Financial Friction, Capital Reallocation and Expectation-Driven Business Cycles

Chen, Kaiji and Song, Zheng

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Kaiji Chen[†]
University of Oslo

Zheng Song[‡]
Fudan University

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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 financial friction on capital allocation. 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 boom in output, consumption, investment and hours worked. Our empirical evidence using firm-level data supports strongly the above mechanisms for news to affect current aggregate productivity.

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[†]Department of Economics, University of Oslo, Box 1095, Blindern, 0371 Oslo, Norway. Phone: (+47) 22855495. Email: kaijic@econ.uio.no

[‡]Department of Economics, Fudan University, Shanghai 200042, China. Phone: (+86) 2165643514. Email: zsong@fudan.edu.cn

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 technological improvement 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 "news-driven business cycles" (NDBC hereafter), which contrast the standard "technology-driven" story in the RBC literature.

This paper shows that these two views can be reconciled in a simple framework with financial frictions on capital allocation: 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. When good news about future technological improvement arrive, stock market starts to boom immediately. Projects that are subject to binding credit constraints are therefore now able to obtain more financing. This triggers a reallocation of capital, via merger and acquisition or partial-firm asset transition, from projects that are not financially constrained to those with binding financial constraint. This reallocation creates an efficiency gain, which shows up in the aggregate economy as an upward shift to current TFP, allowing current output, consumption, investment, and hours worked to comove positively.

Our work is motivated by microeconomic evidence on the importance of reallocation for changes in aggregate productivity and the roles of capital reallocation in business cycles. First, it has been long documented that resource reallocation plays a central role in the aggregate productivity growth. According to Baily, Hulten and Campbell (1992) and Foster, 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.[1]

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[1] On 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

More recent evidence shows that the frictions for reallocation of productive capital across firms through merger and acquisition and partial-firm asset sales are countercyclical. For example, Eisfeldt and Rampini (2006) find that the correlation of standard deviation of productivity dispersion with output is around -0.4.[2] 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 Philips (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 counter-cyclical. Furthermore, recent evidence by Harford (2005) shows that the observed relation between economic expansion and capital allocation is essentially driven by an increase in macro-level capital liquidity and reduction in financial constraint that is correlated with high stock market valuation.

Based on the above observations, we introduce financial frictions on capital reallocation as our key model ingredient. In our benchmark model, more productive projects are subject to binding financial constraints on production scale due to the limited enforcement of debt payment by entrepreneurs, while the less productive projects are not.[3] This friction creates a gap of marginal productivity of capital between different types of projects, and therefore, the potential efficiency gain of reallocating capital from less productive to more productive projects. The nondefaultness of the debt contract, furthermore, implies that the debt limit and thus production scale of more productive projects is positively linked to their expected lifetime profits. The arrival of good news triggers an immediate jump in the lifetime profit of the more productive projects, and therefore, the value of debt contract for the entrepreneur. As a result, entrepreneurs have less incentive to default the debt payment. This alleviates the friction on capital allocation and induces capital to flow from less productive projects to more productive ones. The capital reallocation reduces gap of marginal productivity of capital across different types of projects and pushes distribution of capital towards the first-best. The efficiency gain thus generated is shown up as an increase in current TFP.[4]

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

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to the initial difference in productivity between the buying firm and the purchased firm.

[2]This negative correlation is robust to adjustment of capital utilization.

[3]See Barlevy (2003) for discussion on this type of moral hazard problems and the opposite "cleansing effect".

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

together. The business cycle statistics in our model, moreover, are close to the U.S. data.

We then use Compustat and IBES data to test the mechanisms captured in our model for news shocks to affect current aggregate productivity. In particular, we test the following two theoretical implications: First, news on individual future profitability affect current capital allocation for firms that are financially constrained. In contrast, such news have no effect on impact on capital allocation of firms that are not financially constrained. Second, during an economic expansion firms which are financially constrained acquire more capital than those that are not. In our model, the first implication serves as the driving mechanism for anticipated technological shocks to affect capital allocation, while the second is the key for capital allocation to increase aggregate productivity. Our empirical results support strongly both theoretical implications and therefore our story.

Our work is closely related to Jermann and Quadrini (2006a), which show that in a model with financial frictions due to 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. This implies that a relaxation of financial constraint starts to play a role only *after* the current period output is produced. As a result, when the constraint on investment is relaxed, capital and labor will shift from consumption goods production to investment goods sector, implying that consumption and investment comove negatively.[5] In our model, by contrast, when the financial constraint on allocating existing capital across plants is relaxed, projects subject to binding financial constraint will be able to augment capital stock before current production takes place. This makes it feasible for an immediate expansion of current aggregate productivity, and therefore, other macro aggregates simultaneously.

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.[6] 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

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[5]Beaudry 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).

[6]Beaudry and Portier (2004) and Danthine, Donaldson and Johnsen (1998) reach similar conclusions.

an increase in marginal q, which in fact implies a decline in capital utilization.[7] Den Haan 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.[8] Our work differs from the above studies by exploring the sources of initial expansion in aggregate output in a framework with heterogeneous projects. Both our theoretical and empirical results suggest that capital reallocation is an important channel for news to drive aggregate productivity and business cycles.

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).[9] 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 illustrate the roles of news shock on TFP fluctuations in a simple model without labor. We then extend the economy to incorporate more realistic features of business cycles in Section 3. Section 4 provides a discussion of the calibration procedure and the computation method. In Section 5, we report the impulse responses and business cycle statistics and check the robustness of our model to alternative parameter values. Section 6 tests the mechanisms in our model for anticipated shock to affect aggregate productivity using firm-level data. Section 7 concludes. Appendix contains the definition for recursive competitive equilibrium and the derivation of the enforcement constraint.

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[7]This 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.

[8]In addition, Christiano, Motto and Rostagno (2006) find that it is hard to generate expectation-driven business cycles without norminal fricitons and monetary targeting.

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

2 A model without labor

In this section, we describe a model that abstract from labor as input in production (referred to as "economy without labor") to highlight the role of news shock on TFP and business cycle fluctuation via capital reallocation. A full-blown model with richer business cycle ingredients will be provided in the following section.

Consider an economy with a representative household and a continuum of entrepreneurs with unit mass. The representative household owns physical capital and decides how much to consume and how much to invest in physical capital. In addition, the representative household owns the entitlement, and therefore, the profit of a 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 profit maximization of the project.[10]

Projects can be classified into two categories according to whether working capital (or liquid fund) is needed to pay for the factors of production before production takes place. A fraction η of projects, denoted as type-h projects, have to pay for the factors of production with working capital before production takes place.[11] The size of working capital required, denoted as $D\left(K_t^h\right)$, increases with the scale of production, where K_t^h is the capital deployed in a type-h project at period t. For the remaining $1 - \eta$ fraction of projects, denoted as type-l projects, working capital is not necessary.

With probability $1 - \phi$, projects become unproductive at each period. Once the project is unproductive, a new project with the same productivity type enters the market and starts to be operated by a new entrepreneur. This assumption enables the fraction of each type of projects to be constant over time.

2.1 Project Financing and the Entrepreneur's Problem

To finance the working capital, entrepreneurs of type-h projects 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.[12] Because this is a intra-period load, the net interest

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[10]By assuming rental markets as the avenue to allocate existing capital, we abstract from the issue of firm dynamics in the context of business cycle. Such an abstraction, however, will not affect the qualitative feature of our model. As will be shown later, the key determinant of aggregate TFP is the distribution of capital across different projects.

[11]According to Fazzari and Petersen (1993), for firms in fast growing industries, own-firm innovation and innovation spillovers generate new investment opportunities continuously. This creates a need for working capital to smooth investment.

[12]The assumption for enterpreneurs to borrow working capital each period can be rationalized by the fact that because enterpreneurs become tempted to use excess internal fund inefficiently, it is costly for firms to retain operating cash flows (see Jensen, 1986).

payment is zero. 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 the working capital. Once default, 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 8.1 describes in details the renegotiation process and shows that the incentive-compatibility condition imposes the following financial constraint

$$D\left(K_t^h\right) \leq \theta V_{t+1}^h = \theta E_t \sum_{j=1}^{\infty} \hat{\beta}^j \pi_{t+j}^h \tag{1}$$

where V_t^i $(i = h, l)$ is the value of type-i project to the entrepreneur at the end of period t., $\hat{\beta} = \beta\phi$ is the effective discount factor is the subjective discount factor. π_{t+j}^h is the one-period profit of type-h project at period $t + j$. (1) implies that the entrepreneur can only borrow a fraction θ against the future project value.

The production technology of a type-i, $i \in \{h, l\}$, is given by

$$Y_t^i = A_t^i \left(K_t^i\right)^\alpha.$$

where K_t^i are capital and labor employed in a single type-i project. A_t^i is the productivity associated with project i, which contains two components.

$$A_t^i = \chi_t^i Z_t, \tag{2}$$

The first part, χ_t^i, refers to the project-specific productivity. The second part, Z_t is an aggregate technological shock. In this section, we keep project-specific technology χ_t^i constant over time and normalized to unity, and assume that aggregate technology Z_t is stochastic.

$$\log Z_{t+1} = \rho \log Z_t + \epsilon_t^Z, \tag{3}$$

where ϵ_t^Z denotes innovations regarding information on the next period aggregate productivity Z_{t+1}. Note that the process (3) 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.

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

$$\max_{K_t^h} A_t^h \left(K_t^h\right)^\alpha - (r_t + \delta) K_t^h \tag{4}$$

subject to (1).[13]

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[13] Alternatively, the entrepreneur's problem can be specified as maximizing the present discounted project profit subject to the sequence of financial constraints (1), 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)

The problem of an entrepreneur of a type-l project is

$$\max_{K_t^l} A_t^l \left(K_t^l\right)^\alpha - (r_t + \delta) K_t^l \tag{5}$$

which have the first order condition

$$K_t^l = \left(\frac{\alpha A_t^l}{r_t + \delta}\right)^{\frac{1}{1-\alpha}} \tag{6}$$

Comparing (1) and (6), it is immediate that news about A_{t+j}^h affects K_t^h by changing the tightness of financial constraint. By contrast, news about A_{t+j}^l has no direct impacts on K_t^l (except through affecting r_t). We will use firm-level data to test this implication in Section 6.

2.2 A Decomposition of TFP

To get some intuition of how the aggregate productivity in this economy is determined, we decompose the aggregate TFP (Total Factor Productivity, measured as "Solow Residual") as

$$\log TFP_t = \log \frac{\eta Z_t \left(K_t^h\right)^\alpha + (1-\eta) Z_t \left(K_t^l\right)^\alpha}{K_t^\alpha} \tag{7}$$

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

$$\triangle \log TFP_t = \triangle \log \left(\eta Z_t \left(\frac{K_t^h}{K_t}\right)^\alpha + (1-\eta) Z_t \left(\frac{K_t^l}{K_t}\right)^\alpha\right) \tag{8}$$

Note the right-hand-side ("RHS" hereafter) of (8) can be further decomposed as

$$\triangle \log \left(\eta Z_t \left(\frac{K_t^h}{K_t}\right)^\alpha + (1-\eta) Z_t \left(\frac{K_t^l}{K_t}\right)^\alpha\right)$$

$$= \underbrace{\triangle \log \left(\eta Z_t \left(\frac{K_t^h}{K_t}\right)^\alpha + (1-\eta) Z_t \left(\frac{K_t^l}{K_t}\right)^\alpha\right) |_{Z_t = \overline{Z}}}_{\text{the reallocation effects}}$$

$$+ \underbrace{\triangle \log \left(\eta Z_t \left(\frac{K_t^h}{K_t}\right)^\alpha + (1-\eta) Z_t \left(\frac{K_t^l}{K_t}\right)^\alpha\right) |_{\frac{K_t^i}{K_t} = \frac{\overline{K^i}}{\overline{K}}}}_{\text{the within-project effects}}$$

$$+ \text{cross product terms} \tag{9}$$

The first argument on the RHS of (9) is referred to as "the reallocation effect", capturing the effect of changes in the distribution of capital across projects of different types. The second argument is called "the within-project effects", capturing effect of the exogenous technological change. Note that even before the aggregate productivity shock is materialized,

current TFP could increase in response to good news about future technology through the reallocation effect.

Finally, the representative household's problem is

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

subject to

$$C_t + I_t = (r_t + \delta) K_t + (1 - \eta) \pi_t^l + \eta \pi_t^h. \tag{10}$$

$$K_{t+1} = (1 - \delta) K_t + I_t. \tag{11}$$

2.3 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 are realized. Then the representative household supplies capital 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.

2.4 Calibration

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. We set $\sigma = 1$, which corresponds to the case of logarithmic utility. α is set to be 0.3 to map into a capital income share of 0.3. Also, we set $\delta = 0.07$ to match the investment capital ratio in the absence of long run growth in both technology and population. $\beta = 0.96$ to match a steady state real interest rate of 4%. We set the project survival probability ϕ to be 0.90, which is broadly consistent with the U.S. data for the manufacturing and business service sector reported by OECD (2001).

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.

Finally, θ and η are chosen to target a value of 2 for the ratio of marginal productivity of capital between 75th- and 25th- percentile projects, which is chosen according to the ratio of labor productivity between the 75th- and 25th- percentile plants in an industry's productivity distribution found by Syverson (2004).[14] This gives $\eta = 0.5$ and $\theta = 0.185$.

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[14]As we will show in the next section, in our benchmark economy, the ratio of marginal productivity of capital between two types projects are equal to the ratio of labor productivity.

$D\left(K_t^h\right)$ is specified as $\left(K_t^h\right)^\alpha$ as a proxy for the production scale or cash flows. Table 1 summarizes the parameter values for this economy.

Table 1. Parameterized Values for Economy w/o Labor

Symbol	Definition	Value
	Technology	
α	Capital share in production function	0.3
ϕ	Project survival rate	0.90
δ	Depreciation rate for capital	0.07
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	0.185
η	Fraction of high-tech project	0.50

2.5 Impulse Response to News on 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.[15]

Figure 1 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.[16] Moreover, consistent with Eisfeldt and Rampini (2006),

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[15]The 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.

[16]Note 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.

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financial friction of capital reallocation, as measured by the ratio of marginal productivity of capital between two types of projects is countercyclical.

The reason for the comovement of macro aggregates, as implied by Figure 2, is that aggregate TFP shifts up in response to the news shock. The decomposition of TFP shows that before actual technology realized, all TFP increase at period 1 is accounted for by the increase in reallocation effect.

In summary, we show that in a simple model with financial friction on capital reallocation alone, news on future technological improvement may trigger a reallocation of capital. Such redistribution of capital generates efficiency gain in the current period, shown up as an increase in TFP in aggregate economy. The increase in TFP could then make it feasible for comovement of macro aggregates, before the actual technology shock is realized.

3   A full-blown model

To compare our model's performance with the data, we now extend the above model to incorporate the following more realistic ingredients: heterogeneity in productive efficiency, financial friction on resource reallocation (including both capital and labor), convex investment adjustment cost, and endogenous labor supply. We call this economy the "benchmark economy".

We assume that projects are also differentiated by the expected efficiency of their production technologies.[17] Specifically, A fraction η of projects have higher expected 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

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

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.[18] 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.

$$A_t^i = (1 + \gamma)^t \chi_t^i Z_t, \tag{12}$$

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[17]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.

[18]Basu 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.

The first part, $(1+\gamma)^t$, captures the trend of technology, where γ is the long-run growth rate of aggregate productivity. The second and the third parts, χ_t^i and Z_t, respectively, refer to the project-specific productivity and aggregate technology. As a benchmark, we keep project-specific productivity χ_{t+1}^i constant over time and equal to $\overline{\chi}^i$, with $\overline{\chi}^h > \overline{\chi}^l$. The specification for news shocks on aggregate productivity is the same as that in (3).

We assume again the operation of a type-h project requires an amount of working capital, which magnitude increases in the production scale.[19][20] Entrepreneurs of type-h projects face the same limited enforcement problem of debt repayment as those in the model without labor. For reasons discussed below, the divertible resource is specified as $D\left(K_t^h, H_t^h\right) = \left(\left(K_t^h\right)^\alpha \left(H_t^h\right)^{1-\alpha}\right)^\mu$. Similar to the model without labor, the incentive-compatibility condition imposes the following financial constraint

$$D\left(K_t^h, H_t^h\right) \leq \theta V_t^h = \theta E_t \sum_{j=1}^\infty (\beta\phi)^j \, \pi_{t+j}^h. \qquad (13)$$

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

$$\max_{\left\{K_t^h, H_t^h\right\}} A_t^h \left(\left(K_t^h\right)^\alpha \left(H_t^h\right)^{1-\alpha}\right)^\mu - (r_t + \delta) K_t^h - w_t H_t^h \qquad (14)$$

subject to (13). The problem of an entrepreneur of a type-l project is

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

The first-order conditions of the entrepreneur's problem implies the following allocation of capital between the two types of projects

$$\begin{aligned}
&\alpha\mu \left(K_t^h\right)^{\alpha\mu-1} \left(H_t^h\right)^{(1-\alpha)\mu} \left(A_t^h - \lambda_t^h\right) \\
= \; &\alpha\mu \left(K_t^l\right)^{\alpha\mu-1} \left(H_t^l\right)^{(1-\alpha)\mu} A_t^l \\
= \; &r_t + \delta.
\end{aligned} \qquad (15)$$

where λ_t^h is the Lagrangian multiplier associated with the financial constraint (13). To get the intuition for (15), note that at the first best allocation, where the financial constraint is not binding ($\lambda_t^h = 0$), type-h project should be allocated with more capital until the marginal

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[19]Barlevy (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.

[20]In addition, Carpenter and Peterson (2002) argue that highly variable returns, aysmmetric information and a lack of collateral may cause high-tech firms to have poor access to debt. To support this arguement, they found that many small high-tech firms in Compustat database obtain little debt financing.

productivity of capital, denoted as MPK, between the two types of projects are the same. Similarly, the allocation of labor follows

$$(1 - \alpha) \mu \left(K_t^h \right)^{\alpha\mu} \left(H_t^h \right)^{(1-\alpha)\mu-1} \left(A_t^h - \lambda_t^h \right)$$

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

$$= w_t. \tag{16}$$

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 and allows us to focus on the effect of resource reallocation between projects on aggregate productivity. Finally, it is easy to shows that given the relative magnitude of production efficiency of these two technologies, the first best allocation of capital follows

$$\frac{K_t^h}{K_t^l} = \left(\frac{A_t^h}{A_t^l} \right)^{\frac{1}{1-\mu}}. \tag{17}$$

3.1 A Decomposition of TFP

We assume the labor income share is correctly measured, that is $(1 - \alpha) \mu = 1 - \widehat{\alpha}$. We then decompose the aggregate TFP (Total Factor Productivity, measured as "Solow Residual") as

$$\log TFP_t = \log \frac{\sum_i A_t^i \left((K_t^i)^\alpha (H_t^i)^{1-\alpha} \right)^\mu}{K_t^{\widehat{\alpha}} H_t^{1-\widehat{\alpha}}} \tag{18}$$

$$= \log \frac{\sum_i A_t^i (K_t^i/H_t^i)^{(\alpha-1)\mu} (K_t^i)^\mu}{(K_t/H_t)^{\widehat{\alpha}-1} K_t}$$

$$= (\mu - 1) \log K_t + \log \sum_i A_t^i \left(\frac{K_t^i}{K_t} \right)^\mu$$

The first term on the right hand side of (18) is a level effect: given decreasing returns 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

$$\triangle \log TFP_t = \triangle \log \left(\frac{\eta A_t^h (K_t^h)^\mu + (1 - \eta) A_t^l (K_t^l)^\mu}{K_t} \right)$$

$$= (\mu - 1) \triangle \log K_t + \triangle \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1 - \eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right) \tag{19}$$

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

$$
\triangle \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right)
$$

$$
= \underbrace{\triangle \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\mu + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\mu \right) |_{Z_t = \overline{Z}}}_{\text{the reallocation effects}}
$$

$$
+ \underbrace{\triangle \log \left(\eta A_t^h \left(\frac{K_t^h}{K_t} \right)^\alpha + (1-\eta) A_t^l \left(\frac{K_t^l}{K_t} \right)^\alpha \right) |_{\frac{K_t^i}{K_t} = \frac{\overline{K^i}}{\overline{K}}}}_{\text{the within-project effects}} + \quad \text{cross product term} \quad (20)
$$

Again, the first and second arguments on the right-hand-side of (20) are the "reallocation effect" and the "within-project effect", which bear similar meanings as their counterparts in the economy without labor. 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.

3.2 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

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

subject to

$$
C_t + G\left(I_t, K_t\right) = (r_t + \delta) K_t + w_t H_t + (1-\eta) \pi_t^l + \eta \pi_t^h, \tag{21}
$$

$$
K_{t+1} = (1-\delta) K_t + I_t, \tag{22}
$$

$$
G\left(I_t, K_t\right) = I_t + \kappa \left(\frac{I_t}{K_t} - \delta - n - g_y \right)^2 K_t. \tag{23}
$$

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

$$u_c\left(c_t, h_t\right) w_t = -u_h\left(c_t, h_t\right) \tag{24}$$

$$q_t = 1 + 2\kappa \left(\frac{I_t}{K_t} - \delta - n - g_y\right) \tag{25}$$

$$q_t u_c\left(c_t, h_t\right) = \beta E_t \left[u_c\left(c_{t+1}, h_{t+1}\right) \left(\begin{array}{c} r_t + \delta + 2\kappa \left(\frac{I_t}{K_t} - \delta - n - g_y\right)\frac{I_t}{K_t} - \kappa \left(\frac{I_t}{K_t} - \delta - n - g_y\right)^2 \\ +q_{t+1}\left(1 - \delta\right) \end{array}\right)\right] \tag{26}$$

where q_t is the marginal q, $u_x\left(c_t, h_t\right)$ is the marginal utility (or disutility) associated with x, $x = c$ or h. Equation (24) is the first order condition for labor. Equation (25) is the first order condition for investment, and Equation (26) is the standard Euler equation with quadratic adjustment cost.

Finally, we keep the timing and information structures the same as those in the economy without labor.

3.3 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 (21).

- Given prices, the allocation solves the entrepreneur's profit maximization problem (14).

- 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:

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

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

4 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). Again, one period in the model corresponds to one calendar year.

4.1 Preference

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

$$u(c_t, h_t) = \frac{\left(c_t - \psi A_t \frac{h_t^{1+\nu}}{1+\nu}\right)^{1-\sigma} - 1}{1 - \sigma} \tag{27}$$

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 ν 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.

4.2 Technology

We set $g_y = 0.0183$, which is consistent with the long-run average growth rate of U.S. real GNP per capita. μ is set to 0.85, 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 normalize the expected detrended value of technology at low-tech project $\overline{\chi}^l$ to 1. To calibrate $\overline{\chi}^h$, the expected productivity of the high-tech projects and θ, the collateral ratio, we use the fact that at steady state,

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

Therefore, we set the values of $\overline{\chi}^h$ 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 $\frac{\overline{y}^h/\overline{n}^h}{\overline{y}^l/\overline{n}^l} = 2$. As a result, $\overline{\chi}^h = 1.69$ and $\theta = 0.13$. This implies a value of 0.26 for the standard deviation of $\log \overline{\chi}^i$, which is well within the range estimated in the literature.[21]

For all other parameters, the calibration procedure follows the calibration in the economy without labor. Table 2 summarizes the calibrated parameters.

Table 2. 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	Project survival rate	0.90
δ	Depreciation rate for capital	0.04
$\overline{\chi}^h$	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

5 Results

In this section, we first plot 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.

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[21]Cooper 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.

5.1 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.

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

Figure 3 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 3, 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 3. 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 4. Figure 4 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.

$$\frac{MPK_t^h}{MPK_t^l} = \left(\frac{K_t^h}{K_t^l}\right)^{\mu-1}\left(\frac{A_t^h}{A_t^l}\right) \tag{28}$$

The bottom panels of Figure 4 shows that when good news arrive, capital (and labor) is reallocated from low-tech projects to high tech projects. As in the upper right panel, the magnitude of capital reallocation on impact is 0.6 percent of capital stock, somewhat below that is estimated by Eisfeldt and Rampini (2006). Accordingly, we see from the upper-left panel that the gap of marginal productivity between the two types of projects decreases.

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Figure 5 and 6 plot the response of TFP and its components to the good news. In Figure 5, 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 3), which is one third of the magnitude of TFP increase when technology improvement is realized. Figure 6 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.

5.1.2 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 (29). Specifically, we let Z_t and χ_t^l remain constant (equal to their mean) and assume that

$$\log \chi_{t+1}^h = (1 - \rho) \log \overline{\chi}^h + \rho \log \chi_t^h + \epsilon_t^{\chi^h}, \tag{29}$$

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 7 to 10.

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 the two right columns of Table 3). 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.

5.2 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 (3) and (29). 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

$$\Pi = \left[\begin{array}{ccc} 0.8099 & 0.1874 & 0.0027 \\ 0.1667 & 0.6667 & 0.1667 \\ 0.0027 & 0.1874 & 0.8099 \end{array} \right], \tag{30}$$

and the supports for the estimated Markov chains of (3) and (29) 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 4, together with the U.S. data.

Table 4. 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 middle column of Table 4. 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 right column of Table 4. 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 5. 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 5. 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 under either shock 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.

5.3 Robustness

In our benchmark 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 6.

Table 6. Combination of Parameter Values that Generate NDBC

	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. One 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. 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.

6 Empirical Evidence

Our theory has the following testable implications: news on *individual* firm's future prof-itability can affect current capital allocation for those that are financially constrained. In contrast, such news have *no* effect on impact on capital allocation for those that are not financially constrained, since the capital deployed in those firms can only be affected by the current level of productivity. This section provides evidence supporting the prediction, and thus the fundamental mechanism in our model for news shocks to affect capital allocation.

6.1 Data

One of the major difficulties in testing the first prediction is how to distinguish firms that are financially constrained. We use an index constructed by Lamont, Polk and Saa-Requejo (2001), which is based on work of Kaplan and Zingales (1997), to measure the likelihood of a firm to be financial constrained. Denote it as KZ index.

KZ is a weighted average of a firm-year's cash flow, cash dividends, cash balances, leverage and firm's average Q, with negative weights on the first three and positive ones on the last two. These weights are obtained by estimation of ordered logit models of the probability that a firm falls in one of the five categories: (1) not financially constrained; (2) likely not to be financially constrained; (3) difficult to classify as either constrained or not; (4) likely to be financially constrained; (5) undoubtedly to be financially constrained.[22] A higher KZ therefore implies a higher possibility of being financially constrained. The KZ index has been adapted in some recent empirical work by Lamont, Polk and Saa-Requejo (2001) and Baker, Stein and Wurgler (2003). In particular, Baker *et al.* (2003) found that the investment of firms with larger KZ is more sensitive in response of Q. We will borrow the empirical strategy of Baker *et al.* (2003), with a focus on the impact of expectations on acquisition (rather than the impact of Q on investment).

Expectation data are from the IBES database. IBES asks analysts to provide forecasts of earnings for each firm in the database. There are three variables on expectations; one- and two-year-ahead forecasts for earning per share, and the long-term growth forecast (LTG) representing an expected annual increase in earnings over the next business cycle (a period over the next three to five years). "When calculating their forecasts of long-term growth, IBES instructs analysts to ignore the *current state* of the business cycle and to project, instead, the expected trend growth of the company's earnings. Thus, the long-term growth forecasts should contain information not in the one-year-ahead and two-year-ahead forecasts,

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[22]See Kaplan and Zingales (1997) for details on how to classify the firm-years into these five category based on both objective and subjective criteria. Since firm's average Q is closely related to expected future profits, we use a four-variable version of the index which omits average Q (see also Baker, Stein and Wurgler, 2003). Using the original index does not change our main results.

which necessarily will be affected by current conditions." (Cummins *et al.*, 2006, pp. 799) Therefore, the long-term growth forecast (LTG), by the instruction of IBES, is orthogonal to the current state, and thus can be used as a proxy for "news" in our model. We use the mean of LTG across analysts.[23]

Firm-level data on capital reallocation and variables used to construct KZ index are from Compustat database. We measure the size of capital reallocation (CR) as acquisition (Compustat Annual Item 129) minus sale of property, plant and equipment (Item 107). Following Baker *et al.* (2003), we exclude financial firms (i.e., firms with a one-digit SIC of six) and firm-years with a book value under \$10 million, but includes all observations with data on capital reallocation and KZ index.

The combination of Compustat and IBES databases results in a unbalanced panel which covers the period between 1981 and 2005.[24] The full sample includes 43722 observations, for an average of 1749 observations per year. We use CR_t^i/A_{t-1}^i as the scaled measure of capital reallocation, where A denotes book assets (Compustat Annual Item 6). To reduce the influence of outliers, we Winsorize each of the variables used at the first and ninety-ninth percentile; i.e., we set all variables beyond these tolerances to the first and ninety-ninth percentile values, respectively. Our results upholds qualitatively without Winsorizing the data.[25] Table 7 reports summary statistics for CR_t^i/A_{t-1}^i, LTG_t^i and KZ_t^i.

Table 7. Summary Statistics

	mean	SD	max	min
CR_t^i/A_{t-1}^i	0.0320	0.1152	0.7432	-0.1354
LTG_t^i	19.9398	11.8883	70.0000	1.97
KZ_t^i	0.0518	1.5240	4.5764	-10.6466

6.2 Empirical Results

We apply the method of Baker *et al.* (2003). All firms in the sample data are classified into quintiles according to their mean value of KZ_t^i over the full sample period.[26] For each KZ quintile, we estimate

$$\frac{CR_t^i}{A_{t-1}^i} = a_i + a_t + b \cdot LTG_t^i + u_t^i, \tag{31}$$

where a_i and a_t are firm dummies and year dummies, respectively. Note that LTG_t^i is by definition uncorrelated to u_t^i. The first hypothesis predicts that the estimated coefficient b

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[23]Using the median value of LTG, as recommended by IBES, gives similar results.

[24]The appendix provides details for how to merge Compustat and IBES databases.

[25]We Winsorize the indredients of the KZ index before constructing it.

[26]Using the median value of KZ_t^i gives similar results.

should be statistically insignificant for firms in lower KZ quintiles, while significantly positive for firms in higher KZ quintiles.

Table 8 presents the results. As predicted by the theory, the estimates of b are not significantly different from zero for the first and second quintiles, but positive and highly significant for the third to fifth quintiles. Moreover, there is a strong relationship between KZ and the effect of long-term growth forecasts on capital reallocation. The coefficient b rises monotonically from 0.0007 in the third quintile to 0.0015 in the top quintile, suggesting that the firms that are more likely to be financially constrained have a stronger sensitivity of capital reallocation to long-term expectations than firms that are less likely to be financially constrained.

Table 8. Expectation and Capital Reallocation

KZ index	b	Obs.	Adj. R^2
Quintile 1	0.0001 (0.0001)	8744	0.2828
2	0.0001 (0.0001)	8730	0.1563
3	0.0007** (0.0002)	8759	0.1783
4	0.0010** (0.0002)	8744	0.2258
5	0.0015** (0.0003)	8745	0.2588

Note: ** stands for is significant at 1%. Robust standard errors are in parentheses.

We use the mean value of KZ_t^i over the full sample period to measure the likelihood for each firm to be financially constrained. A key issue is whether the likelihood varies over time. As a robustness check, we classify firms based on their five-year mean value of KZ_t^i and run the same panel regression (31) for each KZ quintile. Column (1) of Table 9 shows that our main results uphold. In Column (2), we add a discounted sum of one- and two-year-ahead earnings forecasts to the regression as a control variable.[27] As a further check, we add cash flow over A_{t-1}^i (Compustat Annual Item 14 + Item 18) as an additional control variable in Column (3). The results are essentially the same and the estimates of b for each quintile are rather stable across different specifications.

Table 9. Robustness Check

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[27]We multiply the one- and two-year-ahead earning forecasts per share by the number of shares outstanding to yield forecasts of future earning levels. We use a discount rate of 0.91, as in Cummins *et al.* (2006). However, the results are insensitive to the value of discount rate.

KZ index	(1)	(2)	(3)	(4)
Quintile 1	0.0000	0.0001	0.0000	0.0064**
	(0.0002)	(0.0001)	(0.0001)	(0.0017)
2	−0.0000	−0.0002	−0.0002	0.0098**
	(0.0002)	(0.0002)	(0.0002)	(0.0023)
3	0.0003	0.0005*	0.0005**	0.0169**
	(0.0002)	(0.0002)	(0.0002)	(0.0038)
4	0.0008**	0.0007**	0.0008**	0.0338**
	(0.0002)	(0.0002)	(0.0002)	(0.0048)
5	0.0013**	0.0014**	0.0013**	0.0498**
	(0.0003)	(0.0003)	(0.0003)	(0.0074)

Note: ** and * stands for is significant at 1% and 5%, respectively. Robust standard errors are in parentheses. In Column (1), we classify firms based on their five-year mean value of KZ_t^i. In Column (2), we add a discounted sum of one- and two-year-ahead earnings forecasts as a control variable. In Column (3), we further add cash flow over A_{t-1}^i as an additional control variable to the control variable in Column (2). We replace LTG with the long-run real Q in Cummins *et al.* (1999).

Finally, we replace LTG with "long-run real Q" constructed by the way proposed in Cummins *et al.* (2006). The long-run real Q computes the two-year-ahead expected market value for each firm according to two-year-ahead earning forecasts as well as the long-term growth forecasts LTG. One-year-ahead earning forecasts are excluded since they are most likely affected by the current state of the economy. Column (4) of Table 9 shows that the estimates of b now become positive and highly significant for each quintile. This is not surprising; the estimates of b is biased upwards since two-year-ahead earning forecasts are also likely correlated to u_t^i. However, there is a strong relationship between KZ and the effect of expected market value on capital reallocation. The coefficient b rises monotonically from 0.0064 in the bottom quintile to 0.0498 in the top quintile.

6.3 Aggregate Implications

The above micro-level empirical finding delivers an important macro-level implication; firms that are financially constrained acquire more capital in boom periods than firms that are not. The opposite is true for the recessions.[28] Put differently, we should observe that capital reallocation for firms that are financially constrained are more volatile along the business cycles. In our model, this macro-level implication is the prerequisite for capital allocation to increase aggregate productivity in boom periods.

We use $CR_t^J \equiv \frac{1}{N^J} \sum_{i \in KZ^J} CR_t^i$ to measure the average size of capital reallocation for firms whose mean value of KZ_t^i over the full sample period belongs to the J-th quintile, where N^J refers to the number of firms in the J-th quintile. $\widehat{CR}_t^J$ is the cyclical part of CR_t^J

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[28]In boom periods, LTG_t^i on average are better than those in the recessions. For instance, the mean of LTG_t^i across firms during 1997 and 2000 is 23.71, much higher than that of 17.57 in the period during 1991 and 1994.

by HP filter. Compustat started to record acquisition (item 129) since 1971. Therefore, we have data on $\widehat{CR}_t^{J}$ from 1971 to 2005. Figure 11 plots $\widehat{CR}_t^{1}$, $\widehat{CR}_t^{5}$ (i.e. the sizes of total acquisition by firms in the bottom and top (mean) KZ quintiles, respectively), and the HP filtered GDP of the U.S., denoted by $\widehat{GNP}_t$. Note that the sizes of capital reallocation before 1980 recorded by Compustat are much smaller than those afterwards. It is obvious in Figure 11 that after 1980, while both of $\widehat{CR}_t^{1}$ and $\widehat{CR}_t^{5}$ are procyclical, capital reallocation for firms in the top KZ quintile is much more volatile than that by firms in the bottom quintile.

[Insert Figure 11]

Table 10 shows that standard deviation of $\widehat{CR}_t^{J}$ is monotonically increasing in J. The increase of volatility is sizable: the variance of $\widehat{CR}_t^{5}$ is more than two times larger than the variance of $\widehat{CR}_t^{1}$. Due to the sizes of capital reallocation in Compustat, one may suspect that capital reallocation has much smaller effect on business cycles before 1980. For this concern, we also report results for the subperiod since 1981. The main findings are still there. This evidence strongly supports the mechanism for capital reallocation to affect aggregate productivity captured by our model.

Table 10. Financial Constraint and Standard Deviation of Capital Reallocation

	Full Sample (1971-2005)	Subsample (1981-2005)
$\widehat{CR}^{1}$	0.0054	0.0063
$\widehat{CR}^{2}$	0.0054	0.0062
$\widehat{CR}^{3}$	0.0068	0.0079
$\widehat{CR}^{4}$	0.0087	0.0101
$\widehat{CR}^{5}$	0.0117	0.0135

7 Conclusion

We show that good news on future technological improvement generate an immediate expansion in output, consumption, hours and investment. The key element in our model is financial friction on allocating capital, which generates a gap of marginal productivity of capital across different types of projects. The arrival of goods news on future technology reduces the financial friction and triggers capital to reallocate from projects that are not financially constrained to those for which the constraints are binding. This reduces the gap of marginal productivity of capital and pushes the distribution of capital toward the first best. 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.

Furthermore, our empirical evidence based on Compustat data provides direct support for our theory. In particular, we find that in a broad sample of firms recorded in both Compustat

and IBES database, news on individual future profitability have significant impact on current capital allocation of firms that are financially constrained, while the impact is insignificant for those that are not financially constrained. Furthermore, acquisitions by firms that are financially constrained are more volatile along the business cycles. These findings strongly support the mechanism captured in our model for news on future technological improvement to affect current aggregate productivity and other macro aggregates.

8 Appendix

8.1 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 $s_t = \left(Z_t, \epsilon_t^Z, k_t, K_t\right)$ or simply (Z_t, Z_{t+1}, k_t, K_t), since next period productivity is perfectly predictable by (3). The household's problem can be rewritten as

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

subject to

$$
\begin{aligned}
c + i + \kappa \left(\frac{i}{k} - \delta - n - g_y\right)^2 k &= \left(r\left(Z, \ Z^{'}, K\right) + \delta\right) k + w\left(Z, \ Z^{'}, K\right) h + (1 - \eta)\pi^l + \eta\pi^h. \\
k^{'} &= (1 - \delta) k + i \\
K^{'} &= (1 - \delta) K + I \\
\log Z^{'} &= \rho \log Z + \epsilon^Z
\end{aligned}
\tag{32}
$$

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

1. The household's problem (32);

2. The entrepreneurs' problem (14);

3. The consistency of individual and aggregate decisions, that is $c\left(Z,\ Z',k,K\right)=C\left(Z,\ Z',K\right)$, $i\left(Z,\ Z',k,K\right)=I\left(Z,\ Z',K\right)$ and $h\left(Z,\ Z',k,K\right)=H\left(Z,\ Z',K\right)$.

4. The aggregate resource constraint

$$C\left(Z,\ Z',K\right)+I\left(Z,\ Z',K\right)+\kappa\left(\frac{I\left(Z,\ Z',K\right)}{K}-\delta-n-g_y\right)^2 K=Y\left(Z,\ Z',K\right)$$

$$=\ \eta A^h\left(\left(K^h\left(Z,\ Z',K\right)\right)^\alpha\left(H^h\left(Z,\ Z',K\right)\right)^{1-\alpha}\right)^\mu$$

$$+\left(1-\eta\right)A^l\left(\left(K^l\left(Z,\ Z',K\right)\right)^\alpha\left(H^l\left(Z,\ Z',K\right)\right)^{1-\alpha}\right)^\mu,\forall\left(Z,\ Z',K\right).$$

8.2   Enforcement Constraint

The renegotiation process described here follows closely to Jermann and Quadrini (2006b). Assume in addition to factor inputs, production of type-h project at each period requires an amount of working capital, denoted as $f_t = D\left(K_t^h, H_t^h\right)$ (or $D\left(K_t^h\right)$ in the economy without labor), 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.[29] 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^h, 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 the lender. Bargaining is over the repayment of the debt, denoted as $\widehat{f}_t$. If they reach an agreement, the entrepreneur gets $f_t - \widehat{f}_t + V_t^h$, and the lender get $\widehat{f}_t$, If there is no agreement, the entrepreneur gets f_t and the lender gets λV_t^i. Therefore, the net value for the entrepreneur to reach an agreement is $V_t^h - \widehat{f}_t$ and the net value for lender is $\widehat{f}_t - \lambda V_t^h$. The bargaining problem solves:

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

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

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[29]Similarly, 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.

the value of default, that is $f_t - \widehat{f}_t + V_t^h$. Hence we have

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

Denote $[1 - \omega\,(1 - \lambda)]$ as θ. Then we get (13) (or (1) in the model without labor).

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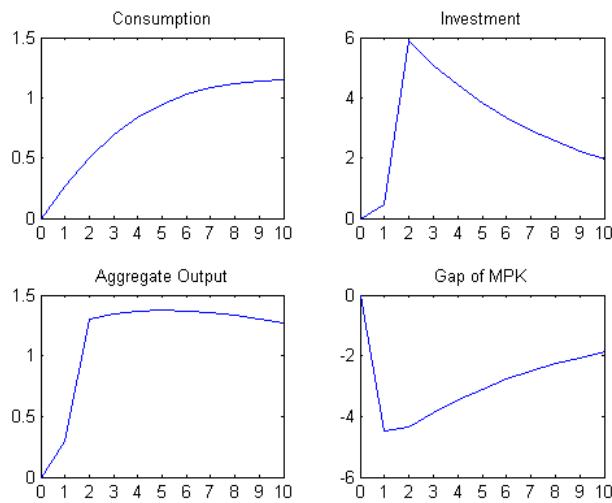
Figure 1: Response of Macro Aggregates to News Shock in Aggregate Technology, Economy w/o Labor
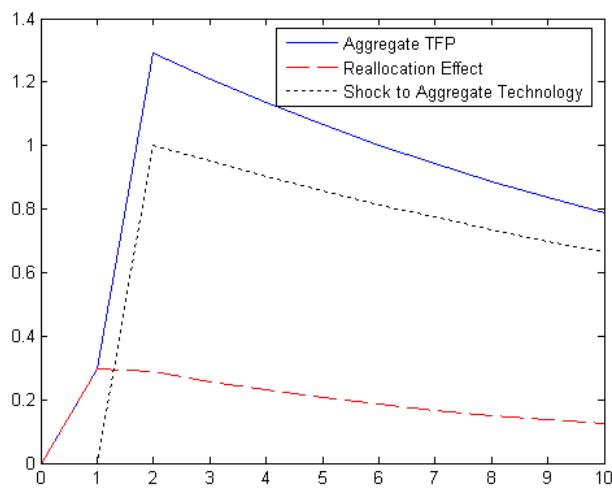
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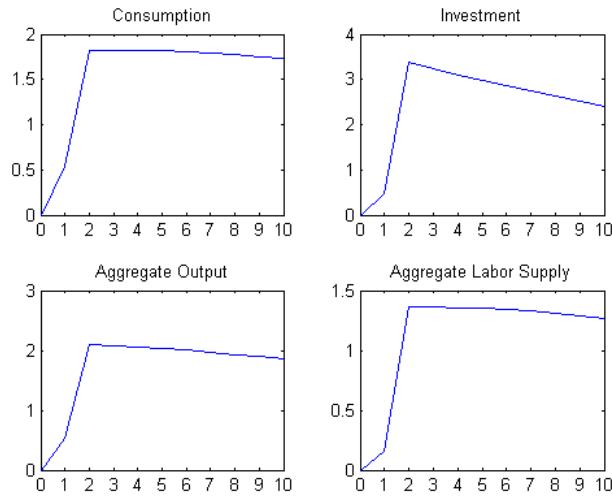
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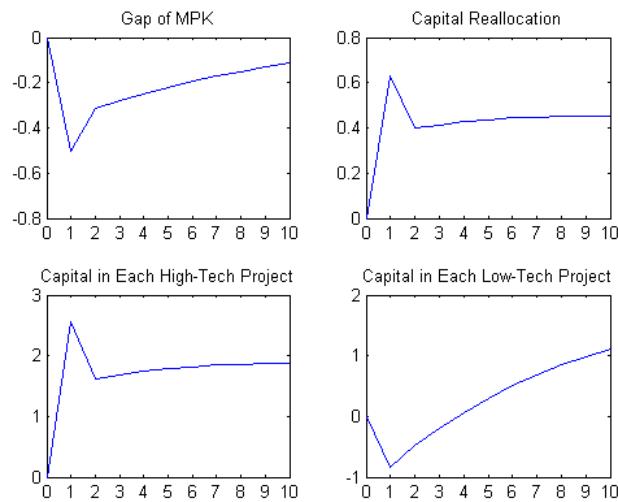

Figure 4: Response of Capital Reallocation to News Shock in Aggregate Technology, Benchmark Model
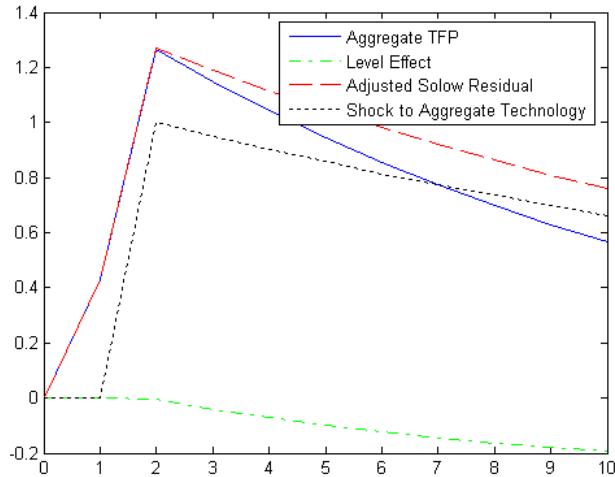
Figure 5: Response of Aggregate TFP and its Components to News Shock on Aggregate Technology, Benchmark Economy
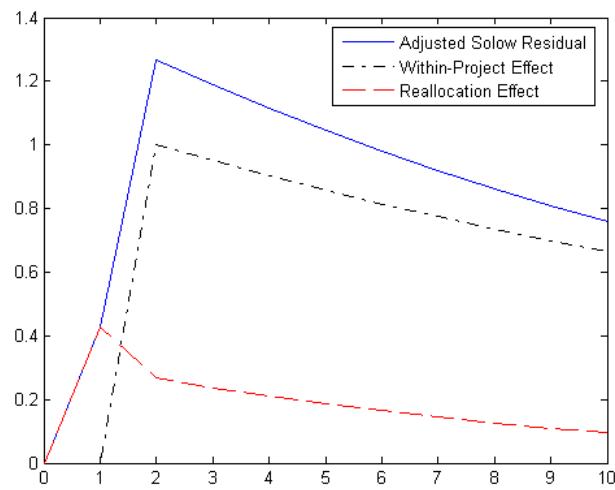
Figure 6: Response of Adjusted Solow Residual and its Components to News Shock in Aggregate Technology, Benchmark Economy
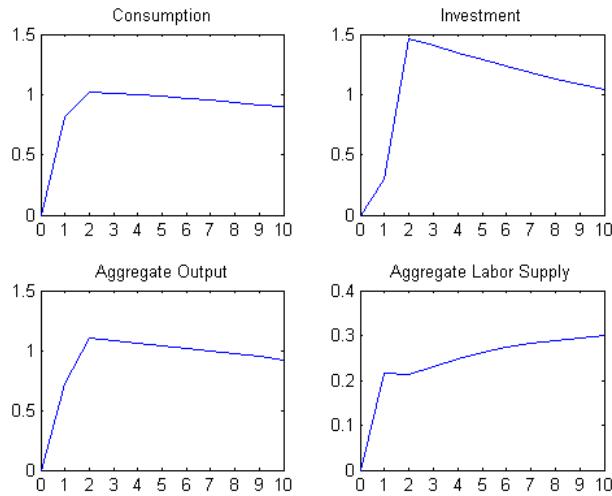
Figure 7: Response of Macro Aggregates to News Shock to High-Tech Technology, Benchmark Model
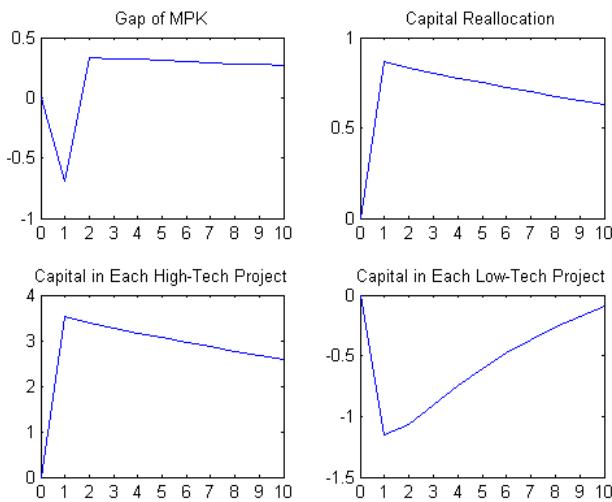
Figure 8: Response of Capital Reallocation to News Shock to High-Tech Technology, Benchmark Model
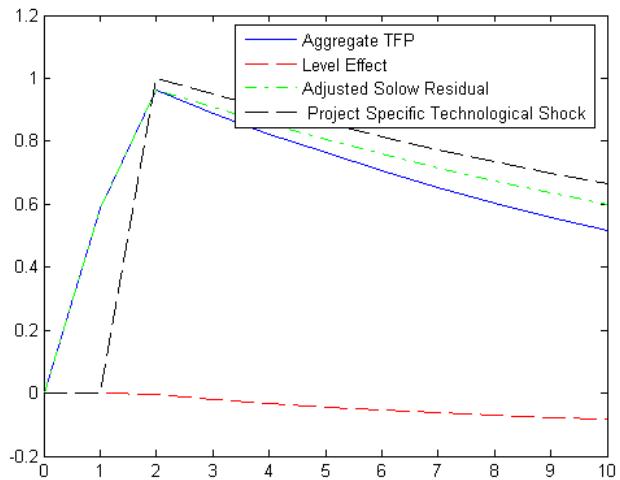
Figure 9: Response of Aggregate TFP and its Components to News Shocks to High-Tech Technology, Benchmark Economy
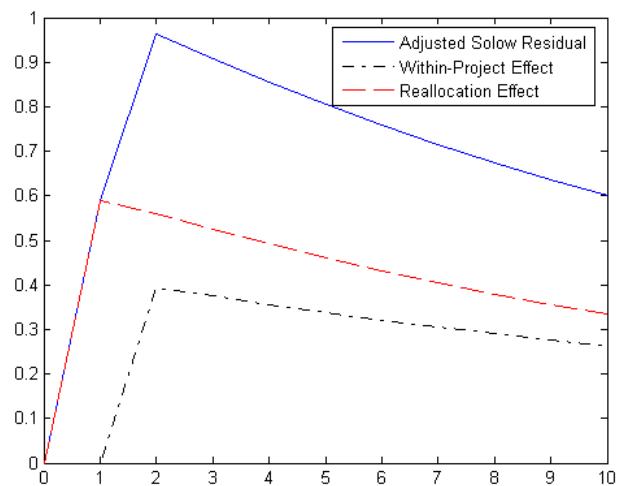

Figure 10: Response of Adjusted Solow Residual and its Components to News Shocks to High-Tech Technology, Benchmark Economy
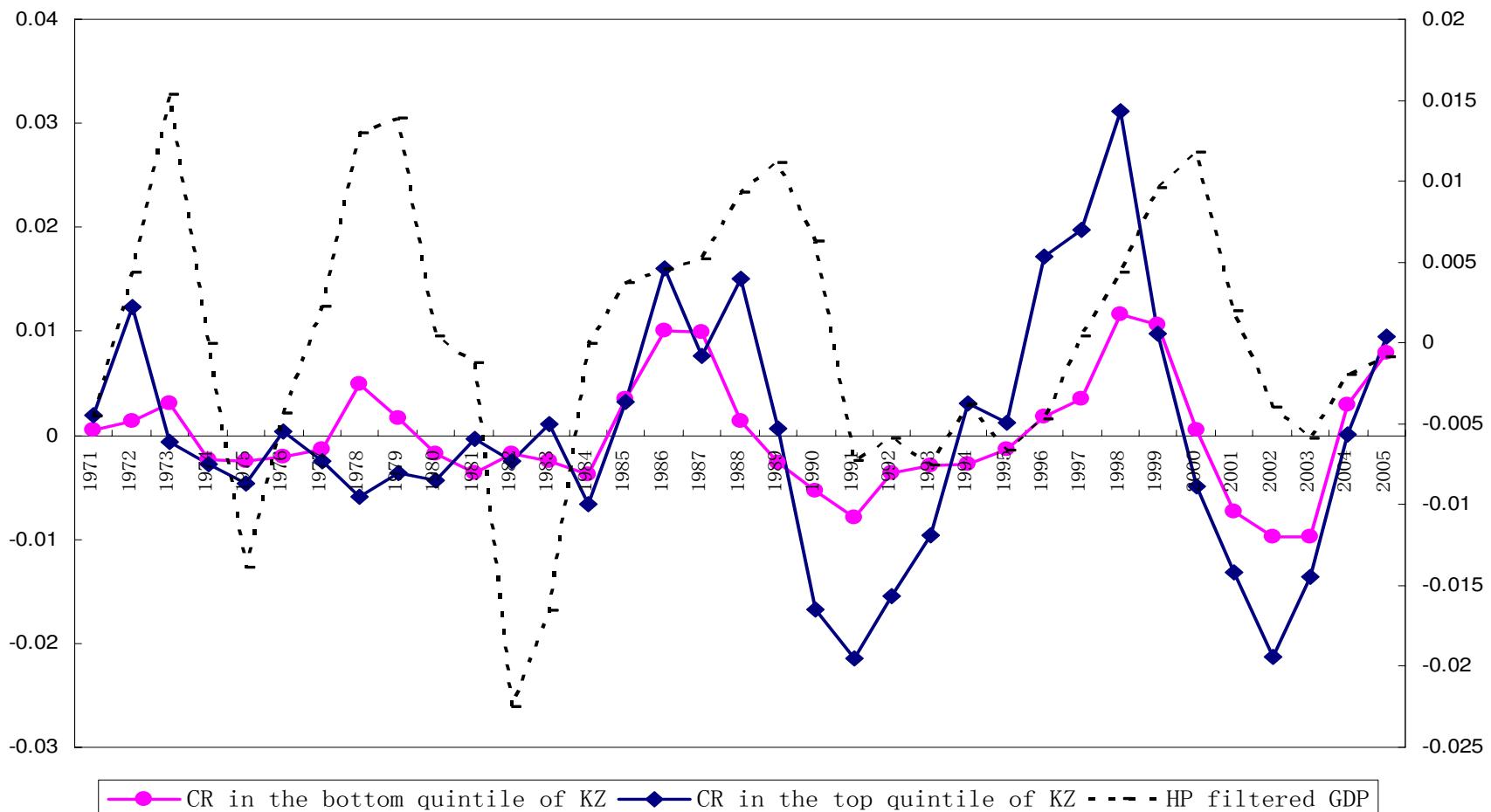
Figure 11: Volatility of Acquisition by Firms in the Top and Bottom KZ Quintiles