investment goods sector, implying that consumption and investment comove negatively.⁷ In contrast, the key question in our paper is whether anticipated future technological improvement can trigger both consumption and investment, together with other macro variables, to increase simultaneously. With financial frictions on capital reallocation, our results show that this is feasible.

Our paper is also related to several strands of literature. First, it contributes to the recent discussion on the role of expectation in triggering business cycle. Beaudry and Portier (2006b) show that in a wide class of business cycle models mere changes in expectation about future productivity cannot generate comovement between consumption, investment and hours worked.⁸ The reason is simple: without current expansion in output, consumption and investment will always comove negatively if they substitute one to one with each other. One potential source for the observed initial response of TFP to news shocks is simply changes of capital utilization, as argued by Jaimovich and Rebelo (2006). However, in the standard setup with convex investment adjustment costs, investment boom must be associated with an increase in marginal q , which in fact implies a decline in capital utilization.⁹ Den Haan

⁶Consistent with the empirical findings, the financial friction in this context implies countercyclical benefits for capital reallocation.

⁷Beaudry and Portier (2006) have proved that in a two-sector model with constant returns to scale for production, an increase in investment is necessarily associated with a decrease in consumption or hours worked or both. Similar proof can be easily extended to two-sector models with decreasing returns to scale in one or both sectors and financial frictions on investment goods sector (see, for example, Kiyotaki and Moore, 1997).

⁸Beaudry and Portier (2004) and Danthine, Donaldson and Johnsen (1998) reach similar conclusions.

⁹This holds even if there is an expected investment good specific technological improvement. Only after such a shock is realized, investment and marginal q can move in opposite directions.

and Kaltenbrunner (2006) argue that labor hoarding may translate into additional resources for economic expansion when there is matching friction in labor market. Nonetheless, absent initial productivity increase, either consumption or total investment must decrease in the first period, as both capital and employment are predetermined in the period that the news shock occurs.¹⁰ Our work differs from the above studies by exploring the sources of initial expansion in aggregate output in a framework with heterogeneous productive efficiency. The results in this paper show that capital reallocation is potentially an important channel for the initial increase in aggregate TFP and expectation-driven business cycle.

Another line of the literature that is closely related to this paper is the role of financial market frictions in business cycles. It is well documented in the empirical literature that a large fraction of firms are financially constrained. This observation has invoked many theoretical works, most of which focus on the role of credit market frictions for the *propagation* of cyclical fluctuations driven by TFP shocks (see Bernanke, Gertler and Gilchrist, 1999 for a literature review).¹¹ By contrast, this paper explores the role of financial friction in the *transmission* of news shocks, and therefore, complements the existing studies on the roles of financial frictions for business cycles.

Finally, this paper is related to the recent work on reallocation as source of TFP (e.g. Restuccia and Rogerson, 2003, Barseghyan and Dicecio, 2006). All these studies, however, focus on the role of reallocation for the cross-country difference in long-run TFP, instead of its role for TFP fluctuations over the business cycle.

The paper is organized as follows. In Section 2, we describe the environment of the economy and define the equilibrium. Section 3 provides a discussion of the calibration procedure and the computation method. In Section 4, we report the impulse responses and business cycle statistics and check the robustness of our model to alternative parameter values. Section 5 discusses the role of capital allocation in our model. Section 6 concludes. Appendix contains the definition for recursive competitive equilibrium and the derivation of the enforcement constraint.

2 The model

Consider an economy with a representative household and a continuum of entrepreneurs with unit mass. The representative household owns both capital and labor and decides how much to consume, how much to invest in physical capital, and how much labor to supply. In addition, the representative household owns the entitlement, and therefore, the profit of a

¹⁰In addition, Christiano, Motto and Rostagno (2006) find that it is hard to generate expectation-driven business cycles without nominal frictions and monetary targeting.

¹¹Another strand of literature focus on the impact of recession on job reallocation. See, among others, Davis and Haltiwanger (1990), Caballero and Hammour (1994), Caballero and Hammour (2005).

continuum of projects. The entrepreneur has access to the technology to operate the project. Each entrepreneur operates only one project. At each period, the entrepreneurs decide how much capital and labor to rent from the representative household for the profit maximization of the project.¹²

2.1 Project Financing and the Entrepreneur's Problem

Projects can be classified into two categories according to the efficiency of their production technologies. A fraction η of projects have higher productivity, denoted as type- h or high-tech projects. Similarly, denote the remaining $1 - \eta$ fraction of projects as type- l or low-tech projects. The production technology of a type- i , $i \in \{h, l\}$, is given by

$$Y_t^i = A_t^i \left((K_t^i)^\alpha (H_t^i)^{1-\alpha} \right)^\mu.$$

where K_t^i and H_t^i are capital and labor employed in a single type- i project. $\mu < 1$, implying decreasing returns to scale.¹³ The magnitude of μ captures the “span of control” of the entrepreneur, as mentioned by Lucas (1978). A_t^i is the productivity associated with project i , which contains three components.

$$A_t^i = (1 + \gamma)^t \chi_t^i Z_t, \tag{1}$$

The first part, $(1 + \gamma)^t$, captures the trend of technology, where γ is the long-run growth rate of aggregate productivity. The second part, χ_t^i , refers to the project-specific productivity. Finally, Z_t is a economy-wide technological shock. As a benchmark, we assume aggregate productivity Z_t is stochastic, and keep project-specific productivity χ_{t+1}^i constant over time and equal to $\bar{\chi}^i$, with $\bar{\chi}^h > \bar{\chi}^l$.

The process for news shocks on aggregate productivity can be specified as

$$\log Z_{t+1} = \rho \log Z_t + \epsilon_t^Z, \tag{2}$$

where ϵ_t^Z denotes innovations regarding information on the next period aggregate productivity Z_{t+1} . Note that the process (2) is different from the stochastic technology process in RBC models: new information on Z_{t+1} arrives at time t , before Z_{t+1} is realized. As a result, next period productivity is perfectly predictable. In contrast, in the RBC models, shocks occurs at $t + 1$, the same time when Z_{t+1} is realized.

With probability $1 - \phi^i$, the type- i project becomes unproductive at each period. The survival probability ϕ^i can be interpreted as the probability that a type- i project remain productive. Once the project is unproductive, a new project with the same productivity type

¹²By assuming rental markets as the avenue to allocate existing capital, we abstract from the issue of firm dynamics in the context of business cycle.

¹³Basu and Fernald (1997) estimate returns to scale using data on 34 industries and find that without correcting for aggregation, returns to scale appear strongly diminishing.

enters the market and starts to be operated by a new entrepreneur. We assume $\phi^h < \phi^l$. Implicitly, (expected) more productive projects are more risky.

To finance the operation of a project, entrepreneurs borrow from the representative household at the beginning of each period and repays the debt at the end of the period after all transactions are completed. The ability to borrow, however, is bounded by the limited enforcement of the debt. At the end of the period, the entrepreneur has the ability to divert project resources. The divertible resources increase with the scale of production. For reasons discussed below, the divertible resource is specified as $D(K_t^i, H_t^i) = \left((K_t^i)^\alpha (H_t^i)^{1-\alpha}\right)^\mu$. Once defaulting, the representative household can take over the control right of the project from the entrepreneur and recover a fraction (< 1) of the future project value. The entrepreneur and the representative household can then renegotiate over repayment of the debt. Appendix A describes in details the renegotiation process and shows that the incentive-compatibility condition imposes the following financial constraint

$$D(K_t^i, H_t^i) \leq \theta V_t^i = \theta E_t \sum_{j=1}^{\infty} \beta \phi^i \pi_{t+j}^i. \quad (3)$$

where V_t^i is the value of type- i project to the entrepreneur at the end of period t , β is the subjective discount factor. $\pi_{t+j}^i = A_{t+j}^i \left((K_{t+j}^i)^\alpha (H_{t+j}^i)^{1-\alpha}\right)^\mu - (r_{t+j} + \delta) K_{t+j}^i - w_t H_{t+j}^i$ is the one-period profit of type- i project at period $t+j$. (3) implies that the entrepreneur can only borrow a fraction θ against the future project value.

At each period, the entrepreneur of a type- i project chooses capital K_t^i , labor H_t to solve

$$\max_{\{K_t^i, H_t^i\}} A_t^i \left((K_t^i)^\alpha (H_t^i)^{1-\alpha}\right)^\mu - (r_t + \delta) K_t^i - w_t H_t^i \quad (4)$$

subject to (3).¹⁴

The first-order conditions of (4) implies the following allocation of capital between the two types of projects

$$\begin{aligned} & \alpha \mu \left(K_t^h\right)^{\alpha \mu - 1} \left(H_t^h\right)^{(1-\alpha) \mu} \left(A_t^h - \lambda_t^h\right) \\ = & \alpha \mu \left(K_t^l\right)^{\alpha \mu - 1} \left(H_t^l\right)^{(1-\alpha) \mu} \left(A_t^l - \lambda_t^l\right) \\ = & r_t + \delta. \end{aligned} \quad (5)$$

where λ_t^i is the Lagrangian multiplier for type- i project associated with financial constraint (3). To get the intuition for (5), note that at the first best allocation, where the financial

¹⁴Alternatively, the entrepreneur's problem can be specified as maximizing the present discounted project profit subject to the sequence of financial constraints (3), by choosing the whole path of capital and labor. The assumption of rental market for capital, however, makes the choice of capital at each period independent of the previous allocated capital. Therefore the dynamic problem boils down to the sequence of one-period profit-maximization problem, as stated in (4)

constraint of neither project is binding ($\lambda_t^i = 0$), type- h project should be allocated with more capital until the marginal productivity of capital, denoted as MPK , between the two types of projects are the same. Similarly, the allocation of labor follows

$$\begin{aligned}
& (1 - \alpha) \mu \left(K_t^h \right)^{\alpha \mu} \left(H_t^h \right)^{(1 - \alpha) \mu - 1} \left(A_t^h - \lambda_t^h \right) \\
&= (1 - \alpha) \mu \left(K_t^l \right)^{\alpha \mu} \left(H_t^l \right)^{(1 - \alpha) \mu - 1} \left(A_t^l - \lambda_t^l \right) \\
&= w_t.
\end{aligned} \tag{6}$$

Our specification of default value gives rise to the following properties: capital-labor ratios in both types of projects are the same, independent of the production scale.

$$\frac{K_t^h}{H_t^h} = \frac{K_t^l}{H_t^l} = \frac{\alpha w_t}{(1 - \alpha)(r_t + \delta)}.$$

This shuts down the within-project resource misallocation (between capital and labor) as a potential source for productivity gain. Finally, it is easy to show that given the relative magnitude of production efficiency of these two technologies, the first best allocation of capital follows

$$\frac{K_t^h}{K_t^l} = \left(\frac{A_t^h}{A_t^l} \right)^{\frac{1}{1 - \mu}}. \tag{7}$$

2.2 A Decomposition of TFP

To get some intuition of how the aggregate productivity in our economy is determined, we assume the labor income share is correctly measured, that is $(1 - \alpha) \mu = 1 - \hat{\alpha}$. We then decompose the aggregate TFP (Total Factor Productivity, measured as “Solow Residual”) as

$$\begin{aligned}
\log TFP_t &= \log \frac{\sum_i A_t^i \left((K_t^i)^\alpha (H_t^i)^{1 - \alpha} \right)^\mu}{K_t^{\hat{\alpha}} H_t^{1 - \hat{\alpha}}} \\
&= \log \frac{\sum_i A_t^i (K_t^i / H_t^i)^{(\alpha - 1) \mu} (K_t^i)^\mu}{(K_t / H_t)^{\hat{\alpha} - 1} K_t} \\
&= (\mu - 1) \log K_t + \log \sum_i A_t^i \left(\frac{K_t^i}{K_t} \right)^\mu
\end{aligned} \tag{8}$$

The first term on the right hand side of (8) is a level effect: given decreasing return to scale, larger average scales reduce aggregate productivity. The second term is the sum of the project-specific technology weighted by the share of capital in each type of project, which we call “adjusted Solow Residual”. Accordingly, the percentage deviation of aggregate TFP

from its balanced growth path can be decomposed as

$$\begin{aligned}\Delta \log TFP_t &= \Delta \log \left(\frac{\eta A_t^h (K_t^h)^\mu + (1-\eta) A_t^l (K_t^l)^\mu}{K_t} \right) \\ &= (\mu-1) \Delta \log K_t + \Delta \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right) \quad (9)\end{aligned}$$

where the percentage change of “adjusted Solow Residual” can be further decomposed as

$$\begin{aligned}\Delta \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right) &= \\ \Delta \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right) &\Big|_{\frac{K_t^i}{K_t} = \frac{\bar{K}_t^i}{\bar{K}_t}} + \\ \Delta \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right) &\Big|_{Z=\bar{Z}} + \text{cross product term} \quad (10)\end{aligned}$$

The first argument on the right-hand-side of (10) is the percentage change of “adjusted Solow Residual” attributable to exogenous changes in project-specific technology, which we denote as “within-project effect”. The second argument is the percentage change of “adjusted Solow Residual” due to reallocation of capital between the two types of projects, which we call “reallocation effect”. Note that before the aggregate productivity shock is materialized, the change of “adjusted Solow Residual” (and the initial change in aggregate TFP) is purely due to the reallocation effect.

2.3 Household Sector

There is a stand-in household with N_t working-age members at date t . The size of the household evolves over time exogenously at a constant rate $n = N_t/N_{t-1} - 1$. The household values both consumption and leisure. In addition, investment in capital is subject to a quadratic adjustment cost. In this framework a representative household solves

$$\max_{\{c_t, H_t, k_{t+1}\}_{t=0}^{\infty}} E_0 \left[\sum_{t=0}^{\infty} \beta^t N_t u(c_t, h_t) \right],$$

subject to

$$C_t + G(I_t, K_t) = (r_t + \delta) K_t + w_t H_t + (1-\eta) \pi_t^l + \eta \pi_t^h, \quad (11)$$

$$K_{t+1} = (1-\delta) K_t + I_t, \quad (12)$$

$$G(I_t, K_t) = I_t + \kappa \left(\frac{I_t}{K_t} - \delta - n - g_y \right)^2 K_t. \quad (13)$$

where $c_t = C_t/N_t$ is per member consumption, $h_t = H_t/N_t$ is the fraction of hours worked per member of the household, H_t is total hours worked by all working-age members of the

household, and K_t is the capital stock owned by the household at the beginning of period t . g_y is the growth rate of output per capita at the balanced growth path, which follows

$$1 + g_y = (1 + \gamma)^{\frac{1}{1-\alpha\mu}} (1 + n)^{\frac{\mu-1}{1-\alpha\mu}}$$

The first order conditions implies the following standard equations

$$u_c(c_t, h_t) w_t = -u_h(c_t, h_t) \quad (14)$$

$$q_t = 1 + 2\kappa \left(\frac{I_t}{K_t} - \delta - n - g_y \right) \quad (15)$$

$$q_t u_c(c_t, h_t) = \beta E_t \left[u_c(c_{t+1}, h_{t+1}) \left(r_t + \delta + 2\kappa \left(\frac{I_t}{K_t} - \delta - n - g_y \right) \frac{I_t}{K_t} - \kappa \left(\frac{I_t}{K_t} - \delta - n - g_y \right)^2 + q_{t+1} (1 - \delta) \right) \right] \quad (16)$$

where q_t is the marginal q , $u_x(c_t, h_t)$ is the marginal utility (or disutility) associated with x , $x = c$ or h . Equation (14) is the first order condition for labor. Equation (15) is the first order condition for investment, and Equation (16) is the standard Euler equation with quadratic adjustment cost.

2.4 Timing and Information

At each period, the events proceed as follows. At the beginning of each period, news regarding future technological opportunities arrive. At the same time, current-period aggregate and project-specific technologies are realized. Then the representative household supplies capital and labor to entrepreneurs. After consumption goods are produced, the household receives factor payments and profits, and makes consumption-saving choice. Finally, uncertainty about project survival is revealed.

2.5 Competitive Equilibrium

A competitive equilibrium of this economy consists of an allocation $\{c_t, h_t\}_{t=0}^{\infty}$ for the representative household, allocation $\{K_t^h, H_t^h, K_t^l, H_t^l, K_t, H_t, Y_t\}_{t=0}^{\infty}$ for entrepreneurs and price system $\{w_t, r_t\}$ such that

- Given prices, the allocation solves the household's problem (11).
- Given prices, the allocation solves the entrepreneur's profit maximization problem (4).
- Capital market clears: $\eta K_t^h + (1 - \eta) K_t^l = K_t$
- Labor market clears: $\eta H_t^h + (1 - \eta) H_t^l = H_t$
- Good market clears:

$$\begin{aligned} C_t + G(I_t, K_t) &= Y_t \\ &= \eta A_t^h \left((K_t^h)^\alpha (H_t^h)^{1-\alpha} \right)^\mu + (1 - \eta) A_t^l \left((K_t^l)^\alpha (H_t^l)^{1-\alpha} \right)^\mu. \end{aligned}$$

For numerical simulation, we also define the recursive competitive equilibrium in the Appendix. We solve for the decision rules by policy function iterations.

3 Calibration

In this section, we calibrate the model economy using data from the 2005 revision of National Income and Product Accounts (NIPA) to target the average values of U.S. data over the 1960-2004 period. Our measure of capital stock includes government capital and stock of consumer durables, following Cooley and Prescott (1995). One period in our model corresponds to one calendar year, the frequency adopted by Eisfeldt and Rampini (2006) in their measurement of the magnitude of capital reallocation.

3.1 Preference

In our baseline experiment, the period utility of the household follows the utility specification in Greenwood, Hercowitz and Hoffman (1988) (“GHH” hereafter).

$$u(c_t, h_t) = \frac{\left(c_t - \psi A_t \frac{h_t^{1+\nu}}{1+\nu}\right)^{1-\sigma} - 1}{1-\sigma} \quad (17)$$

where $A_t = (1 + g_y)^t$ is incorporated in the utility to ensure the stationarity of hours on the balanced growth path. Under GHH preference, the intertemporal substitution effect on labor supply is shut down. Jaimovich and Rebelo (2006) use a preference that nests both the GHH form and that used by King, Plosser and Rebelo (1988) (“KPR” hereafter), and find that to achieve comovement between consumption and hours worked, the preference must be very close to the GHH form.

We set $\sigma = 1$, which corresponds to the case of logarithmic utility. ν is set to 0.4 to match a Frisch elasticity of 2.5. The parameter ψ is set to 1.5 so that the hours worked is 0.31 at the steady state. The discount factor β is set to 0.979, implying a steady state real interest rate of 4%. The population growth rate n is set to 0.0147, which is the average growth rate of civilian population aged 16-64 between 1960 and 2004.

3.2 Technology

We set $g_y = 0.0183$, which is consistent with the long-run average growth rate of U.S. real GNP per capita. $\mu = 0.85$, which is the value used by Atkeson and Kehoe (2001). The parameter α is then set so that the labor income share is 0.6. This yields a value of α of 0.294. The depreciation rate δ is set to match an investment capital ratio of 0.074, the average between 1960 and 2004. This gives $\delta = 0.04$. The adjustment cost parameter, κ , is set to 2.0, which is close to the estimated result by Gilchrist and Himmelberg (1995).

We set the survival probability for the high-tech project ϕ^h to be 0.875, which is broadly consistent with the U.S. data for the manufacturing and business service sector reported by OECD (2001). According to this source, about 75 percent of entering firms are still alive after the first two years. The survival probability for the low-tech project ϕ^l is set to be 0.975.

We set $\eta = 0.5$ so that the number of high-tech projects and low-tech projects are equal. We normalize the expected detrended value of technology at low-tech project $\bar{\chi}^l$ to 1. To calibrate $\bar{\chi}^h$, the expected productivity of the high-tech projects and θ , the collateral ratio, we use the fact that at steady state,

$$\theta = \frac{\frac{1}{\beta\phi^h(1+g_y)} - 1}{\bar{\chi}^h \left(1 - \mu / \left(\frac{\bar{y}^h/\bar{n}^h}{\bar{y}^l/\bar{n}^l}\right)\right)}.$$

Therefore, we set the values of $\bar{\chi}^h$ and θ simultaneously to match two targets, the ratio of labor productivity between the two types of projects and an aggregate capital-output ratio of 2.5. Typically, the ratio of the labor productivity of the 25 percentile producer to the 75th percentile producer is about 2 (see Bartelman and Doms, 2001 for a survey of the empirical literature and Syverson, 2004, Table 1.) The fact that in our model economy the number of high-tech projects and low tech projects are set to be equal in our economy, accordingly, implies $\frac{\bar{y}^h/\bar{n}^h}{\bar{y}^l/\bar{n}^l} = 2$. As a result, $\bar{\chi}^h = 1.69$ and $\theta = 0.13$. This implies a value of 0.26 for the standard deviation of $\log \bar{\chi}^i$, which is well within the range estimated in the literature.¹⁵

For the parameter governing the technology process, we set $\rho = 0.95$ to match a quarterly persistence of 0.987. We let the standard deviation of innovation σ_ϵ^Z equal to 1.30% such that the standard deviation of the log of HP detrended TFP simulated from the model (1.25%) is equal to the corresponding value from annual US data. Table 1 summarizes the calibrated parameters.

¹⁵Cooper and Haltiwanger (2006) specify a log AR(1) process for the plant-specific shock and obtained a value of 0.64 for the estimated standard deviation.

Table 1. Parameter Values For the Benchmark Economy

Symbol	Definition	Value
Demographics		
n	Population growth rate	0.015
Technology		
α	Capital share in production function	0.294
g_y	Growth rate of output per capita	0.018
ϕ^h	Survival rate for high-tech project	0.875
ϕ^l	Survival rate for low-tech project	0.975
δ	Depreciation rate for capital	0.04
$\bar{\chi}^h$	Expected high-tech project-specific productivity	1.69
μ	Production parameter	0.85
ρ	Autocorrelation coefficient	0.95
σ_ϵ^Z	Standard deviation of information innovation	0.013
κ	Adjustment cost parameter	2.0
Preference		
β	Discount factor in utility function	0.979
ψ	Disutility parameter for leisure	1.6
σ	Coefficient of relative risk aversion	1
ν	Inverse of Frisch elasticity	0.4
Market		
θ	Default parameter	0.13
η	Fraction of high-tech projects	0.50

4 Results

In this section, we first plots the impulse responses of macro aggregate to news on future technological improvements. We then report the business cycle statistics under the news shocks. Finally, we check the robustness of our results to different parameter values.

4.1 Impulse Response to News

Our key question is whether news shocks can trigger comovement of output, consumption, investment, and hours. To this end, we study the impulse responses to anticipated future technological improvement. In the baseline case, the economy is subjective to news shocks on aggregate technological improvement. In order to unravel the underlying propagation mechanism, we also study the impulse responses to news shocks on technological improvement specific to high-tech projects.

4.1.1 Impulse Response to News on the Economy-Wide Productivity Z_t

To examine how the economy reacts to news about future productivity, we consider the following experiment: at period 0, the economy is at steady state. At the beginning of period 1, all agents receive unanticipated news that the economy-wide productivity Z will increase by one percent in period 2. At the beginning of period 2, the technology improvement is materialized. Our choice of one period as the lag for technological improvement to be realized is motivated by Beaudry and Portier (2006a), which evidence suggests that a permanent change in TFP may be associated with an up to 10 quarters long period where there may be no actual change in technological opportunities.¹⁶

Figure 1 plots the impulse responses of macroeconomic variables to this news shock. Though the exogenous technology improvement materializes at period 2, the economy starts an expansion at period 1. Consumption, investment, output and hours worked all increases in period 1. As one can see from the first two column of Table 2, the effects of such a news shock are sizable: output, consumption and investment increase by 0.52%, 0.54% and 0.46%, respectively. The change of hours is not significant, however.

Table 2. Response to News

	Z		A^h	
	$t = 1$	$t = 2$	$t = 1$	$t = 2$
Y	0.52	2.10	0.72	1.10
C	0.54	1.82	0.81	1.02
I	0.46	3.38	0.30	1.47
H	0.16	1.36	0.22	0.21
$\tilde{K}$	0.63	0.40	0.87	0.83
TFP	0.43	1.26	0.59	0.96

The reason for the comovement of macro aggregates, as mentioned earlier, is the increase in total factor productivity brought by the reallocation of capital from low-tech projects to high-tech projects. This is evident in Figure 2. Figure 2 depicts the response of capital reallocation, together with the benefit of reallocating capital, measured by the ratio of marginal productivity to capital between the two types of projects.

$$\frac{MPK_t^h}{MPK_t^l} = \left(\frac{K_t^h}{K_t^l} \right)^{\mu-1} \left(\frac{A_t^h}{A_t^l} \right) \quad (18)$$

Note that in our model capital reallocation and the benefits of reallocating capital are negatively correlated. This negative correlation is consistent with the empirical findings of

¹⁶The results remain qualitatively the same if we assume that an anticipated shock is realized at period 3. Our choice of one year as the lag for actual technological improvement to be materialized greatly eases the computation burden to solve for the policy functions.

Eisfeldt and Rampini (2006). As in Figure 2, when good news arrive, capital (and labor) is reallocated from low-tech projects to high tech projects. The upper right panel shows that on impact capital reallocation is 0.6 percent of capital stock, the magnitude somewhat below that is estimated by Eisfeldt and Rampini (2006). Accordingly, the gap of marginal productivity between the two types of projects decreases, as illustrated by the upper-left panel.

Figure 3 and 4 plot the response of TFP and its components to the good news. In Figure 3, we see that the level effect plays a minor role in the change of TFP, especially during the initial periods. The initial response of TFP amounts to 0.43% (Table 2), which is one third of the magnitude of TFP increase when technology improvement is realized. Figure 4 shows that reallocation effects explain *all* the increase in TFP before the shock is materialized. After the technology improvement is realized, the contribution of capital reallocation to TFP starts to decline.

4.1.2 Impulse Response to News on the Project-Specific Productivity χ_t^h

The U.S. boom in the 90s is largely fueled by optimism of a New Economy, represented by technological breakthrough in computer sector and its wide usage in other sectors. Therefore, it is interesting to explore the effect of news on high-tech project specific technology, controlling for economy-wide productivity shocks.

Accordingly, we consider news shocks on project-specific productivity (19). Specifically, we let Z_t and χ_t^l remain constant (equal to their mean) and assume that

$$\log \chi_{t+1}^h = (1 - \rho) \log \bar{\chi}^h + \rho \log \chi_t^h + \epsilon_t^{\chi^h}, \quad (19)$$

where $\epsilon_t^{\chi^h}$ denotes information innovations on the next period productivity χ_{t+1}^h . Here again, we assume that the next period productivity is perfectly predictable: households receive a perfect signal on the future productivity innovation.

We set $\rho = .95$, the value used in our benchmark case. We then choose $\sigma_{\epsilon}^{\chi^h}$ such that the standard deviation of the log of HP detrended TFP simulated from the model (1.25%) is equal to the corresponding value from annual US data. The calibrated $\sigma_{\epsilon}^{\chi^h}$ is equal to 2.40%.

The experiment is similar as before: at period 0, the economy is at steady state. At the beginning of period 1, all agents received unanticipated news that χ_t^h will increase by one percent from period 2. At the beginning of period 2, the technology improvement is materialized. The results can be seen from Figure 5 to 8.

Although the dynamics looks qualitatively similar, the initial response of macroeconomic variables to such news on project-specific technological improve is considerably larger than the initial response to news shocks on the economy-wide technology (see Table 4). The expectation drives the initial output by 0.72%, more than 2/3 of the output increase to the

realized technological shock at period 2. The initial response of TFP is also remarkable: it increases nearly 0.60%. The intuition for the amplified effect of news shock on future A^h is straightforward. Given χ_t^l unchanged, high-tech projects are more easy to get financed in future. This implies a larger value of high-tech projects, which relaxes further the financial constraint and thus induces more resource to flow from low-tech projects to high-tech projects. Hence, capital reallocation in response to news shocks on χ_t^h (0.87%) turns out to be more active than capital reallocation in response to news shocks on z (0.63%), resulting in a larger efficiency gain as reflected by the response of TFP.

4.2 Business Cycle Statistics

We would like to know how our model performs in other dimensions of business cycles. We compare with the U.S. data the business cycle statistics under the above mentioned two different specifications for technological process as in (2) and (19). To simulate the economy, we first use the quadrature method described in Tauchen and Hussey (1991) to construct a three-state Markov chain that approximates the autocorrelation in the AR(1) process. The estimated transition matrix is

$$\Pi = \begin{bmatrix} 0.8099 & 0.1874 & 0.0027 \\ 0.1667 & 0.6667 & 0.1667 \\ 0.0027 & 0.1874 & 0.8099 \end{bmatrix}, \quad (20)$$

and the supports for the estimated Markov chains of (2) and (19) are equal to $\{0.031, 0, -0.031\}$ and $\{0.057, 0, -0.057\}$, respectively. We then simulate the economy 500 times, each containing 45 periods. The sample mean of the standard deviation of macro variables are reported in Table 3, together with the U.S. data.

Table 3. Volatility of Macro Variables

	Data	Model Specifications	
		News to Z_t	News to χ_t^h
Used for calibration			
the standard deviation of TFP	0.0125	0.0127	0.0126
Not used for calibration			
the standard deviation of output	0.0173	0.0220	0.0127
the standard deviation of consumption	0.0120	0.0179	0.0095
the standard deviation of investment	0.0597	0.0402	0.0294
the standard deviation of hours	0.0154	0.0162	0.0016

We first examine news shocks on the aggregate productivity Z_t . The results are reported in the second column of Table 2. Note that the implied standard deviation for the log of output is equal to 2.2%, larger than the corresponding value for U.S. data (1.73%). Different

from our model, the standard RBC models imply less volatile output than data. This suggests that financial frictions enhance the propagation of technological shocks, as pointed out by Carlstrom and Fuerst (1997), among many others. The generated volatilities of consumption and investment have the standard ordering: consumption is less volatile and investment is more volatile relative to output. The volatility of hours implied by the model is almost the same as data.

The results implied by the news shocks to χ_t^h is given in the third column of Table 2. Not surprisingly, the volatilities fall sharply, since low-tech projects are immune of technological shocks. The decline of the volatility of hours is the most remarkable. Recall that wage rate is determined by the marginal labor productivity of low-tech projects. The constant productivity χ_t^l thus implies rather stable wage rate and labor supply over business cycles.

Table 4. Cross-Correlation Table

	t-2	t-1	t	t+1	t+2
Data					
correlation(Y,Y)	-0.0214	0.5565	1.0000	0.5527	-0.0463
correlation(C,Y)	-0.1948	0.3038	0.7186	0.7153	0.4458
correlation(I,Y)	0.2357	0.6444	0.8540	0.1967	-0.4495
correlation(H,Y)	0.0316	0.5168	0.9343	0.5049	-0.1705
correlation(TFP,Y)	0.4162	0.6279	0.4099	-0.3638	-0.6303
News on Z_t					
correlation(Y,Y)	0.0377	0.4490	1.0000	0.4529	0.0385
correlation(C,Y)	0.0276	0.4510	0.9996	0.4659	0.0563
correlation(I,Y)	0.0578	0.4440	0.9982	0.4260	0.0030
correlation(H,Y)	0.0120	0.3959	0.9982	0.4677	0.0563
correlation(TFP,Y)	0.1349	0.5396	0.9835	0.3544	-0.0792
News on χ_t^h					
correlation(Y,Y)	0.0835	0.6223	1.0000	0.6249	0.0867
correlation(C,Y)	0.1246	0.7366	0.9778	0.5519	0.0664
correlation(I,Y)	0.0202	0.4160	0.9558	0.6825	0.1119
correlation(H,Y)	-0.0082	0.6866	0.6295	0.3863	0.2833
correlation(TFP,Y)	0.1514	0.6367	0.9892	0.5627	-0.0162

The cross correlation matrix is reported in Table 4. A prominent feature is that under both types of news shocks, all macro variables are highly procyclical, consistent with the stylized facts of U.S. business cycles. Of course, quantitatively, our news shock models overestimate the current correlation coefficients, similar to RBC model.

Also interesting is the correlation coefficients between output and TFP. In the U.S. data, TFP leads output by one year. An interpretation of this leading behavior in the RBC model is that output peaks several quarters after the economy is hit by the technology shock,

indicating there exist some mechanism that propagate the technology shocks. Though in all three shocks the model generates a comovement of output and TFP, the one-period leading correlation coefficient for TFP is actually higher than the corresponding one-period lagging correlation coefficient. The reason, as we mentioned before, is that reallocation effect contributes more to aggregate TFP increase at the initial stages of economic expansion than later on.

4.3 Robustness

In our model with parameter calibrated to U.S. data, news about future rises in Z_{t+1} or χ_{t+1}^h triggers an expansion of output, consumption, investment and hours. Moreover, TFP and stock prices also increase before the actual rise in Z_{t+1} or χ_{t+1}^h . This is consistent with all empirical aspects of expectation-driven business cycles found in Beaudry and Portier (2006). In this subsection, we use different parameterization to check the robustness. We focus on the adjustment cost coefficient κ , the inverse of intertemporal elasticity of substitution σ and the inverse of the Frisch elasticity ν , since these parameters values are not calibrated but simply borrow from the literature. The possible ranges of parameter values which can generate expectation-driven business cycles are given in Table 5.

Table 5. Combination of Parameter Values that Generate EDBC

	κ	σ	ν
News Shock to Z_t	$(0.13, \infty)$	$(0.11, 1.48)$	$(0, \infty)$
News Shock to χ_t^h	$(0, \infty)$	$(0, 2.95)$	$(0, \infty)$

For news shock to Z_t , the adjustment cost coefficient κ has to be larger than 0.13, which is lower than the lowest estimate 0.20 in the literature (see Cooper and Haltiwanger, 2006). Capital adjustment costs help investment to comove with output and consumption with a news shock. To see this, consider a news shock that predicts technological improvement in the future. If the intertemporal elasticity of substitution σ were very large, agents would increase consumption substantially for consumption smoothing, resulting in a decline of investment. However, this would not occur with sufficiently large adjustment costs, since otherwise agents would have to pay large adjustment costs for increasing investment as the technological shift materializes.

To have the comovement of consumption and investment, σ has to fall into the range of $(0.11, 1.48)$ under the benchmark parameterization. If σ is too small, consumption will decline in the first period due to the very large intertemporal elasticity of substitution. On the other hand, if σ is too large, the desire for consumption smoothing is too strong, resulting in the large initial response of consumption to a news shock, which forces investment to decline. This also implies that larger capital adjustment costs tend to relax the upper bound of σ . In fact, if we raise the adjustment cost coefficient to 5, a value within the

range estimated by the literature (see Cooper and Haltiwanger, 2006), the upper bound of σ increases to 1.91. The Frisch elasticity turns out to be irrelevant.

The conditions for comovement are substantially relaxed when news shocks are project-specific as characterized by (19). Under benchmark parameterization, business cycles can be triggered by expectations in an economy without capital adjustment costs. The upper bound of σ also increase to 2.95.

5 The Role of Capital Reallocation

Compared with the standard RBC model, our benchmark economy incorporates the following ingredients: heterogeneity in productive efficiency, financial friction on resource reallocation (including both capital and labor), convex investment adjustment cost, and endogenous labor supply. It is interesting to know whether our results holds when the only driving mechanism for comovement in output, consumption and investment is capital reallocation. To this end, we would like to shut down labor reallocation and endogenous labor supply as potential source for increase in current aggregate output.

We make the following modifications to our benchmark economy. First, we assume the production technology follows

$$Y_t^i = A_t^i (K_t^i)^\alpha$$

Implicitly, production requires capital input and a fixed factor with capital income share α . Accordingly the divertible resource is specified as $D(K_t^i) = (K_t^i)^\alpha$. These modifications shut down labor reallocation and leave capital reallocation the only potential source for efficiency gain before technology shock is realized. As a result, the only channel for current output to increase is through productivity gain. Also, to highlight the roles of capital reallocation, we state the representative household's problem for a stationary economy.

$$\max_{\{c_t, H_t, k_{t+1}\}_{t=0}^\infty} E_0 \left[\sum_{t=0}^\infty \beta^t \frac{c^{1-\sigma} - 1}{1 - \sigma} \right],$$

subject to

$$c_t + i_t = (r_t + \delta) k_t + (1 - \eta) \pi_t^l + \eta \pi_t^h. \quad (21)$$

$$k_{t+1} = (1 - \delta) k_t + i_t. \quad (22)$$

Finally, we shut down investment adjustment cost. We call this economy as “Economy without Labor”.

The aggregate TFP in this economy can be decomposed as

$$\log TFP_t = \log \sum_i A_t^i \left(\frac{K_t^i}{K_t} \right)^\alpha. \quad (23)$$

Accordingly, the percentage deviation of aggregate TFP from its steady state value can be decomposed as

$$\Delta \log TFP_t = \Delta \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\alpha + (1 - \eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\alpha \right) \quad (24)$$

Comparing (24) with (9), we see that the only difference is that now the level effect is missing in the aggregate TFP.

The calibration procedure follows the calibration in the benchmark economy with the following exceptions. First, we set $\alpha = 0.4$, corresponding to a labor income share of 0.6. Second, we set $\delta = 0.07$ to match the investment capital ratio in the absence of long run growth in both technology and population. We then set $\beta = 0.96$ to match a steady state real interest rate of 4%. Finally, θ and $\bar{\chi}^h$ are chosen to target a value of 2 for the ratio of marginal productivity of capital and an aggregate capital output ratio of 2.5.¹⁷ Table 6 summarizes the parameter values for this economy.

Table 6. Parameterized Values for Economy w/o Labor

Symbol	Definition	Value
Technology		
α	Capital share in production function	0.4
ϕ^h	Survival rate for high-tech project	0.875
ϕ^l	Survival rate for low-tech project	0.975
δ	Depreciation rate for capital	0.07
$\bar{\chi}^h$	Expected high-tech project-specific productivity	1.69
ρ	Autocorrelation coefficient	0.95
σ_ϵ^Z	Standard deviation of technological innovation	0.013
σ_ϵ^Z	Standard deviation of information innovation	0.013
$\sigma_\epsilon^{\chi^h}$	Standard deviation of information innovation	0.024
Preference		
β	Discount factor in utility function	0.96
σ	Coefficient of relative risk aversion	1
Market		
θ	Default parameter	0.14
η	Fraction of high-tech project	0.50

5.1 Impulse Response to News

We perform the same experiment as in our benchmark economy: at period 0, the economy is at steady state. At the beginning of period 1, all agents receive unanticipated news that the

¹⁷In our benchmark economy, the ratio of marginal productivity of capital between two types projects are equal to the ratio of labor productivity.

economy-wide productivity Z will increase by one percent from period 2. At the beginning of period 2, the technology improvement is materialized.

Figure 8 plots the impulse responses for this economy to the news shock. We see that in response to news on productivity increase at period 2, aggregate output, consumption, and investment all goes up at period 1.¹⁸ Moreover, the capital reallocation on impact is 1.7% of aggregate capital stock, which magnitude is consistent with the empirical findings of Eisfeldt and Rampini (2006). The reason for the comovement of macro aggregates, as implied by Figure 9, is that aggregate TFP shifts up in response to the news shock. The magnitude of the percentage increase in TFP is about one thirds of the TFP increase when technology shock is realized. This is roughly the same as what we found in our benchmark case. Therefore, we conclude that the key element for the expectation-driven business cycle in our model economy is capital reallocation.

6 Conclusion

We show that good news on future technological improvement generates an immediate expansion in output, consumption, hours and investment in a model with heterogeneous productive efficiency. The key elements in our model are financial friction on allocating capital from less productive to more productive projects and decreasing returns to scale in production. The arrival of goods news on future technology reduces the financial friction and triggers capital to reallocate from less productive to more productive projects. The efficiency gains created by this reallocation show up in the aggregate economy as an upward shift to current TFP, and lead output, consumption, investment, and hours worked to comove positively.

7 Appendix

7.1 Definition of Recursive Competitive Equilibrium for Benchmark Economy

This section sketches out the definition of the recursive competitive equilibrium for our benchmark economy. To simplify notation we abstract from population and denote lower-case variables as individual variables and upper-case variables as aggregate variables. In our benchmark economy with news shocks, the state variables for the households are $s_t =$

¹⁸Note that the impulse response of output is hump-shaped even after the technology is realized. This is well consistent with the finding of Cogley and Nason (1995). The reason for this hump-shape response is that reallocation effects keep contributing to the increase in TFP even after the technology shock is realized.

$(Z_t, \epsilon_t^Z, k_t, K_t)$ or simply (Z_t, Z_{t+1}, k_t, K_t) , since next period productivity is perfectly predictable by (2). The household's problem can be rewritten as

$$v(Z, Z', k, K) = \max_{c, i, h} \left\{ u(c, h) + \beta E \left[v(Z', Z'', k', K') \mid Z' \right] \right\}$$

subject to

$$\begin{aligned} c + i + \kappa \left(\frac{i}{k} - \delta - n - g_y \right)^2 k &= \left(r(Z, Z', K) + \delta \right) k + w(Z, Z', K) h + (1 - \eta) \pi^l + \eta \pi^h. \\ k' &= (1 - \delta) k + i \\ K' &= (1 - \delta) K + I \\ \log Z' &= \rho \log Z + \epsilon^Z \end{aligned} \tag{25}$$

A recursive competitive equilibrium for this economy consists of a value function, $v(Z, Z', K)$; a set of decision rules $c(Z, Z', k, K)$, $i(Z, Z', k, K)$, $h(Z, Z', k, K)$ for the household; a corresponding set of aggregate per capita decision rules, $C(Z, Z', K)$, $I(Z, Z', K)$, $H(Z, Z', K)$; a set of decision rules for the entrepreneurs, $K^h(Z, Z', K)$, $H^h(Z, Z', K)$, $K^l(Z, Z', K)$, $H^l(Z, Z', K)$ and factor prices functions $r(Z, Z', K)$, $w(Z, Z', K)$, such that these function satisfies

1. The household's problem (25);
2. The entrepreneurs' problem (4);
3. The consistency of individual and aggregate decisions, that is $c(Z, Z', k, K) = C(Z, Z', K)$, $i(Z, Z', k, K) = I(Z, Z', K)$ and $h(Z, Z', k, K) = H(Z, Z', K)$.
4. The aggregate resource constraint

$$\begin{aligned} & C(Z, Z', K) + I(Z, Z', K) + \kappa \left(\frac{I(Z, Z', K)}{K} - \delta - n - g_y \right)^2 K = Y(Z, Z', K) \\ &= \eta A^h \left(\left(K^h(Z, Z', K) \right)^\alpha \left(H^h(Z, Z', K) \right)^{1-\alpha} \right)^\mu \\ &+ (1 - \eta) A^l \left(\left(K^l(Z, Z', K) \right)^\alpha \left(H^l(Z, Z', K) \right)^{1-\alpha} \right)^\mu, \forall (Z, Z', K). \end{aligned}$$

7.2 Enforcement Constraint

The renegotiation process described here follows closely to Jermann and Quadrini (2006b). Assume in addition to factor inputs, production at each period requires working capital, denoted as $f_t^i = D(K_t^i, H_t^i)$, which increases with the scale of the production. Working

capital consists of liquid fund that are used at the beginning of time t and are recovered at the end of time t , after all transactions have been completed. Because this is a intra-period load , the net interest payment is zero.

The entrepreneurs have the ability to divert the working capital and default.¹⁹ Once default, the lender (or the representative household) can take over the control right of the project and recover a fraction λ of the future project value, denoted as V_t^i , which is the simply the present discount value of the project profits from tomorrow on. Here the underlying assumption is that only the entrepreneur has the required talent to run this project efficiently. Denote by ω the bargaining power of the entrepreneur and $1 - \lambda$ the bargaining power of the the lender. Bargaining is over the repayment of the debt, denoted as $\widehat{f}_t^i$. If they reach an agreement, the entrepreneur gets $f_t^i - \widehat{f}_t^i + V_t^i$, and the lender get $\widehat{f}_t^i$. If there is no agreement, the entrepreneur gets f_t^i and the lender gets λV_t^i . Therefore, the net value for the entrepreneur to reach an agreement is $V_t^i - \widehat{f}_t^i$ and the net value for lender is $\widehat{f}_t^i - \lambda V_t^i$. The bargaining problem solves:

$$\max_{\widehat{f}_t^i} \left\{ \left(V_t^i - \widehat{f}_t^i \right)^\omega \left(\widehat{f}_t^i - \phi V_t^i \right)^{1-\omega} \right\}$$

Taking the first order condition we get $\widehat{f}_t^i = [1 - \omega(1 - \lambda)] V_t^i$. Incentive compatibility requires that the value of nondefault, that is V_t^i , for the entrepreneur should be no less than the value of default, that is $f_t^i - \widehat{f}_t^i + V_t^i$. Hence we have

$$[1 - \omega(1 - \lambda)] V_t^i \geq f_t^i$$

Denote $[1 - \omega(1 - \lambda)]$ as θ . Then we get Equation (3).

¹⁹Similarly, Hart and Moore (1998) assume that beyond the project cost, a fraction of the loan that the debtor receives from the creditor represents the nonrecourse financing, which is not seizable by the creditor.

References

- [1] Atkeson A. and P. Kehoe (2001), “The Transition to a New Economy after the second Industrial Revolution,” Minneapolis Fed Working Paper #606
- [2] Baily, M. N., C. Hulten and D. Campbell (1992), “Productivity Dynamics in manufacturing establishments,” *Brookings Papers on Economic Activity: Microeconomics*, 187-249
- [3] Barlevy, G. (2003), “Credit Market Frictions and the Allocation of Resources over the Business Cycles,” *Journal of Monetary Economics*, 50, 1795-1818
- [4] Barseghyan L. and R. Dicecio (2005), “Heterogeneous Firms, Productivity, and Poverty Traps”, Federal Reserve Bank of St. Louis, Working Paper
- [5] Bartelsman, E. and M. Doms (2001), “Understanding Productivity: Lessons from Longitudinal Microdata”, *Journal of Economic Literature*, 38, 569-594
- [6] Bartelsman, E. and P. Dhrymes (1998), “Productivity Dynamics: U.S. Manufacturing Plants, 1979-1996,” *Journal of Productivity Analysis*, 9, 5-34
- [7] Basu, S. and J. Fernald (1997), “Returns to Scale in U.S. Production: Estimates and Implications,” *Journal of Political Economy*, 105, 249-283
- [8] Beaudry, P. and F. Portier (2004), “An Exploration into Pigou’s Theory of Cycles,” *Journal of Monetary Economics*, 51, 1183-1216
- [9] Beaudry, P. and F. Portier (2006a), “Stock prices, news and economic Fluctuations, ” *The American Economic Review*, September, 1293-1307
- [10] Beaudry, P. and F. Portier (2006b), “When can Changes in Expectations cause Business Cycle Fluctuations in Neo-classical Setting?”, *Journal of Economic Theory*, forthcoming.
- [11] Bernanke, B. M. Gertler and S. Gilchrist (1998), “The Financial Accelerator in A Quantitative Business Cycle Framework,” in *Handbook of Macroeconomics*
- [12] Caballero, R. J. and M.L. Hammour (1994), “ The Cleansing Effect of Recessions,” *The American Economic Review*, 84, 1350-1368
- [13] Caballero, R. J. and M.L. Hammour (2005), “The Cost of Recession Revisited: A Reverse-Liquidationist View,” *Review of Economic Studies*,
- [14] Carlstrom, C. and T. Fuerst (1997), “Agency Costs, Net Worth, and Business Fluctuations: A Computable General equilibrium Analysis,” *The American Economic Review*, December, 893-910

- [15] Christiano, L. R. Motto and M. Rostagno (2006), “Monetary Policy and Stock Market Boom-Bust Cycles”, manuscript, Northwestern University and European Central Bank
- [16] Cogley, T. and J. Nason (1995), “Output Dynamics in Real Business Cycle Models,” *American Economic Review*, 85, 491-511
- [17] Cooley, T. and E. Prescott (1995), “Economic Growth and Business Cycles,” in *Frontiers of Business Cycle Research*, ed. by T.F. Cooley, 1-38 Princeton, Princeton University Press
- [18] Cooper, R. and J. Haltiwanger (2006), “On the Nature of Capital Adjustment Costs,” *Review of Economic Studies*, 73 (3), 611-633
- [19] Danthine, J.-P., J.B. Donaldson and T. Johnsen (1998), “Productivity Growth, Consumer Confidence and the Business Cycle,” *European Economic Review*, 42, 1113-1140
- [20] Davis, S. and J. Haltiwanger (1990), “Gross Job Creation and Destruction: Microeconomic Evidence and Macroeconomic Implications,” in Blanchard, O. and S. Fisher (Eds.) NBER Macroeconomic Annual, MIT Press, Cambridge, 123-168
- [21] Den Haan, W. and G. Kaltenbrunner (2006), “Anticipated Growth and Business Cycles in a matching Models”, working paper
- [22] Eisfeldt, A. and A. Rampini (2006), “Capital reallocation and Liquidity,” *Journal of Monetary Economics*, 119 (3), 899-927
- [23] Foster, L. J. Haltiwanger and C.J. Krizan (1998), “Aggregate Productivity Growth: Lessons from Microeconomic Evidence,” in *New Developments in Productivity Analysis*, ed. by E. dean, M. harper and C. Hulten, Chicago: University of Chicago press, 2001
- [24] Foster, L. J. Haltiwanger and C.J. Krizan (2002), “The Link Between Aggregate and Micro Productivity Growth: Evidence from Retail Trade,” NBER working paper 9120
- [25] Gilchrist, S. and C. Himmelberg (1995), “Evidence on the Role of cash Flow for Investment,” *Journal of Monetary Economics*, December 1995, 36(3), 541-572
- [26] Greenwood, J., Z. Hercowitz and G. Hoffman (1988), “Investment, Capital Utilization and the Business Cycle,” *American Economic Review*, 78, 402-417
- [27] Hart, O. and J. Moore (1998), “Default and Renegotiation: A Dynamic Model of Debt,” *Quarterly Journal of Economics*, 1-41
- [28] Jaimovich, N. and S. Rebelo (2006), “Can News About the Future Drive the Business Cycles”, working paper, Northwestern University.

- [29] Jermann, U. and V. Quadrini (2006a), “Stock Market Boom and the Productivity Gains of the 1990s”, forthcoming, *Journal of Monetary Economics*
- [30] Jermann, U. and V. Quadrini (2006b), “Financial Innovations and Macroeconomic Volatility,” NBER working paper, 12308
- [31] Jovanovic, B. and P. Rousseau (2002), “Mergers as Reallocation”, New York University, working paper
- [32] King, R., C. Plosser and S. Rebelo (1988), “Production, Growth and Business Cycles: I, The Basic Neoclassical Model,” *Journal of Monetary Economics*, 21, 195-232
- [33] Kiyotaki, N. and J. Moore (1997), “Credit Cycles”, *Journal of Political Economy*, 105 (2), 211-248
- [34] Lucas, J. R. (1978), “On the Size Distribution of Business Firms”, *The Bell Journal of Economics*, 9 (2) 508-523
- [35] Maksimovic, V. and P. Gordon (2001), “The Market for Corporate Assets: Who Engages in mergers and Asset sales and Are There Gains?” *Journal of Finance*, LVI (6), 2019-2065
- [36] OECD (2001), “Productivity and Firm Dynamics: Evidence from Microdata,” *Economic Outlook*, 69(1), 209-223
- [37] Restuccia, D. and R. Rogerson (2003), “Policy Distortions and Aggregate Productivity with Heterogeneous Plants,” unpublished manuscript, University of Toronto
- [38] Syverson, C. (2004), “Product Substitutability and Productivity Dispersion,” *Review of Economics and Statistics*, 86 (2), 534-550
- [39] Tauchen, G. and R. Hussey (1991), “Quadrature Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models,” *Econometrica*, 371-396

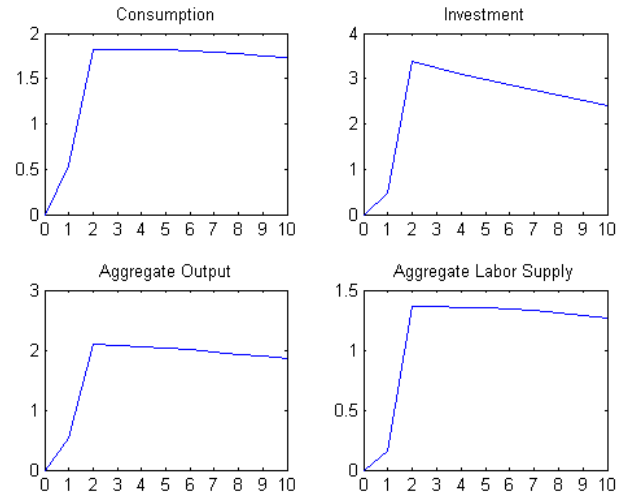


Figure 1: Response of Macro Aggregates to News Shock in Aggregate Technology, Benchmark Model

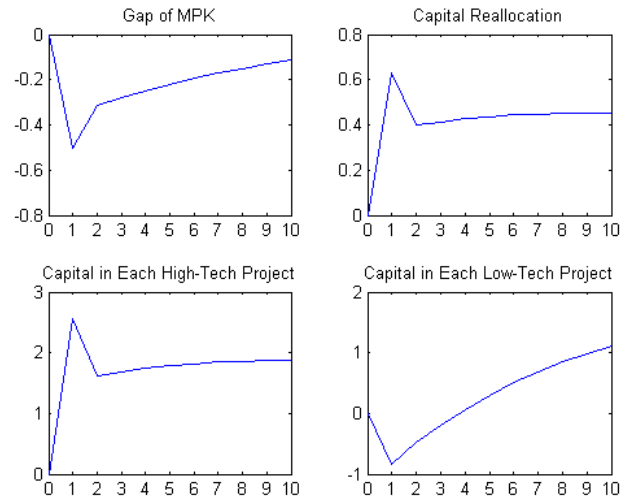


Figure 2: Response of Capital Reallocation to News Shock in Aggregate Technology, Benchmark Model

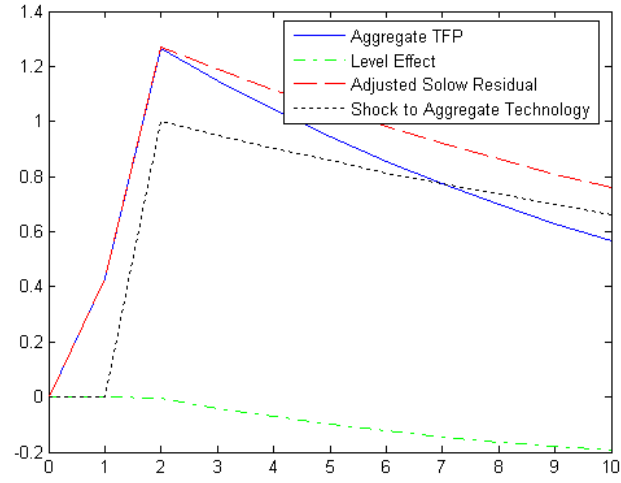


Figure 3: Response of Aggregate TFP and its Components to News Shock on Aggregate Technology, Benchmark Economy

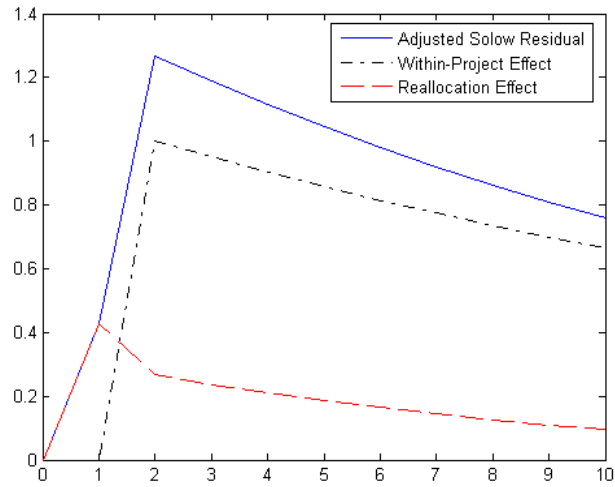


Figure 4: Response of Adjusted Solow Residual and its Components to News Shock in Aggregate Technology, Benchmark Economy

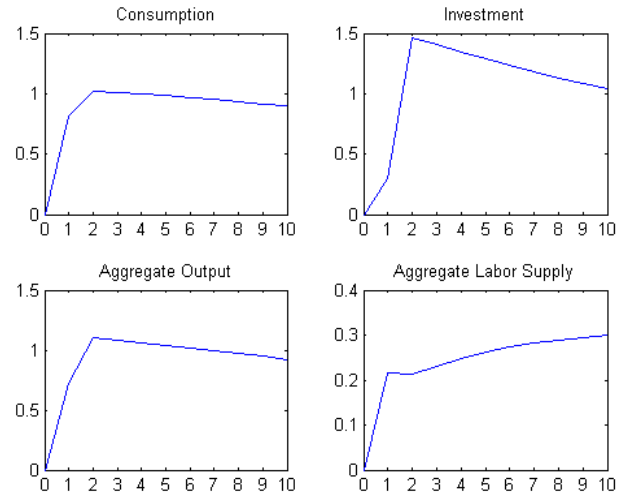


Figure 5: Response of Macro Aggregates to News Shock to High-Tech Technology, Benchmark Model

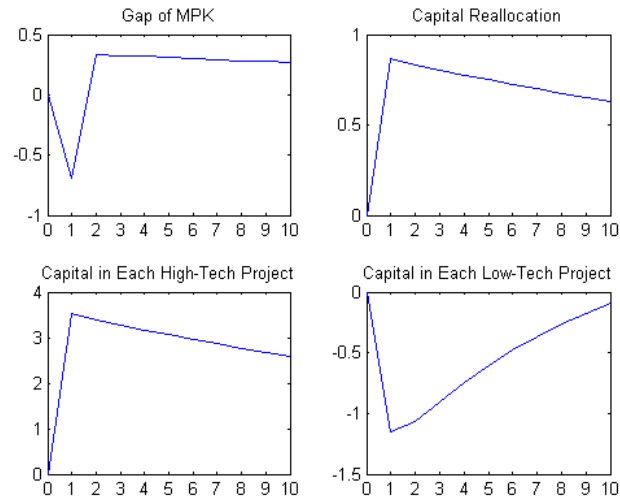


Figure 6: Response of Capital Reallocation to News Shock to High-Tech Technology, Benchmark Model

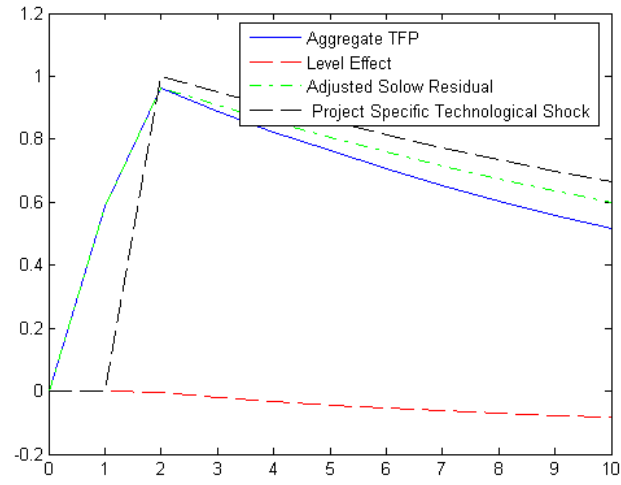


Figure 7: Response of Aggregate TFP and its Components to News Shocks to High-Tech Technology, Benchmark Economy

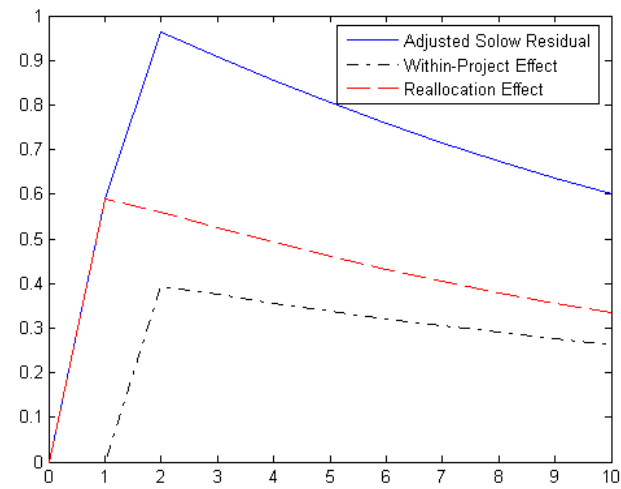


Figure 8: Response of Adjusted Solow Residual and its Components to News Shocks to High-Tech Technology, Benchmark Economy

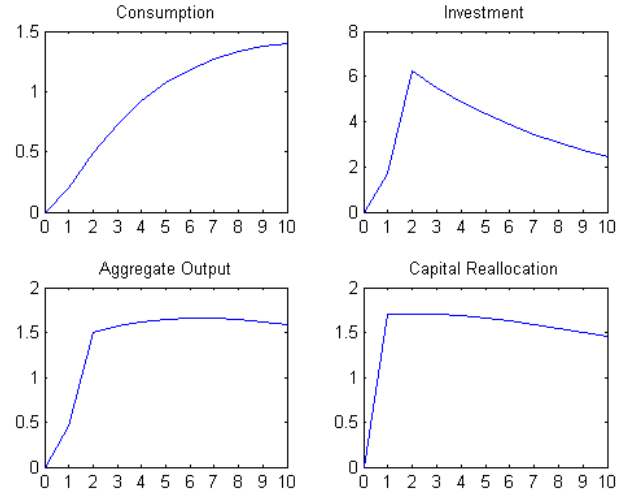


Figure 9: Response of Macro Aggregates to News Shock in Aggregate Technology, Economy w/o Labor

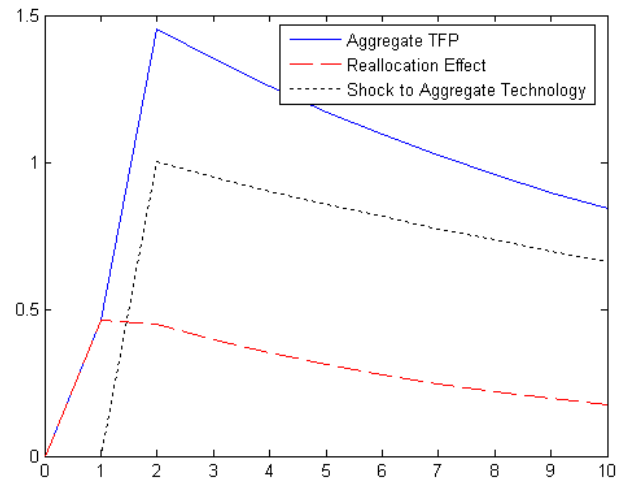


Figure 10: Response of Aggregate TFP and its Components to News Shock on Aggregate Technology, Economy w/o Labor