News Shocks to Investment-specific Technology in Business Cycles*

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Abstract

Recent research in DSGE and VAR models has indicated that the most important drivers of business cycles are IST shocks, not traditional TFP and other shocks. Research in VAR models has also empirically identified IST news shocks as a significant driving force behind the U.S. business cycle. However, recent New-Keynesian DSGE models have found that IST news shocks do not produce comovement of aggregate variables, with the share of the forecast error variance explained by IST news shocks being very small in a flexible-price model and essentially zero in a sticky-price model. This paper uses the Bayesian methods to estimate the parameters and shock processes to study the business cycle effects of IST news shocks in a two-sector sticky-price DSGE model with consumer durables and collateral constraints. Our variance decompositions indicate that IST news shocks are a more relevant source of uncertainty than IST non-news and other shocks.

Keywords: Credit constraints; sticky prices; news shocks; investment-specific technology; comovement;

JEL classification: E21, E22, E30, E32, E37

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1. Introduction

Recent work explores whether news shocks about future total factor productivity (TFP) are an important source of business cycles and quantifies the importance of anticipated shocks to fundamentals (e.g., Beaudry and Portier, 2004; Jaimovich and Rebelo, 2009).[1] Using the Bayesian methods to estimate the parameters and shock processes, this paper analyzes the effects of news shocks to future investment-specific technology (IST) on business cycles in a New Keynesian dynamic stochastic general equilibrium (DSGE) model.[2] We use a two-sector sticky-price DSGE model with consumer durables and financial frictions to study IST news shocks, motivated by the following two reasons.

First, research suggests that the most important driver of business cycles is not Hicks-neutral TFP shocks (e.g., Galí, 1999; Francis and Ramey, 2005), but is IST shocks (e.g., Greenwood et al., 2000; Christensen and Dib, 2008). Fisher (2006) estimated a vector autoregression (VAR) model to compare the business cycle effects of unanticipated TFP and IST shocks. He found that the majority of business cycles and forecast errors of hours and output over a three- to eight-year horizon is driven by IST shocks. Moreover, Justiniano et al. (2010) studied a one-sector New Keynesian model with nominal and real frictions such as price and wage rigidities, habit formation, and variable capital utilization. They found that over 50% of the fluctuations in output and hours, and over 80% of the fluctuations in investment were driven by IST shocks.[3] In particular, in a recent VAR model with the maximum forecast error variance approach, Chen and Wemy (2015) have highlighted again the importance of IST shocks by establishing that IST innovations are quantitatively important drivers of long-run movements in aggregate TFP.[4]

Next, in a one-sector DSGE model with flexible prices, Jaimovich and Rebelo (2009) found that IST news shocks drive business cycles only if there are variable capital utilization, investment adjustment costs, and small short-run wealth effects on the labor supply. From then on, using an otherwise identical model, Schmitt-Grohé and Uribe (2012) uncovered that IST news shocks have very small effects on consumption and labor hours, but large effects on investment. In another similar one-sector DSGE model with sticky prices, Ben Zeev and Khan (2015) also found that IST news shocks cannot produce comovement. In particular, they found that the share of the forecast error variance of real aggregate variables attributable to

[1] Barro and King (1984) posited that it is a challenge to make news shocks about future fundamentals work in the context of relatively standard business cycle models. Yet, Beaudry and Portier (2004) found that TFP news shocks can explain several patterns associated with business cycles and recessions in the US, while Jaimovich and Rebelo (2009) discovered that news shocks can be drivers of business cycles in a standard neoclassical model under some conditions.

[2] For New Keynesian microfoundations, readers are referred to Rotemberg (1987).

[3] Christiano et al. (2014) investigated risk shocks to marginal efficiency of converting raw capital into effective capital, but perceived that it is hard to distinguish risk shocks from IST shocks of converting investment into installed capital studied by Justiniano et al. (2010). Using a baseline model, they found that risk shocks account for 62% of GDP fluctuations, as compared to 13% accounted by IST shocks. Yet, their risk shocks only explain 1% of GDP fluctuations, as compared to 44% accounted by IST shocks, when four financial variables are dropped from their baseline model, which are credit to entrepreneurs, the slope of term structure, entrepreneurial net worth, and the credit spread.

[4] Readers are referred to Papanikolaou (2011), which studied the effect of IST shocks on asset prices, in particular on the risk premium and volatility of the market portfolio. Effects on asset prices are not within the scope of our study.

IST news shocks is very small in a one-sector flexible-price DSGE model (Schmitt-Grohé and Uribe, 2012) and essentially zero in a one-sector sticky-price DSGE model (Khan and Tsoukalas, 2012). However, the above results are at odds with those of VAR-based empirical models by Ben Zeev and Khan (2015), which have empirically identified IST news shocks as a significant driving force behind the U.S. business cycle, and by Ben Zeev (2018), which provides robust evidence that IST news shocks result in comovement among aggregate variables and account for the majority of their business cycle variations in the boom-bust period of 1997–2003.[5]

This paper uses the Bayesian method to estimate the parameters and shock processes and analyzes whether IST news shocks are the dominant source of business cycle fluctuations. Specifically, following Monacelli (2009), Justiniano et al. (2010), and Chen and Liao (2018), this paper studies a DSGE model with two sectors. One sector produces nondurable goods for consumption, and the other sector produces durable goods for investment in capital and consumer durables, with nondurable prices being stickier than durable prices, as in Bils and Klenow (2004).[6] Financial frictions are in the form of collateral constraints. Under the two-sector model with sticky prices and collateral constraints, we carry out a τ-period-ahead news shock about anticipated shifts of stationary IST that are uncorrelated with innovations to unanticipated IST contemporaneous shocks. To compare whether the source of fluctuations is from IST news or other shocks, we also study eleven other shocks, including non-news (contemporaneous) shocks to IST, and news and non-news shocks to aggregate TFP, to sectoral TFPs in the durable and the nondurable goods sectors, to durables preferences, and to labor supply. We carry out variance decompositions to each of the twelve orthogonal shocks in our baseline model.

We find that positive IST news shocks increase key variables on impact, and thus aggregate variables comove. By contrast, in an otherwise identical model except sticky prices or collateral constraints, positive IST news shocks decrease consumption. Our variance decomposition indicates that news shocks to IST account for over 50 percent of the fluctuations in all variables, followed by non-news shocks to IST that account for about 30 percent of the fluctuations, while each of the other shocks explains less than 10 percent of the fluctuations. IST news shocks are thus the most relevant source of uncertainty than other shocks. We also perform the forecast error variance decomposition to the twelve shocks at different forecast horizons. Different from Sims (2016), for all variables, the variance shares attributable to news shocks to IST are in a majority for all periods. In particular, no matter whether news becomes realized or not, IST news shocks are always a dominant source of volatility for all forecast horizons in our baseline model.

Different from Jaimovich and Rebelo (2009) and Schmitt-Grohé and Uribe (2012), in our sticky-price model, financial constraints play key roles in creating business cycles and comovement of variables in

[5] By contrast, the VAR model by Ben Zeev et al. (2020) indicates that monetary news shocks only account for less than 10% of the forecast variance in output and inflation, indicating a small role behind the U.S. business cycle.

[6] As will be seen, our results are robust as long as durable prices are less sticky than nondurable prices.

response to IST news shocks, even if there are no investment adjustment costs, variable capital utilization, and small wealth effects in the utility function.[7] Moreover, our IST news shocks create large effects on investment, consumption and labor hours, different from Schmitt-Grohé and Uribe (2012), wherein stationary IST news shocks create large effects on investment but not on consumption and labor hours.[8]

In a recent two-sector DSGE model, Görtz and Tsoukalas (2017) uncovered that TFP news shocks, especially consumption-sector TFP news shocks, can generate comovement of aggregate variables if there are sticky prices and wages, and found that the presence of financial leverage amplifies the effects of TFP news shocks. Like Görtz and Tsoukalas (2017), we study a two-sector DSGE model. Yet, our model is different from theirs. While their sectors produce goods for investment and consumer nondurables, our sectors also produce consumer durables. Moreover, we focus IST news shocks, rather than TFP news shocks. In particular, we find that IST news shocks generate comovement of aggregate variables if there are sticky prices and collateral constraints, where the loan-to-value ratio is smaller than one, different from their leverage ratio, which is larger than one.

Our two-sector model adds value to two-sector models of Beaudry and Portier (2004) and Jaimovich and Rebelo (2009). Our model is different from theirs in several ways. First, our two sectors involve consumer durables, but their two sectors do not. Moreover, while we study a sticky-price model, they study a flexible-price model. In particular, Beaudry and Portier (2004) did not study IST news shocks, and we do not have to introduce variable capital utilization, investment adjustment costs, and small wealth effects on the labor supply to produce comovement (see Jaimovich and Rebelo, 2009).

Several authors have analyzed news shocks in New Keynesian models with nominal rigidities.[9] To the best of our knowledge, Khan and Tsoukalas (2012) is the only paper that studied IST news shocks in a sticky-price New Keynesian model, but they found that IST news shocks cannot generate business cycle fluctuations. Our paper also builds on work that estimated the effects of TFP news shocks in VAR models,[10] but we mainly investigate IST news shocks in a DSGE model.

Moreover, following Kiyotaki and Moore (1997), our model introduces borrowing constraints on producers and thus, is related to DSGE models with financial frictions on producers. Although the setup may slightly differ in the existing literature, the transmission mechanism is the same: all directly connect

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[7] In early versions, we have shown that our comovement results do not rely on investment adjustment costs.

[8] As our model does not involve the four financial variables in Christiano et al. (2014), if news shocks to risks are introduced, we expect that news shocks to IST account for more GDP fluctuations than news shocks to risks.

[9] Gilchrist and Leahy (2002) found that TFP news shocks cause consumption to rise but labor and output to fall in a sticky-price model. Christiano et al. (2008) discovered that TFP news shocks cannot increase consumption on impact in a sticky-price or wage model. Fujiwara et al. (2011) found that TFP news shocks are a minor source of fluctuations in the US in a sticky-price model. Thus, all these models found that TFP news shocks incur a comovement problem.

[10] Among these models, Barsky and Sims (2011) and Barsky et al. (2015) found that positive TFP news shocks failed to generate comovement of variables on impact, as output, hours, and investment fell in Barsky and Sims (2011), while investment, consumer durables, and hours decreased insignificantly in Barsky et al. (2015). By contrast, Bouakez and Kemoe (2017) obtained that TFP news shocks were an important driver of business cycles, and Cascaldi-Garcia and Galvao (2021) found the positive responses of economic activity to TFP news shocks in the short term.

firms' assets with investment.[11] The difference is that our paper studies IST news shocks, but they do not. In our model with nominal rigidities, financial frictions on producers play the role of not only resolving the inconsistent comovement problem of IST news shocks in the standard DSGE model, but also increasing the shares of the forecast error variance of real aggregate variables attributable to IST news shocks. Besides, our paper is broadly related to the literature of expectation-driven business cycles, including the noise shocks literature (cf. Lorenzoni, 2009; Blanchard et al., 2013), and the sentiment shocks literature (cf. Barsky and Sims, 2012; Angeletos and La'O, 2013; Benhabib et al., 2015). While the former line focused on noise shock formulations in generating demand-side fluctuations, the latter strand explored confidence shocks in generating demand-side fluctuations. Our paper studies IST news shocks in creating supply-side fluctuations, which is different from expectation-driven shocks in generating demand-side fluctuations.

Finally, in a recent paper that resolved countercyclical consumption puzzle following the marginal efficiency of investment (MEI) shocks, Choi (2020) also produced comovement following a MEI news shock.[12] Choi (2020) is a one-sector model that uses naïve hyperbolic discounting, wherein the lifetime utility of the representative household is discounted not only by the standard long-run discount factor but also by a short-run discount factor. There are two key differences between our model and Choi's model. First, while Choi (2020) studied a one-sector flexible-price model with non-standard naïve hyperbolic discounting that features time inconsistency, we study a two-sector sticky-price model with standard discounting that is time consistent. Moreover, we find that IST news shocks are a more relevant source of uncertainty than IST non-news shocks, but Choi (2020) did not investigate whether MEI news shocks or MEI non-news shocks explain more fluctuations.

The rest of this paper is organized as follows. In Section 2, we set up a baseline sticky-price two-sector model with borrowing constraints. In Section 3, we estimate the models, and Section 4 envisages the impulse responses to a positive IST news shock and the variance decomposition. Section 5 carries out the sensitivity analysis. Finally, concluding remarks are made in Section 6.

2. The Model

Time is discrete and lasts for an infinite horizon. Following Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), and Iacoviello (2005), the economy consists of two types of agents: households and entrepreneurs. Both types of agents consume, but households supply labor while entrepreneurs do not.[13] Following Iacoviello (2005) and Monacelli (2009), there is a continuum of households of a unit mass, who has two types: patient and impatient. Patient households have the lowest time preference rate and are savers.

[11] See Carlstrom and Fuerst (1997), Bernanke and Gertler (1989), Bernanke et al. (1999), Cooley et al. (2004), Iacoviello (2005), Faia and Monacelli (2007), and Gerali et al. (2010), among others.

[12] MEI shocks enter Choi's model in the same way as IST shocks do in our model.

[13] On this, our setup follows from Iacoviello (2005) and is different from Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997), wherein both types of agents supply labor.

Impatient households, along with entrepreneurs, have higher time preference rates and are borrowers. Agents with varied discount rates trade nominal private debts, with borrowers being subject to collateral constraints that are tied to the expected future value of the stock of durables.

As Barsky et al. (2007) and Monacelli (2009), the economy includes two sectors: nondurables and durables.[14] Nondurable final goods are for consumption. Durable final goods are for consumer durables and capital investment, which accumulate the stock of consumer durable services and the stock of capital, respectively. Each sector comprises a continuum of producers, which sell final goods at competitive prices. Final goods in each sector are assembled using intermediates produced by a continuum of entrepreneurs in the sector. Both types of households consume both kinds of final goods, and so do entrepreneurs.

In addition, there are retailers. While entrepreneurs sell intermediates to a continuum of retailers at competitive prices, retailers sell intermediates to final goods producers at monopolistic prices that incur adjustment costs when setting prices.

2.1 Households

A typical household consumes an index of composite consumption $X_{i,t}$ given by

$$X_{i,t} \equiv [(1-\mu_t)^{\frac{1}{\eta}}(C_{i,t})^{\frac{\eta-1}{\eta}} + \mu_t^{\frac{1}{\eta}}(D_{i,t})^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}},\ i=b,\ s,$$

where $C_{i,t}$ is nondurables and $D_{i,t}$ is services from the stock of consumer durables, with subscript $i=b, s$ labelling borrowers and savers, respectively. The parameter $\eta\geq 0$ is the elasticity of substitution between nondurables and durables in consumption. The variable μ_t is the preference shock to durables (housing) and is assumed to follow a first-order autoregressive (AR(1)) process given by

$$\ln\mu_t = (1-\rho_\mu)\ln\mu + \rho_\mu \ln\mu_{t-1} + e_{\mu,t} + \nu_{\mu,t-\tau},$$

where $\mu>0$ is the share of consumer durables in the composite consumption index in the steady state, the parameter $\rho_\mu\in(0, 1)$ measures the persistence of shocks, the term $e_{\mu,t}$ is unanticipated contemporaneous innovations in relation to the durables preference, which are assumed to be independent and identically distributed (*i.i.d.*) normally with mean 0 and variance σ_μ^2 ($N(0, \sigma_\mu^2)$). The term $\nu_{\mu,t-\tau}$ is a preference news shock to durables, which provides τ-period-ahead news about an expected shift in future preferences. The news shock $\nu_{\mu,t-\tau}$ is *i.i.d.* with $N(0, \sigma_{\mu\nu}^2)$ and uncorrelated with the innovation in relation to the durables preference, $e_{\mu,t}$. We assume the same parameter η and durables preference shock in the composite consumption index for savers and borrowers.

As in Monacelli (2009), the impatient household maximizes the expected lifetime utility given by $E_0\sum_{t=0}^{\infty}(\beta_b)^t(\ln X_{b,t} - \nu_b \frac{(\omega_t L_{b,t})^{1+\phi_b}}{1+\phi_b})$, where E_t is an expectation operator conditional on information

[14] We go along Monacelli (2009) and refer to the nondurable consumption goods sector and the durable goods sector as sectors c and d, respectively.

available in t.[15] The discount factor is $\beta_b \in (0, 1)$, which is smaller than the discount factor of patient households, $\beta_s \in (0, 1)$. Thus, impatient households are borrowers. $L_{b,t}$ is hours of work. The parameter $\nu_b>0$ is the coefficient associated with the disutility of labor, and $\phi_b>0$ is the inverse of the Frisch labor supply elasticity. Labor is freely mobile across sectors. The variable ω_t is the labor supply shock and is assumed to follow an AR(1) process given by

$$\ln \omega_t = \rho_\omega \ln \omega_{t-1} + e_{\omega,t} + \nu_{\omega,t-\tau},$$

where the parameter $\rho_\omega \in (0, 1)$ measures the persistence of shocks. The innovations $e_{\omega,t}$ and $\nu_{\omega,t-\tau}$ are the contemporaneous and news shocks, which are assumed to be *i.i.d.* with $\mathcal{N}(0, \sigma_\omega^2)$ and $\mathcal{N}(0, \sigma_{\omega\nu}^2)$, respectively. The two innovations $e_{\omega,t}$ and $\nu_{\omega,t-\tau}$ are uncorrelated. We assume the same labor supply shock for both types of households.

Impatient households receive labor income at the nominal wage rate W_t. They may borrow by issuing one-period nominal debts $B_{b,t}$. They use the income to buy nondurables and consumer durables and to service the debt. Expressed in units of nondurables, an impatient household's budget constraint is

$$C_{b,t} + p_t[D_{b,t} - (1-\delta)D_{b,t-1}] + R_{t-1}\frac{b_{b,t-1}}{\pi_{c,t}} = b_{b,t} + w_t L_{b,t}, \tag{1}$$

where R_{t-1} is the gross nominal interest rate on a loan between periods t-1 and t, $p_t \equiv P_{d,t}/P_{c,t}$ is the durable price in terms of nondurables, $b_{b,t} \equiv B_{b,t}/P_{c,t}$ is real debts, and $w_t \equiv W_t/P_{c,t}$ is real wage, with $\pi_{c,t} \equiv P_{c,t}/P_{c,t-1}$ being the gross inflation of nondurables and δ being the depreciation rate.

The loan market is imperfect, as lenders cannot force borrowers to repay their debts and thus, collateral is required in order to take out loans. Consumer durables, like housing, play a dual role. They are used not only for consumption but also for collateral when households secure loans (e.g., Kiyotaki and Moore, 1997; Iacoviello, 2005). The value of the stock of consumer durables is an upper limit of loans. If borrowers repudiate their debt obligations, lenders can liquidate borrowers' collateral by paying transactions costs at a proportion $(1-m_b) \in (0,1)$ of the collateral value. Thus, the amount that a borrower agrees to pay back in the following period ($R_t B_{b,t}$) is tied to $m_b E_t[(1-\delta)P_{d,t+1}D_{b,t}]$, the expected value of non-depreciated consumer durables one period ahead. In real terms, this borrowing constraint becomes

$$R_t b_{b,t} \le m_b(1-\delta)E_t(p_{t+1}D_{b,t}\pi_{c,t+1}) = m_b(1-\delta)p_t E_t(D_{b,t}\pi_{d,t+1}), \tag{2}$$

where $\pi_{d,t} \equiv P_{d,t}/P_{d,t-1}$, and m_b is the loan-to-value ratio of impatient households. The expected gross inflation of durables in the next period affects the constraint.

The first-order conditions for nondurable consumption, labor hours, consumer durables, and real debts are similar to those obtained in Monacelli (2009). In particular, the optimal choice of consumer durables is

[15] Like Monacelli (2009) and Chen and Liao (2014) with two types of households (savers and borrowers), we specify the preference with the wealth elasticity of labor supply, as opposed to the preference specified in Jaimovich and Rebelo (2009) featuring a parameter that governs the wealth elasticity of labor supply that nests the two classes of utility functions characterized in King et al. (1988) and Greenwood et al. (1988).

such that the marginal rate of substitution between consumer durables and nondurables equals the *user cost of durables* (Erceg and Levin, 2006), which is the relative price of durables p_t, net of two marginal gains. One of the marginal gains is the expected discounted marginal utility of nondurables in the next period stemming from the non-depreciated consumer durables, and the other is the marginal utility of relaxing collateral constraints. We note that if the shadow price of collateral constraints, denoted by $\psi_{b,t}$, is zero, the marginal utility of relaxing collateral constraints is zero. Moreover, the optimal condition for real debts is a modified Euler equation, which reduces to the standard Euler condition if $\psi_{b,t}=0$. However, if $\psi_{b,t}>0$, the condition suggests that the marginal utility of nondurables exceeds the expected discounted marginal utility of shifting a unit of nondurables to the next period. An increase in $\psi_{b,t}$ indicates a tighter collateral constraint. When $\psi_{b,t}$ is larger, the net marginal benefit of consumer durables today is higher, since one more unit of consumer durables relaxes collateral constraints at the margin, which allows for extra consumption today.

As for the patient household, it maximizes $E_0 \sum_{t=0}^{\infty} (\beta_s)^t (\ln X_{s,t} - \nu_s \frac{(\omega_t L_{s,t})^{1+\phi_s}}{1+\phi_s})$, which is otherwise identical to that of an impatient household except for variables and parameters labeled by subscript *s*. Patient households are savers, because their discount factor is larger than that of impatient households, $\beta_s > \beta_b$. The representative patient household faces the following flow budget constraint

$$C_{s,t} + p_t [D_{s,t} - (1-\delta) D_{s,t-1}] + R_{t-1} \frac{b_{s,t-1}}{\pi_{c,t}} = b_{s,t} + w_t L_{s,t} + \frac{F_t}{P_{c,t}}. \quad (3)$$

Note that (3) is otherwise the same as (1) except for the term F_t, which is a nominal lump-sum profit remitted from retailers, as patient households are savers and thus own the share of retailers. The representative patient household chooses $C_{s,t}$, $L_{s,t}$, $D_{s,t}$, and $b_{s,t}$. The first-order conditions are otherwise the same as those in the impatient household's problem, except for subscripts replaced by *s*, and $\psi_{s,t}=0$.

2.2 Final goods producers

Each sector has a continuum of final goods producers of a unit mass. In sector $j=c, d$, the representative producer uses a continuum of intermediates $Y_{j,t}(z)$, indexed by $z \in [0, 1]$, and produces final goods $Y_{j,t}$, according to the following technology

$$Y_{j,t} = [\int_0^1 (Y_{j,t}(z))^{(\varepsilon_j - 1)/\varepsilon_j} dz]^{\varepsilon_j/(\varepsilon_j - 1)}, \; j=c, d,$$

where $\varepsilon_j > 1$ is the elasticity of substitution between intermediates in sector *j*.

Nondurable goods $Y_{c,t}$ are for consumption only, while durable goods $Y_{d,t}$ are for capital investment and consumer durable services. Maximization of profits gives the following demand for intermediate *z*.

$$Y_{j,t}(z) = (\frac{P_{j,t}(z)}{P_{j,t}})^{-\varepsilon_j} Y_{j,t}, \quad z \in (0,1), \quad j=c, d, \quad (4)$$

where $P_{j,t}(z)$ is the price of an intermediate *z* and $P_{j,t}$ is the price index of final goods in sector *j*. A zero profit implies $P_{j,t} = [\int_0^1 (P_{j,t}(z))^{1-\varepsilon_j} dz]^{1/(1-\varepsilon_j)}$, j=c, d.

2.3 Entrepreneurs

Each sector has a continuum of entrepreneurs, indexed by $z\in[0, 1]$. Entrepreneurs are both producers and consumers. As producers in sector j, they produce intermediates for producing final goods in sector j. An intermediate z in sector j is produced according to the following technology.

$$Y_{j,t}(z) = A_t A_{j,t} K_{j,t}(z)^{\alpha_j} L_{j,t}(z)^{1-\alpha_j}, \;\; j=c, d, \tag{5a}$$

where $K_{j,t}(z)$ and $L_{j,t}(z)$ are, respectively, capital and labor used by an entrepreneur z in sector j, $\alpha_j\in(0,1)$ is the capital share in sector j. While the variable A_t is an aggregate TFP across sectors, $A_{j,t}$ is a sector-specific TFP in sector j. Thus, production functions across two sectors differ in capital shares and sectoral TFPs. The two types of TFPs are assumed to follow AR(1) processes given by

$$\ln A_t = \rho_A \ln A_{t-1} + e_{A,t} + \nu_{A,t-\tau},$$

$$\ln A_{j,t} = \rho_{Aj} \ln A_{j,t-1} + e_{Aj,t} + \nu_{Aj,t-\tau}, \;\; j=c, \; d,$$

where the parameters ρ_A and $\rho_{Aj}\in(0, 1)$ measure the persistence of shocks. The innovations $e_{A,t}$ and $e_{Aj,t}$ are the contemporaneous shocks, which are assumed to be *i.i.d.* with $\mathcal{N}(0, \sigma_A^2)$ and $\mathcal{N}(0, \sigma_{Aj}^2)$, respectively, and $\nu_{A,t-\tau}$ and $\nu_{Aj,t-\tau}$ are the news shocks, which are assumed to be *i.i.d.* with $\mathcal{N}(0, \sigma_{A\nu}^2)$ and $\mathcal{N}(0, \sigma_{Aj\nu}^2)$, respectively. The TFP news shock provides τ-period-ahead news about an anticipated shift in future TFP. All innovations are assumed to be uncorrelated.

Following Bernanke et al. (1999) and Iacoviello (2005), an entrepreneur z in sector j does not sell an intermediate directly to final goods producers in sector j; it sells an intermediate to retailers at the wholesale price $P_{j,t}^W(z)$, and retailers then sell the intermediate to final goods producers in sector j at price $P_{j,t}(z)$.

As a consumer, an entrepreneur's expected lifetime utility is $E_0 \sum_{t=0}^{\infty} (\beta_j)^t \ln X_{j,t}$,[16] where $\beta_j \leq \beta_s$, j=c, d, and the composite consumption index $X_{j,t}$ takes the same form as $X_{i,t}$ for households. An entrepreneur's flow budget constraint is

$$C_{j,t} + p_t[D_{j,t} - (1-\delta)D_{j,t-1}] + R_{t-1}\tfrac{b_{j,t-1}}{\pi_{c,t}} + w_t L_{j,t} + p_t I_{j,t} = \tfrac{P_{j,t}^W(z)}{P_{j,t}} \tfrac{P_{j,t}}{P_{c,t}} Y_{j,t}(z) + b_{j,t}, \;\; j=c, \; d, \tag{5b}$$

where $P_{j,t}/P_{j,t}^W(z)$ is the markup of final goods in sector j over intermediates. An entrepreneur uses the flow income to pay for nondurable consumption, consumer durables, and the cost of labor and investment $I_{j,t}$. The relative price of investment p_t is the relative price of durables, since durables can be used for investment. The evolution of the capital stock is

$$K_{j,t+1} - (1-\delta)K_{j,t} = \xi_t \Big[1 - \Phi_j(\tfrac{I_{j,t}}{I_{j,t-1}})\Big] I_{j,t}, \;\; j=c, d, \tag{5c}$$

[16] Like Iacoviello (2005, 2015), entrepreneurs are risk averse here, unlike risk-neutral entrepreneurs in models of agency costs (Bernanke et al., 1999). As will be seen, our results are robust when entrepreneurs are risk neutral.

where $0<\delta<1$ is the depreciation rate of capital. For tractability of analysis, we assume that capital depreciates at the same rate as consumer durables.[17] The function Φ_j is the investment adjustment cost. Following Christiano et al. (2005), the adjustment cost takes the quadratic form $\Phi_j(\frac{I_{j,t}}{I_{j,t-1}}) = \frac{\varphi_j}{2}(\frac{I_{j,t}}{I_{j,t-1}} - 1)^2$, $\varphi_j \geq 0$, $j=c$, d. As for the accumulation of consumer durable services, we follow Iacoviello (2005), Barsky et al. (2007), and Monacelli (2009), and set zero adjustment cost for consumer durables.

Following Greenwood et al. (1997, 2000) and Justiniano et al. (2010), we include a factor ξ_t in the accumulation of capital, which specifies the current state of the technology for capital formation. It is an exogenous variation in efficiency, which determines the amount of capital in the next period that is formed from one unit of investment in this period. Changes in ξ_t formalize the notion of IST changes. For simplicity, we assume that the efficiency in the accumulation of capital is the same in both sectors. As in existing work on IST shocks, we assume that ξ_t follows an AR(1) process given by

$$\ln \xi_t = \rho_I \ln \xi_{t-1} + e_{I,t} + v_{I,t-\tau}, \tag{5d}$$

where the parameter $\rho_I \in (0, 1)$ measures the persistence of shocks. The innovations $e_{I,t}$ and $v_{I,t-\tau}$ are stationary IST contemporaneous shocks and stationary IST news shocks, respectively, which are assumed to be *i.i.d.* with $\mathcal{N}(0, \sigma_I^2)$ and $\mathcal{N}(0, \sigma_{Iv}^2)$.[18] The IST news shock $v_{I,t-\tau}$ provides τ-period-ahead news about an expected shift in future IST. The IST news shock is uncorrelated with the IST contemporaneous shock. The IST shock under study is a stationary process.[19]

Some remarks are in order. First, as is standard, capital investment is accumulated into the stock of capital and ready for use as an input in production in the next period in (5c). On the other hand, in terms of value, consumer durables are mainly accounted for by residential houses. When these consumer durables are purchased, they are ready for use as consumption services, as in the conventional wisdom in Barsky et al. (2007), Monacelli (2009), and Sudo (2012). Hence, in (1), (3), and (5b), the stock of consumer durable services is formed from the flow of consumer durables in the same period.

Moreover, we posit that only capital investment involves IST shocks. Our formulation is based on the following reasons. First, in Greenwood et al. (1997, 2000), both equipment capital and structure capital are accumulated from final goods produced in the same sector, but only equipment capital has IST shocks while structure capital is not affected by IST shocks. Second, and more importantly, existing studies, such as Chung et al. (2010), argued that there are two categories of consumer durables, and they are different in how they are affected by IST shocks. The first category of consumer durables comprises personal

[17] The existing literature usually set the same depreciation rate for consumer durables and capital (e.g., Carlstrom and Fuerst, 2010 and Sudo, 2012, among others).

[18] A similar process was used by Barsky and Sims (2011) and Leeper et al. (2013).

[19] Since our model has no trends, there are no permanent components, and thus, no nonstationary IST shocks (e.g., Miyamoto and Nguyen, 2020). Here we also ignore the distinction between IST and MEI shocks. Stationary IST shocks are equivalent to MEI shocks in our model, as in Justiniano et al. (2010) and Miyamoto and Nguyen (2020).

computers and home appliances. Production of these goods is likely to receive a favorable impact from a positive IST shock. The second category includes residential investment. Existing studies agree that productivity of residential investment is not affected by IST shocks. In terms of value, the majority of consumer durables are residential houses. Thus, we can think of consumer durables in our paper as residential houses, and their productivity is not affected by IST shocks.

In the budget constraint (5b), in addition to revenues from sales of intermediates, an entrepreneur may borrow by issuing one-period nominal debts. Like impatient households, the amount of real loans $b_{j,t}$ is limited by the following collateral constraint.

$$R_t b_{j,t} \le m_j(1-\delta)E_t[p_{t+1}(D_{j,t}+K_{j,t+1})\pi_{c,t+1}] = m_j(1-\delta)p_t E_t[(D_{j,t}+K_{j,t+1})\pi_{d,t+1}],\ \ j=c,\ d, \quad (5e)$$

where $D_{j,t}$ is the stock of consumer durables that an entrepreneur in sector j holds and $m_j \in (0,1)$ is the entrepreneur's loan-to-value ratio. Different from impatient households, entrepreneurs use not only consumer durables but also capital as collateral for borrowing. Since we will focus on an economy in which entrepreneurs' borrowing constraints are binding, we assume that entrepreneurs' discount rates are no less than savers' discount rates. Then, entrepreneurs will not postpone consumption and would not quickly accumulate wealth to completely self-finance, so as not to give a nonbinding borrowing constraint.

An entrepreneur in sector $j=c$, d maximizes expected lifetime utility, subject to the technology (5a), the flow budget constraint (5b), capital accumulation (5c), and the borrowing constraint (5e). Let $\lambda_{j,t}$, $q_{j,t}$, and $\lambda_{j,t}\psi_{j,t}$ be the current-valued Lagrange multipliers on constraints (5b), (5c), and (5e), respectively. We denote $MU_{j,t}^C$, $MU_{j,t}^D$, $MP_{j,t}^L$, and $MP_{j,t}^K$, respectively, as the marginal utility of nondurables and consumer durables, and the marginal product of labor and capital for entrepreneurs in sector $j=c$, d in period t. The first-order conditions for $C_{j,t}$, $L_{j,t}$, $D_{j,t}$, $b_{j,t}$, $K_{j,t+1}$, and $I_{j,t}$, $j=c$, d, are

$$MU_{j,t}^C = \lambda_{j,t}, \quad (6a)$$

$$\frac{P_{j,t}^W(z)}{P_{c,t}} MP_{j,t}^L = w_t, \quad (6b)$$

$$\frac{MU_{j,t}^D}{MU_{j,t}^C} = p_t - \beta_j(1-\delta)E_t\left(\frac{MU_{j,t+1}^C}{MU_{j,t}^C} p_{t+1}\right) - m_j(1-\delta)\psi_{j,t} p_t E_t(\pi_{d,t+1}), \quad (6c)$$

$$R_t \psi_{j,t} = 1 - \beta_j E_t\left(\frac{MU_{j,t+1}^C}{MU_{j,t}^C}\frac{R_t}{\pi_{c,t+1}}\right), \quad (6d)$$

$$p_t q_{j,t} = \beta_j E_t\left[MU_{j,t+1}^C \frac{P_{j,t+1}^W(z)}{P_{c,t+1}} MP_{j,t+1}^K + p_{t+1}q_{j,t+1}(1-\delta)\right] + m_j(1-\delta)MU_{j,t}^C\psi_{j,t}E_t[p_{t+1}\pi_{c,t+1}], \quad (6e)$$

$$p_t MU_{j,t}^C = p_t q_{j,t}\xi_t\left[1-\Phi_j\left(\frac{I_{j,t}}{I_{j,t-1}}\right) - \frac{I_{j,t}}{I_{j,t-1}}\Phi_j'\left(\frac{I_{j,t}}{I_{j,t-1}}\right)\right] + \beta_j E_t\left[p_{t+1}q_{j,t+1}\xi_{t+1}\left(\frac{I_{j,t+1}}{I_{j,t}}\right)^2 \Phi_j'\left(\frac{I_{j,t+1}}{I_{j,t}}\right)\right], \quad (6f)$$

along with transversality conditions $\lim_{t\to\infty}(\beta_j)^t\lambda_{j,t}D_{j,t}=0$, $\lim_{t\to\infty}(\beta_j)^t\lambda_{j,t}\psi_{j,t}b_{j,t}=0$, and $\lim_{t\to\infty}(\beta_j)^t q_{j,t}K_{j,t+1}=0$.

Conditions (6a) and (6b) are standard. Conditions (6c) and (6d) are similar to the first-order conditions for impatient households. Condition (6e) determines the demand for capital in the next period, in which the marginal cost of capital is the effective relative price of durables evaluated by $q_{j,t}$, the shadow value of installed capital in t. The marginal benefits of capital include the expected discounted sum of the marginal value product of capital (in terms of consumption) and the effective relative price of non-depreciated capital evaluated by the shadow value of installed capital in t+1 (cf. the first term in the right-hand side). Besides, the marginal benefit of capital contains the marginal gain of relaxing the collateral constraint from capital (cf. the second term in the right-hand side).

Like Justiniano et al. (2010), Tobin's Q is the marginal value of installed capital relative to foregone consumption, $\frac{q_{j,t}}{\lambda_{j,t}}$, which is the real price of capital. Thus, in (6f), capital investment is optimal when its foregone value is equal to the marginal value of capital investment. The marginal value of capital investment includes the shadow value of installed capital net of adjustment costs in this period (the first term) and the enhanced shadow value of capital due to lowering adjustment costs in the next period (the second term). In the case of no investment adjustment costs (i.e. Φ_j=0 and Φ'_j=0, j=c, d.), (6f) reduces to $\frac{q_{j,t}}{\lambda_{j,t}} = \frac{1}{\xi_t}$, and Tobin's Q equals the reciprocal of IST. Thus, a positive IST shock reduces the real price of capital and raises the demand for investment in capital.

2.4 Retailers and the price setting

There is a continuum of retailers indexed by $z \in (0,1)$. A retailer buys intermediates from entrepreneurs in sector j at the competitive wholesale price $P_{j,t}^{W}(z)$ and then sells them to final goods producers in sector j. As is standard in the existing literature that motivates sticky prices, retailers have monopoly powers when selling intermediates. Following Rotemberg (1982), in setting its monopolistic price $P_{j,t}(z)$, a retailer faces a quadratic cost of adjusting nominal prices in proportion to the value of the sectoral final output, $\Theta(P_{j,t}(z)) = \frac{\vartheta_j}{2}(\frac{P_{j,t}(z)}{P_{j,t-1}(z)} - 1)^2 P_{j,t} Y_{j,t}$, j=c, d, where ϑ_j is the degree of nominal rigidities in sector j, with ϑ_j=0 under flexible prices.

The representative retailer in sector j chooses a sequence of sale prices $\{P_{j,t}(z)\}_{t=0}^{\infty}$ that maximizes the following expected discounted sum of nominal profits

$$E_0 \sum_{t=0}^{\infty} \Lambda_t \left[P_{j,t}(z) Y_{j,t}(z) - P_{j,t}^{W}(z) Y_{j,t}(z) - \Theta(P_{j,t}(z)) \right], j=c, d,$$

subject to the corresponding demand function for intermediates in (4).

The stochastic discount factor $\Lambda_t \equiv \frac{\beta_s^{\,t} \lambda_{s,t}}{\lambda_{s,0}}$ is relevant to the period-t discount factor and the marginal utility of consumption for patient households. The retailers' optimal pricing condition for $P_{j,t}(z)$, j=c, d, is

$$\Lambda_t \left[(\tfrac{P_{j,t}(z)}{P_{j,t}})^{-\varepsilon_j} - \varepsilon_j \tfrac{P_{j,t}(z) - P_{j,t}^{W}(z)}{P_{j,t}} (\tfrac{P_{j,t}(z)}{P_{j,t}})^{-\varepsilon_j - 1} - \vartheta_j (\pi_{j,t}(z) - 1) \tfrac{P_{j,t}}{P_{j,t-1}(z)} \right] Y_{j,t} + E_t \left\{ \Lambda_{t+1} \left[\vartheta_j (\pi_{j,t+1}(z) - 1) \pi_{j,t+1}(z) \tfrac{P_{j,t+1}}{P_{j,t}(z)} Y_{j,t+1} \right] \right\} = 0, \quad (7)$$

where $\pi_{j,t}(z)\equiv P_{j,t}(z)/P_{j,t-1}(z)$ is the gross inflation of $Y_{j,t}(z)$ in sector j. Imposing the symmetry condition $\frac{P_{j,t}(z)}{P_{j,t}}=1=\frac{P_{j,t}^W(z)}{P_{j,t}^W}$ and letting $\Omega_{j,t}\equiv 1-\vartheta_j(\pi_{j,t}-1)\pi_{j,t}+E_t[\frac{\Lambda_{t+1}}{\Lambda_t}\vartheta_j(\pi_{j,t+1}-1)(\pi_{j,t+1})^2\frac{Y_{j,t+1}}{Y_{j,t}}]$, (7) gives

$$\frac{P_{j,t}}{P_{j,t}^W}=\frac{\varepsilon_j}{\varepsilon_j-\Omega_{j,t}},\ \ j=c,d.$$

Let $\tilde{x}_t$ be a percentage deviation of a variable x_t from its steady-state level x. Log-linearization of the symmetry optimal pricing condition yields the New Keynesian Phillips curve given by

$$\tilde{\pi}_{j,t}=\frac{\varepsilon_j-1}{\vartheta_j}\tilde{\omega}_{j,t}+\beta_s E_t(\tilde{\pi}_{j,t+1}), \tag{8}$$

where $\omega_{j,t}\equiv P_{j,t}^W/P_{j,t}$.

In a steady state, $\pi_{j,t}=\pi_{j,t+1}=1$ for $j=c$, d, and thus $\Omega_{j,t}=\Omega_{j,t+1}=1$ and the markup $P_{j,t}/P_{j,t}^W=\varepsilon_j/(\varepsilon_j-1)$ is a constant. In the special case when $\vartheta_j=0$, it is clear that $\Omega_{j,t}=1$ for all t, and therefore prices are flexible. In this case, even out of a steady state, the markup $P_{j,t}/P_{j,t}^W=\varepsilon_j/(\varepsilon_j-1)$ is a constant for all t.

2.5 Equilibrium

In equilibrium, nondurable and durable final goods markets clear.

$$Y_{c,t}=C_t+\frac{\vartheta_c}{2}(\pi_{c,t}-1)^2Y_{c,t}, \tag{9a}$$

$$Y_{d,t}=[D_t-(1-\delta)D_{t-1}]+I_t+\frac{\vartheta_d}{2}(\pi_{d,t}-1)^2Y_{d,t}, \tag{9b}$$

where $C_t\equiv C_{s,t}+C_{b,t}+C_{c,t}+C_{d,t}$ is aggregate nondurable consumption, $D_t\equiv D_{s,t}+D_{b,t}+D_{c,t}+D_{d,t}$ is the stock of aggregate consumer durables, and $I_t\equiv I_{c,t}+I_{d,t}$ is aggregate capital investment.

Moreover, the capital market, the labor market, and the debt market clear.

$$K_t=K_{c,t}+K_{d,t}, \tag{10a}$$

$$L_{c,t}+L_{d,t}=L_{s,t}+L_{b,t}. \tag{10b}$$

$$b_{s,t}+b_{b,t}+b_{c,t}+b_{d,t}=0. \tag{10c}$$

Finally, the model is closed by the following monetary policy rule.

$$\frac{R_t}{R}=(\frac{\pi_t}{\pi})^\chi,\ \ \chi>1, \tag{11}$$

where $\pi_t\equiv(\pi_{c,t})^{1-\mu}(\pi_{d,t})^\mu$ is a composite inflation index with the weight for durables being the steady-state share of consumer durables in the composite consumption index, and R and π are steady-state values. We assume $\chi>1$, which ensures equilibrium determinacy.

3. Data and Methodology

Before studying the effects of an IST news shock, we employ Bayesian methods to estimate structural parameters and shock processes in the baseline model using quarterly U.S. data over the period

1947Q1-2019Q4 on seven real and nominal variables. The observable variables are output, nondurable consumption, consumer durables, hours worked, business investment, real wage, and the deflator for investment sector.[20] All data are obtained from the Federal Reserve Economic Data published by the Federal Reserve Bank of St. Louis. The quarterly data are seasonally adjusted, expressed in logarithms, deflated by the consumption deflators, and taken the first difference.[21] The prior distributions of parameters are set by the standard DSGE literature, such as Smets and Wouters (2007), Schmitt-Grohé and Uribe (2012), and Görtz and Tsoukalas (2017). The estimation results are summarized in Table 1.

[Insert Table 1 here]

First, we pin down the value of the degree of nominal rigidities ϑ_j, j=c, d, in the following way. Let θ_j be the probability of not resetting prices in sector j=c, d, in the standard Calvo-Yun model. Our estimate yields θ_c=0.8685, which implies $1/(1-\theta_c)$=7.6 and thus, a frequency of nondurable price adjustments of over seven quarters. The slope of the New Keynesian Phillips curve (8) is $(\varepsilon_j-1)/\vartheta_j$, j= c, d. Moreover, the slope of the New Keynesian Phillips curve in the Calvo-Yun model is $(1-\theta_j)(1-\beta_s\theta_j)/\theta_j$, j= c, d.[22] Equating these two slopes gives $\vartheta_j=(\varepsilon_j-1)\theta_j/[(1-\theta_j)(1-\beta_s\theta_j)]$. We set the value of the elasticity of substitution between intermediates in the nondurable final goods production equal to ε_c=6 which is standard. With patient households' discount factor being β_s=0.99, we pin down the value for the degree of nominal price rigidities in nondurables to ϑ_c=235.57. As for the degree of durable-price stickiness, our estimate gets θ_d=0.1702, which implies $1/(1-\theta_d)$=1.2 and thus, a frequency of durable price adjustments of over one quarter. Then we obtain ϑ_d=1.233 in the same way, so durable prices are less sticky than nondurable prices, as shown in Bils and Klenow (2004).[23] Next, the coefficients of investment adjustment costs are estimated to be φ_c=9.97 and φ_d=7.26, which are within the estimates in Schmitt-Grohé and Uribe (2012).

The remaining parameters in the model are standard. We calibrate their values, so the resulting values of key variables in the steady state match the long-term features of the consumption-to-output ratio and the investment-to-output ratio of the postwar US economy, which are 0.63 and 0.17, respectively. Baseline parameter values are summarized in Table 2.

[Insert Table 2 here]

The time frequency is in a quarter. The steady-state real rate of return R is pinned down by savers' discount factor β_s. We choose the real rate of return per annum of 4%. This implies a quarterly discount factor of β_s=0.99. Impatient households (β_b) and entrepreneurs (β_c and β_d) are borrowers and thus have

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[20] The series of observables are gross domestic product (GDP), personal consumption expenditures on nondurables and services, personal consumption expenditures on durables, nonfarm business hours of all persons, gross private domestic investment (GPDI), compensation of employees in wages and salary accruals, and investment deflator, respectively. The investment deflator is a weighted average of the GPDI deflator and the deflator for personal consumption expenditures on durables.

[21] In order to be consistent with our two-sector model, the observables are deflated by the consumption deflator instead of the GDP deflator in the estimation.

[22] See Galí and Gertler (1999) and Sbordone (2002).

[23] See also Monacelli (2009), Carlstrom and Fuerst (2010), Bouakez et al. (2011), and Sudo (2012).

higher discount rates. As in Monacelli (2009), the fraction of borrowers is ½, and we set β_b=0.98, and as in Iacoviello (2005), we set β_c=β_d=0.98. Following Hansen (1985) and Schmitt-Grohé and Uribe (2012), we choose the quarterly depreciation rate of consumer durables and capital at δ=0.025. As in Acemoglu and Guerrieri (2008), the capital shares in the nondurable and the durable goods sectors are set at α_c=0.47 and α_d=0.27, respectively, to match their average capital shares in 1987-2005.

We set the impatient household's loan-to-value ratio at m_b=0.77 so as to match the average ratio in the US from 1990 to 2018. According to Iacoviello (2005), the entrepreneur's loan-to-value ratio is higher than the household's ratio. Hence, we set an entrepreneur's loan-to-value ratio at m_c=m_d=0.80, which is the maximum regulatory loan-to-value ratio of conventional mortgages in the US. The elasticity of substitution between nondurables and durables is set to η=1, implying the Cobb-Douglas form for the composite consumption index. We choose the steady-state share of durables in the composite consumption index of μ=0.2 in order to match the share of consumer durables spending in total private spending in the US. The elasticity of substitution between intermediate varieties in the final goods production ε_j is set to be 6 in both the nondurable sector and the durable sector, which implies a steady-state markup rate of 20%. In addition, following Barsky et al. (2007) and Monacelli (2009), we employ the value of the inverse of the Frisch labor supply elasticity at ϕ_s=ϕ_b=1, which is within the range of values used in the existing literature.

We normalize each household's time endowment at unity. According to the American Time Use Survey, average hours worked per person are about 30% of the time endowment. We use the same value for both patient and impatient households in a steady state and thus set L_s=L_b=0.3. We use the consumption-leisure tradeoff equation for impatient households to calibrate the parameter of leisure in preference at v_b=10.842. In the same fashion, we use the consumption-leisure tradeoff equation for patient households to calibrate the parameter of leisure in preference and obtain v_s=5.249.

Finally, as for the monetary policy rule, we set the reaction coefficient at χ=1.5, which is a standard value in the literature regarding Taylor rules. As a result, in the steady state, the consumption-to-output ratio and the investment-to-output ratio in our model are 0.66 and 0.13, respectively, which match the long-term features of the postwar US economy.

Besides, Table 3 exhibits unconditional correlations of key variables with output in the postwar US data and conditional correlations of those with output in the baseline model with multiple shocks.[24] The correlations of key variables with output conditional on the baseline model match with those in the data reasonably well. Moreover, as will be shown in the section of sensitivity analysis, with the consideration of varied price stickiness and entrepreneurs' attitude toward risk, our baseline models with some variations also match with those in the data. Therefore, our baseline model is capable of generating business cycle comovement in the US.

[24] The quarterly data are seasonally adjusted, expressed in logarithms, deflated by the GDP deflators, and detrended using the Hodrick-Prescott filter with a smoothing parameter of 1,600.

[Insert Table 3 here]

4. Effects of Positive Investment-Specific Technology News Shocks

This section studies the effects of an IST news shock. We analyze the effects of a positive IST news shock on the impulse responses of aggregate macro variables in the same way as Jaimovich and Rebelo (2009). The timing of the news shock is as follows. In period zero, the economy is in the steady state. In period one, a news shock arrives, wherein agents learn that there will be a one-standard-deviation increase in ξ_t beginning three periods later, namely, in period four.

To underscore the role of financial frictions and sticky prices, we first illustrate the impulse responses of the model without both sticky prices and financial frictions, which fails to generate consistent impulse responses of macro variables. Then, the model is followed by an otherwise identical model except adding sticky prices, and we will find that the model still fails to produce consistent impulse responses of macro variables. Finally, we study our baseline model, which is the model with both sticky prices and financial frictions, and we will show that the model creates consistent impulse responses of macro variables.

4.1 A Model without Sticky Prices and Financial Frictions

First, we envisage the impulse responses of aggregate variables in response to IST news shocks in a two-sector real-business-cycle (RBC) model without sticky prices and financial frictions.

Without sticky prices, $\vartheta_c=\vartheta_d=0$. Moreover, without financial frictions, the shadow prices of collaterals are zero, and thus, $\psi_{b,t}=\psi_{c,t}=\psi_{d,t}=0$. In order for the modified Euler equations to be consistent with $\psi_{b,t}=\psi_{c,t}=\psi_{d,t}=0$, it requires that $\beta_b=\beta_c=\beta_d=\beta_s=0.99$. We now carry out a positive news shock, wherein, in period one (or quarter one), agents learn that there will be a one-standard-deviation increase in the IST level beginning in period four. The impulse responses of aggregate variables are illustrated in Figure 1.

[Insert Figure 1 here]

It is clear from the figure that, in response to a positive IST news shock (cf. Panel L), consumption decreases (cf. Panel B), and real debts are not affected on impact (cf. Panel G). Moreover, the real price of capital (Tobin's Q) does not go down until quarter four when an IST news shock is realized (cf. Panel K). A decrease in real prices of capital in and after quarter four indicates that the real price of capital is inversely correlated with IST shocks. Thus, in response to a positive IST news shock, an otherwise standard two-sector RBC model without sticky prices and financial frictions fails to generate consistent impulse responses of macro variables.

4.2 The Model with Sticky Prices

Now, we proceed to analyze a model identical to that in Subsection 4.1 except allowing for sticky prices. Consequently, parameter values for $\psi_{b,t}$, $\psi_{c,t}$, $\psi_{d,t}$, β_b, β_c, β_d, and β_s in Subsection 4.1 still hold. Now, nondurable prices and durable prices are sticky with the coefficient of price adjustment being ϑ_c=235.57 and ϑ_d=1.233, respectively. This case degenerates to a two-sector version of the Khan and Tsoukalas (2012) model. The impulse responses are depicted in Figure 2.

[Insert Figure 2 here]

As seen from the figure, in response to a positive IST news shock (cf. Panel L), consumption still goes down (cf. Panel B), similar to Figure 1. Real debts remain unchanged on impact (cf. Panel G). Hence, in response to an IST news shock, the model with sticky prices without financial constraints still cannot produce consistent impulse responses.

4.3 The Baseline Model: Sticky Prices and Financial Constraints

Now, we turn to our baseline model, which is a two-sector model with sticky prices and financial constraints. That is, financial constraints are added into the model in Subsection 4.2. Hence, the parameter values ϑ_c=235.57 and ϑ_d=1.233 are the same as in Subsection 4.2. Financial constraints are binding for impatient households and entrepreneurs, such that β_s must be larger than β_b, β_c, and β_d. As a result, there are positive shadow prices of collaterals and thus, $\psi_{b,t}$>0, $\psi_{c,t}$>0, and $\psi_{d,t}$>0. The impulse responses are illustrated in Figure 3.

[Insert Figure 3 here]

Figure 3 indicates that a positive IST news shock increases all real variables on impact and thus, output, consumption, labor hours, investment, capital, and real wages all comove (cf. Panels A-F). In addition, real debts also go up (cf. Panel G). As a result of a positive news shock to the marginal efficiency of capital investment, Tobin's Q, and thus the real price of capital, goes down (cf. Panel K), which raises the demand for investment goods on impact (cf. Panel D). As durable prices are more flexible than nondurable prices, the relative price of durables, and thus the relative price of investment, increases (cf. Panel H). With binding borrowing constraints, the increase in the relative price of investment raises the value of assets. This increases the borrowing ability, which in turn leads to more capital investment for business. As a result, labor demand rises and output increases (cf. Panels A and C). As the wealth effect of relaxing the collateral constraint on consumption is larger than the intertemporal substitution effect, consumption goes up (cf. Panel B). Hence, a positive IST news shock causes the business cycle comovement.

In comparison with Figures 1 and 2, when incorporating financial frictions in Figure 3, in addition to comovement, the percentage fluctuations of all real variables are amplified. In particular, the responses of output and investment in Figure 3 are enlarged by the magnitude of about 33 and 7, respectively, as compared to Figure 2 of an identical model except financial frictions. Thus, there is the financial accelerator mechanism, indicating an amplification of shocks to the macroeconomy with financial frictions present, as in Bernanke et al. (1999), Gerali et al. (2010), and Gertler and Karadi (2011), among others.

To understand the reason for the comovement, we note that households' and entrepreneurs' collaterals are durables, which are primarily the value of houses and structures, and thus reflect the value of land. In response to IST news shocks, the demand for investment increases, which raises the relative price of investment goods, and thus, the relative price of durables. A higher durable price increases the value of households' and entrepreneurs' durables/houses, which in turn relaxes the collateral constraint. This creates a strong wealth effect, which dominates the intertemporal substitution effect that would otherwise reduce current consumption and increase future consumption. As a result, investment and consumption both increase on impact, and real aggregate variables comove.

We remark that a positive IST news shock increases the relative price of durables (i.e., the relative price of investment) in our model. Some may argue that the result is at odds with the data, as a branch of research indicated a countercyclical relative price of investment prior to the mid-1980s or 1990s (e.g., Fisher, 2006). However, recent literature suggests no robust evidence that this relative price is indeed countercyclical. For example, using three definitions of aggregate investment (total private investment, business investment, and household investment),[25] two measures of the price of consumption (the numéraire used to compute relative prices), and two subsample periods (1960-1983 and 1984-2013), Beaudry et al. (2015) found that the relative price of investment to consumption was procyclical over the post-1983 period and almost always significantly so for all the measures. Moreover, these authors established that the results are robust to the choice of the consumption deflators, and quality-adjusted investment price series with two from Cummins and Violante (2002) and one from Liu et al. (2011). They also showed that the relative price of investment was rarely countercyclical and never significantly so, when considering a longer sample, and that the result is held for the other G7 countries. Furthermore, Thomet and Wegmueller (2021) also found that the relationship between the relative price of investment and GDP is positive in Canada, France, Japan, the UK, and the US over the 1982Q3-2016Q4 period.

To facilitate comparison of whether the source of aggregate fluctuations is from IST news shocks or other shocks, we perform unconditional variance decompositions to each of the twelve orthogonal shocks in our baseline model, including news and non-news (contemporaneous) shocks to IST, to aggregate TFP, to two sectoral TFPs, to durables preference, and to labor supply.[26] Table 4 presents the unconditional variance decomposition of the aggregate variables accounted for by all these shocks in our baseline model. As seen from the table, IST news shocks account for over 50 percent of the fluctuations in all variables, and IST contemporaneous shocks account for about 30 percent of the fluctuations on average. However, each of the remaining shocks explains no more than 10 percent of the fluctuations at most. Table 4 indicates that news shocks to IST generate sizable effects not only on investment but also on consumption and labor

[25] Total private investment is the sum of business investment and household investment, with business investment being the sum of equipment, structures, and intellectual property rights, and household investment being the sum of residential and durables.

[26] We note that shocks to labor supply are equivalent to wage-markup shocks.

hours.[27] The results are in contrast to Schmitt-Grohé and Uribe (2012), who found that stationary news shocks to IST generate large effects on investment but very small effects on consumption and labor hours. Therefore, IST news shocks are a much more relevant source of uncertainty than IST contemporaneous shocks and other standard shocks in the baseline model as the forecast horizon approaches infinity.

[Insert Table 4 here]

The unconditional forecast error variance decomposition in Table 4 is constructed at an infinite forecast time horizon. In a recent paper, Sims (2016) has argued that the time horizon matters in decomposing the forecast error variance between news shocks and non-news shocks. Simulating the effects of fourteen news shocks and seven unanticipated shocks in the Schmitt-Grohé and Uribe (2012) model, Sims (2016) found that the variance shares due to news shocks for output, consumption, investment, and labor hours are small in the beginning but increase after news shocks are materialized.

In Table 5, we carry out the forecast error variance decomposition to the twelve shocks under concern at different forecast horizons. Different from Sims (2016), for all variables, the variance shares attributable to IST news shocks are in a majority for all periods. In particular, no matter whether news becomes realized or not, IST news shocks are always a dominant source of volatility for all forecast horizons in our baseline model.

[Insert Table 5 here]

5. Sensitivity Analysis

This section carries out sensitivity analysis for the results of our baseline model. Since we underline the role of sticky prices and financial constraints, firstly, we investigate the robustness of the results if nondurable prices are adjusted in less than seven quarters. Moreover, the durable price is less sticky in our baseline. It is interesting to see the robustness of the results if durable prices become stickier. Besides, the baseline model does not separate the role of financial constraints on households from that of financial constraints on entrepreneurs, and thus it is appealing to distinguish their roles in this section. Furthermore, entrepreneurs are assumed to be risk averse in the baseline model, and thus it is interesting to understand the robustness of the results if entrepreneurs are risk neutral. Finally, TFP news shocks will also be explored. This section carries out these sensitivity analyses.

5.1 Price Stickiness of Nondurables

In our baseline estimation, the frequency of nondurable price adjustments is over seven quarters.

[27] We note the work by Guerrieri et al. (2014), which resolved the comovement problem by studying multi-factor productivity (MFP) shocks to a machinery sector in a two-sector model with the extension of Greenwood et al. (1997). The shocks to the TFP in the durables sector in our model act like MFP shocks in the machinery sector in Guerrieri et al. (2014). However, based on our Bayesian estimation, the sectoral TFP news and non-news shocks in the durables sector only account for 7 percent of the fluctuations in output, and thus, are not the main source of volatility.

Justiniano et al. (2010) and Görtz and Tsoukalas (2017) estimated the price-stickiness of consumption goods at over six and five quarters, with the probability of not resetting prices being 0.84 and 0.82, respectively. This subsection examines the sensitivity of our baseline results when nondurable prices are less sticky. Our estimation adjusts the probability of resetting nondurable prices, $1\text{-}\theta_c$=0.13, to pin down ϑ_c=235.57. To see how the result changes when nondurable prices are less sticky, we increase the probability of resetting nondurable prices, and thus lower the cost of nondurable price adjustments, ϑ_c. We envisage the impulse responses, when the probability of resetting nondurable prices increases from 0.13 to 0.17 and then to 0.2, which implies that the nondurable consumption price is reset more frequently from every seven quarters to every six quarters and then to every five quarters, respectively, with the corresponding adjustment cost parameter value of ϑ_c being decreased from 235.57 to 142.80 and then to 96.15, respectively. The impulse responses are displayed in Figure 4.

[Insert Figure 4 here]

With less sticky nondurable prices, more firms raise nondurable prices in response to a positive IST news shock. Then, the durable price relative to the nondurable price does not increase as much as the baseline model on impact (cf. Panel H), so the real debt is less influenced by collateral prices on impact (cf. Panel G). Therefore, the collateral effect becomes weaker, and real aggregate variables also rise by less.

The simulation indicates that our results of comovement are robust as long as the frequency of nondurable price adjustment is higher than four quarters, which lies within the range of the estimates in the literature.

5.2 Price Stickiness of Durables

In our baseline estimation, durable prices are more flexible than nondurable prices. This subsection shows that, if durable prices become stickier, an IST news shock can still generate comovement. Our estimation results in the probability of resetting durable prices, $1\text{-}\theta_d$=0.83, so ϑ_d=1.233. To see how the result changes when durable prices are stickier, we decrease the probability of resetting durable prices and thus raise the cost of durable price adjustments, ϑ_d. We scrutinize the impulse responses of aggregate variables, when the probability of resetting durable prices decreases from 0.83 to 0.33 and then to 0.25, which implies that durable prices are reset less frequently from every 1.2 quarters to every 3 quarters and then to every 4 quarter, respectively, with the corresponding adjustment cost parameter value of ϑ_d being increased from 1.233 to 29.48 and then to 58.25, respectively. The impulse responses are in Figure 5.

[Insert Figure 5 here]

Figure 5 indicates that, with nondurable prices being reset every seven quarters, real aggregates comove when durable prices are reset every three and four quarters. With stickier durable prices, less firms raise durable prices in response to a positive IST news shock. Although on impact, the relative price of durables does not increase as much as the baseline model (cf. Panel H), real aggregate variables still comove. Our simulation result indicates that the comovement is robust as long as the frequency of the durable price adjustment is lower than five quarters, which is within the range of the estimates in the literature.

5.3 Collateral Constraints: Households vs. Entrepreneurs

This subsection differentiates the role played by households' collateral constraints from the role played by entrepreneurs' collateral constraints. We start by the case of an otherwise identical baseline model except removing households' collateral constraints, followed by the case of an otherwise identical baseline model where entrepreneurs' collateral constraints are taken away. The impulse responses are exhibited in Figure 6, wherein the impulse responses of the baseline model are also illustrated.

[Insert Figure 6 here]

First, when households' collateral constraints are not binding, output, consumption, labor hours, investment, real wages, and real debts still rise and comove on impact, but the responses of all variables are mitigated (cf. green dashed lines). However, when entrepreneurs' collateral constraints are not binding, with binding households' collateral constraints, real variables either are not affected or are increased only slightly on impact (cf. red long-dashed lines). In particular, the relative price of investment just slightly goes up (cf. Panel H). Then, entrepreneurs cannot raise their funding via relaxing the collateral constraint (borrowing capacity, cf. Panel G), in order to meet the increase in the demand for investment in capital before positive IST news being realized in the fourth quarter (cf. Panels D and E).

In summary, entrepreneurs' collateral constraints play a crucial role in driving the comovement of real variables in response to an IST news shock, while households' collateral constraints play only a minor role.

5.4 Risk Neutral Entrepreneurs

Finally, we have discovered that, along with sticky prices, it is the entrepreneurial collateral constraint that is crucial. The result is obtained when entrepreneurs are also assumed to be risk averse, as in Iacoviello (2005). It may be interesting to understand what role entrepreneur's risk aversion plays in generating the comovement. To see this, we examine the alternative case when entrepreneurs are risk neutral, which has been used by the financial-contract (agency-cost) literature (cf. Bernanke et al., 1999). Suppose that the model is otherwise identical to our baseline model, except that the entrepreneur's utility is linear in the index of composite consumption as follows.

$$E_0 \sum_{t=0}^{\infty} (\beta_j)^t X_{j,t}, \quad \text{where } \beta_j \leq \beta_s, j=c, d.$$

Figure 7 compares the impulse responses to IST news shocks in our baseline model with those in the otherwise identical model when entrepreneurs are risk neutral. As is clear, the comovement of real aggregate variables still holds true (cf. red dashed lines), despite the smaller amplitudes of all variables than the baseline model.

[Insert Figure 7 here]

5.5 TFP News Shocks

So far, we have focused on IST news shocks. Based on variance decompositions, IST news shocks account for a majority of business cycle fluctuations. Although only about 10 percent of the fluctuations in output are driven by aggregate TFP news shocks, it is also worthwhile to check if TFP news shocks can cause comovement in our baseline model. As reported in Figure 8, in response to a positive aggregate TFP news shock, the relative price of investment increases (cf. Panel H).

With binding collateral constraints, the increase in the relative price of investment raises the value of assets. Then the borrowing capacity is improved (cf. Panel G), which in turn leads to more investment for business (cf. Panel D). As a result, labor demand rises and output increases (cf. Panels A and C). As the wealth effect of relaxing the collateral constraint on consumption is larger than the intertemporal substitution effect, consumption goes up (cf. Panel B). Hence, a positive TFP news shock causes the business cycle comovement. Therefore, our mechanism applies to not only IST news shocks but also TFP news shocks.

[Insert Figure 8 here]

6. Conclusion

Recent research in DSGE models and VAR models has suggested that the most important drivers of business cycle fluctuations are unanticipated IST shocks, not traditional unanticipated TFP and other shocks. Moreover, in VAR models, research has also empirically identified IST news shocks as a significant driving force behind the U.S. business cycle. However, in one-sector DSGE models, research has found that IST news shocks do not produce comovement of real aggregate variables with the share of the forecast error variance explained by IST news shocks being very small in a flexible-price model and essentially zero in a sticky-price model. This paper studies the effects of IST news shocks on business cycles in a two-sector sticky-price DSGE model with consumer durables and collateral constraints.

We found that positive IST news shocks increase output, labor hours, investment, and consumption on impact, and thus, generate comovement of variables in our model. By contrast, positive IST news shocks do not affect real variables on impact in an otherwise identical model except sticky prices and collateral constraints, and positive IST news shocks decrease consumption in an otherwise identical model except collateral constraints. Our variance decomposition indicates that IST news shocks are a more relevant source of uncertainty than IST non-news shocks and other shocks. Different from existing DSGE models with flexible prices, our model produces comovement of aggregate variables in response to IST news shocks without relying on variable capital utilization as well as small wealth effects on the labor supply.

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Table 1. Prior densities and posterior estimates in the baseline model

Parameter	Description	Prior distribution			Posterior distribution			
		Distr.	Mean	St. Dev.	Mode	Mean	10 percent	90 percent
θ_c	Calvo probability of nondurable-sector prices	Beta	0.80	0.10	0.8685	0.8709	0.8691	0.8729
θ_d	Calvo probability of durable-sector prices	Beta	0.20	0.10	0.1702	0.1707	0.1687	0.1730
φ_c	Investment adjustment cost in nondurable sector	Gamma	8.00	1.00	9.9877	9.9692	9.9531	9.9824
φ_d	Investment adjustment cost in durable sector	Gamma	8.00	1.00	7.2426	7.2624	7.2363	7.2854
Shocks: Persistence								
ρ_I	IST	Beta	0.60	0.20	0.4644	0.4610	0.4515	0.4689
ρ_A	Aggregate TFP	Beta	0.60	0.20	0.6092	0.6052	0.6033	0.6071
ρ_{Ac}	TFP in nondurable sector	Beta	0.50	0.20	0.5924	0.5989	0.5922	0.6036
ρ_{Ad}	TFP in durable sector	Beta	0.50	0.20	0.9948	0.9958	0.9939	0.9974
ρ_μ	Preference	Beta	0.60	0.20	0.5895	0.5857	0.5828	0.5883
ρ_ω	Labor supply	Beta	0.60	0.20	0.9929	0.9911	0.9868	0.9962
Contemporaneous Shocks: Volatilities								
σ_I	IST	Invgamma	0.005	2.00	0.3248	0.3175	0.2996	0.3339
σ_A	Aggregate TFP	Invgamma	0.005	2.00	0.0560	0.0567	0.0547	0.0591
σ_{Ac}	TFP in nondurable sector	Invgamma	0.005	2.00	0.0119	0.0132	0.0118	0.0142
σ_{Ad}	TFP in durable sector	Invgamma	0.005	2.00	0.0127	0.0121	0.0106	0.0129
σ_μ	Preference	Invgamma	0.005	2.00	0.0390	0.0461	0.0411	0.0509
σ_ω	Labor supply	Invgamma	0.005	2.00	0.0023	0.0025	0.0015	0.0036
News Shocks: Volatilities								
σ_{Iv}	IST	Invgamma	0.005	2.00	0.3550	0.3450	0.3277	0.3713
σ_{Av}	Aggregate TFP	Invgamma	0.005	2.00	0.0648	0.0665	0.0644	0.0692
σ_{Acv}	TFP in nondurable sector	Invgamma	0.005	2.00	0.0018	0.0020	0.0013	0.0029
σ_{Adv}	TFP in durable sector	Invgamma	0.005	2.00	0.0017	0.0020	0.0012	0.0027
$\sigma_{\mu v}$	Preference	Invgamma	0.005	2.00	0.0231	0.0059	0.0015	0.0121
$\sigma_{\omega v}$	Labor supply	Invgamma	0.005	2.00	0.0080	0.0083	0.0075	0.0089

Note: The posterior distribution is obtained using the Metropolis-Hastings algorithm.

Table 2. Baseline parameter values (frequency: quarters)

Description	Parameter	
elasticity of substitution between nondurables and durables	η	1
elasticity of substitution for nondurable/durable goods	ε_c, ε_d	6
steady-state share of durables in the composite consumption index	μ	0.2
inverse of elasticity of labor supply of patient/impatient households	ϕ_s, ϕ_b	1
discount factor of patient households	β_s	0.99
discount factor of impatient households	β_b	0.98
discount factor of entrepreneurs in nondurable/durable sector	β_c, β_d	0.98
capital share of the nondurable sector	α_c	0.47
capital share of the durable sector	α_d	0.27
depreciation rate of consumer durables and capital	δ	0.025
hours worked of patient or impatient households	L_s, L_b	0.3
borrowers' loan-to-value ratio	m_b	0.77
entrepreneurs' loan-to-value ratio in nondurable/durables sector	m_c, m_d	0.80
coefficient of inflation rate for Taylor rule	χ	1.5
parameter of labor in utility for patient households	v_s	5.2494
parameter of labor in utility for impatient households	v_b	10.842

Table 3. Correlations with output

	Data (1947Q1-2020Q1)	Baseline model	Baseline models with some variations		
			with 4-quarter stickiness of durable prices	with 6-quarter stickiness of nondurable prices	with risk neutral entrepreneurs
Output	1	1	1	1	1
Consumption	0.83	0.84	0.94	0.74	0.71
Hours	0.64	0.79	0.86	0.64	0.70
Investment	0.69	0.49	0.57	0.42	0.56
Real wage	0.89	0.91	0.96	0.84	0.97

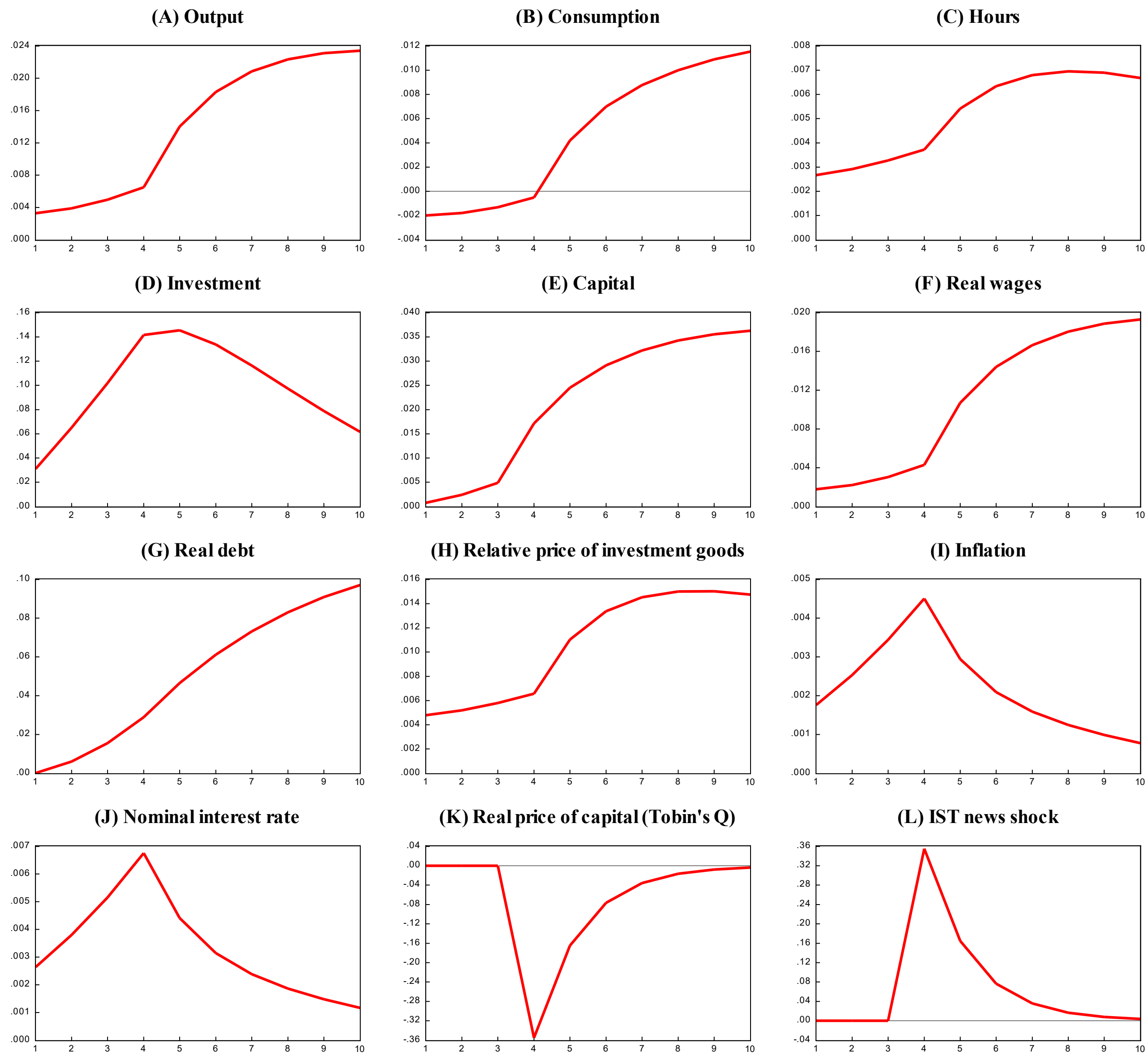
Table 4. Unconditional variance decomposition in the baseline model (%)

	IST shock		Aggregate TFP shock		TFP shock in C-sector		TFP shock in D-sector		Durables preference shock		Labor supply shock	
	News	Non-news	News	Non-news	News	Non-news	News	Non-news	News	Non-news	News	Non-news
Output	51.42	27.10	9.97	2.96	0.01	0.03	0.15	7.22	0.02	0.11	0.93	0.08
Consumption	57.62	34.00	2.44	0.77	0.01	0.06	0.09	4.49	0.04	0.23	0.23	0.02
Hours	58.91	33.13	2.12	0.56	0.01	0.23	0.08	2.35	0.04	0.21	2.19	0.18
Investment	63.76	28.58	0.68	1.52	0.00	0.07	0.10	5.04	0.03	0.12	0.10	0.01
Real wage	60.42	32.23	2.55	0.59	0.01	0.10	0.09	3.86	0.03	0.11	0.01	0.00
Real debt	57.59	34.51	1.53	1.17	0.01	0.07	0.10	4.76	0.03	0.08	0.15	0.01
Relative price of investment goods	60.95	27.99	1.05	1.44	0.00	0.08	0.16	8.19	0.03	0.11	0.01	0.00
Inflation	63.37	30.09	1.10	2.15	0.00	0.17	0.07	2.87	0.03	0.14	0.01	0.00
Nominal interest rate	63.37	30.09	1.10	2.15	0.00	0.17	0.07	2.87	0.03	0.14	0.01	0.00

Table 5. Conditional variance decomposition in the baseline model (%)

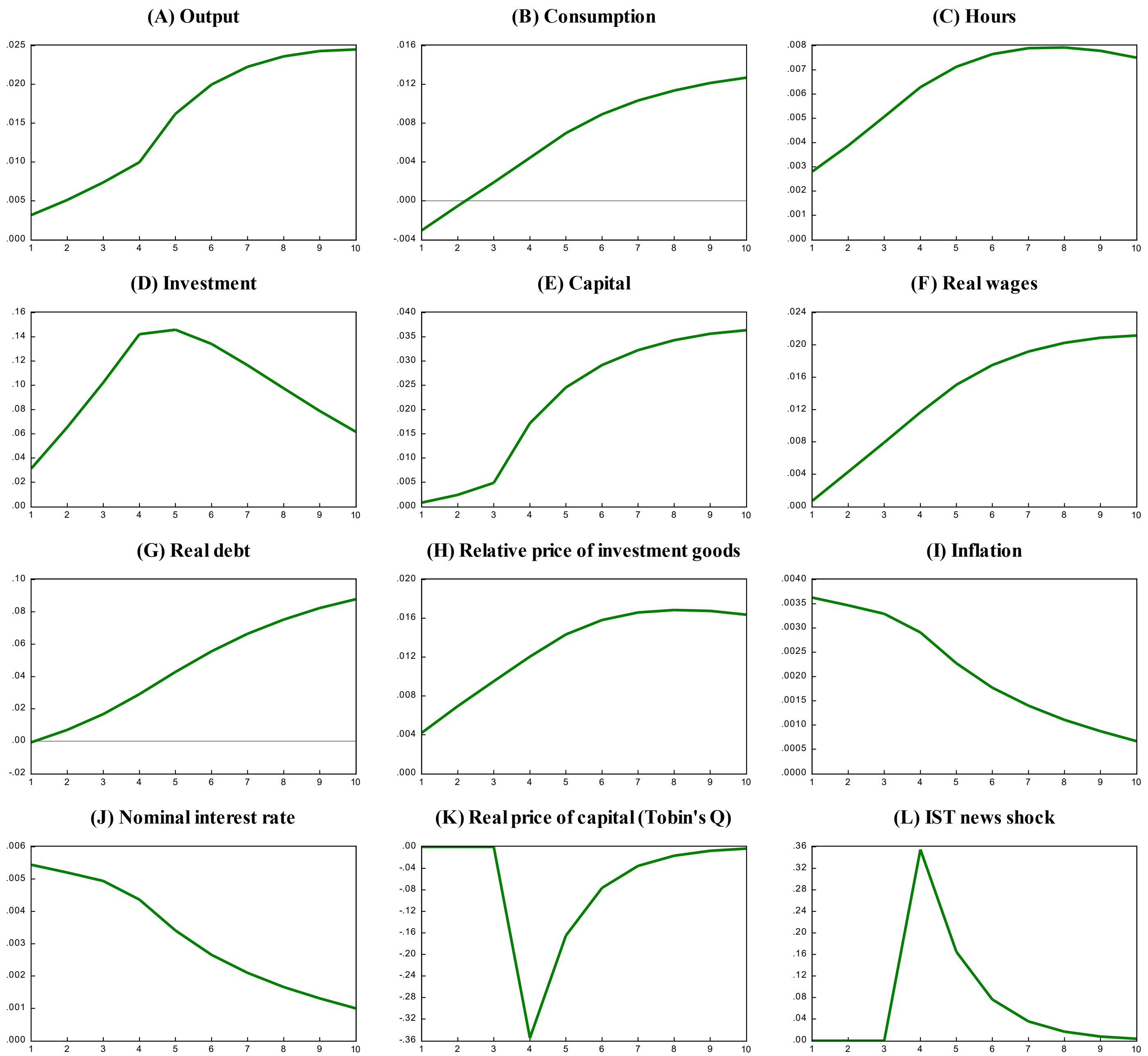
		Forecast Horizon										
	Shock	1	2	3	4	5	6	7	8	16	32	∞
Output	IST news	50.36	52.62	54.33	50.14	50.57	51.71	52.78	53.61	55.18	54.74	51.42
	IST non-news	32.72	34.62	35.22	31.49	30.45	30.03	29.81	29.65	29.22	28.85	27.10
	others	16.92	12.76	10.45	18.37	18.98	18.26	17.41	16.74	15.60	16.41	21.48
Consumption	IST news	55.45	55.84	56.53	57.37	57.96	58.33	58.54	58.65	58.73	58.70	57.62
	IST non-news	37.56	37.24	36.65	35.94	35.46	35.17	35.01	34.92	34.83	34.63	34.00
	others	6.99	6.92	6.82	6.69	6.58	6.50	6.45	6.43	6.44	6.67	8.38
Hours	IST news	57.00	57.63	58.49	59.11	59.65	59.98	60.14	60.19	60.03	59.79	58.91
	IST non-news	37.60	37.07	36.33	35.26	34.66	34.33	34.17	34.09	33.92	33.65	33.13
	others	5.40	5.30	5.18	5.63	5.69	5.69	5.69	5.72	6.05	6.56	7.96
Investment	IST news	52.89	56.68	60.54	64.36	66.67	67.81	68.03	67.55	64.27	64.68	63.76
	IST non-news	43.63	40.13	36.57	33.01	30.80	29.60	29.13	29.20	30.00	29.05	28.58
	others	3.48	3.19	2.89	2.63	2.53	2.59	2.84	3.25	5.73	6.27	7.66
Real wage	IST news	56.18	56.77	57.70	58.69	59.56	60.21	60.67	60.98	61.36	61.29	60.42
	IST non-news	37.44	36.88	36.07	35.03	34.29	33.79	33.46	33.24	32.94	32.69	32.23
	others	6.38	6.35	6.23	6.28	6.15	6.00	5.87	5.78	5.70	6.02	7.35
Real debt	IST news	54.72	54.32	54.36	55.41	56.39	57.11	57.63	57.98	58.51	58.50	57.59
	IST non-news	38.05	38.54	38.60	37.79	37.03	36.46	36.06	35.78	35.33	35.05	34.51
	others	7.23	7.14	7.04	6.80	6.58	6.43	6.31	6.24	6.16	6.45	7.90
Relative price of investment goods	IST news	56.14	57.02	58.16	59.43	60.53	61.36	61.97	62.38	62.87	62.78	60.95
	IST non-news	35.30	34.54	33.57	32.52	31.66	30.99	30.48	30.08	29.05	28.83	27.99
	others	8.56	8.44	8.27	8.05	7.81	7.65	7.55	7.54	8.08	8.39	11.06
Inflation	IST news	60.71	61.84	62.51	62.68	62.59	62.45	62.36	62.34	63.20	63.36	63.37
	IST non-news	32.69	31.75	31.08	30.69	30.60	30.64	30.71	30.74	30.25	30.12	30.09
	others	6.60	6.41	6.41	6.63	6.81	6.91	6.93	6.92	6.55	6.52	6.54
Nominal interest rate	IST news	60.71	61.84	62.51	62.68	62.59	62.45	62.36	62.34	63.20	63.36	63.37
	IST non-news	32.69	31.75	31.08	30.69	30.60	30.64	30.71	30.74	30.25	30.12	30.09
	others	6.60	6.41	6.41	6.63	6.81	6.91	6.93	6.92	6.55	6.52	6.54

Note: Other shocks include contemporaneous (non-news) and news shocks from aggregate TFP, two sectoral TFPs, durables preference, and labor supply. The column labeled "∞" corresponds to the unconditional variance share. The column corresponding to forecast horizon 4 means news shocks become realized.



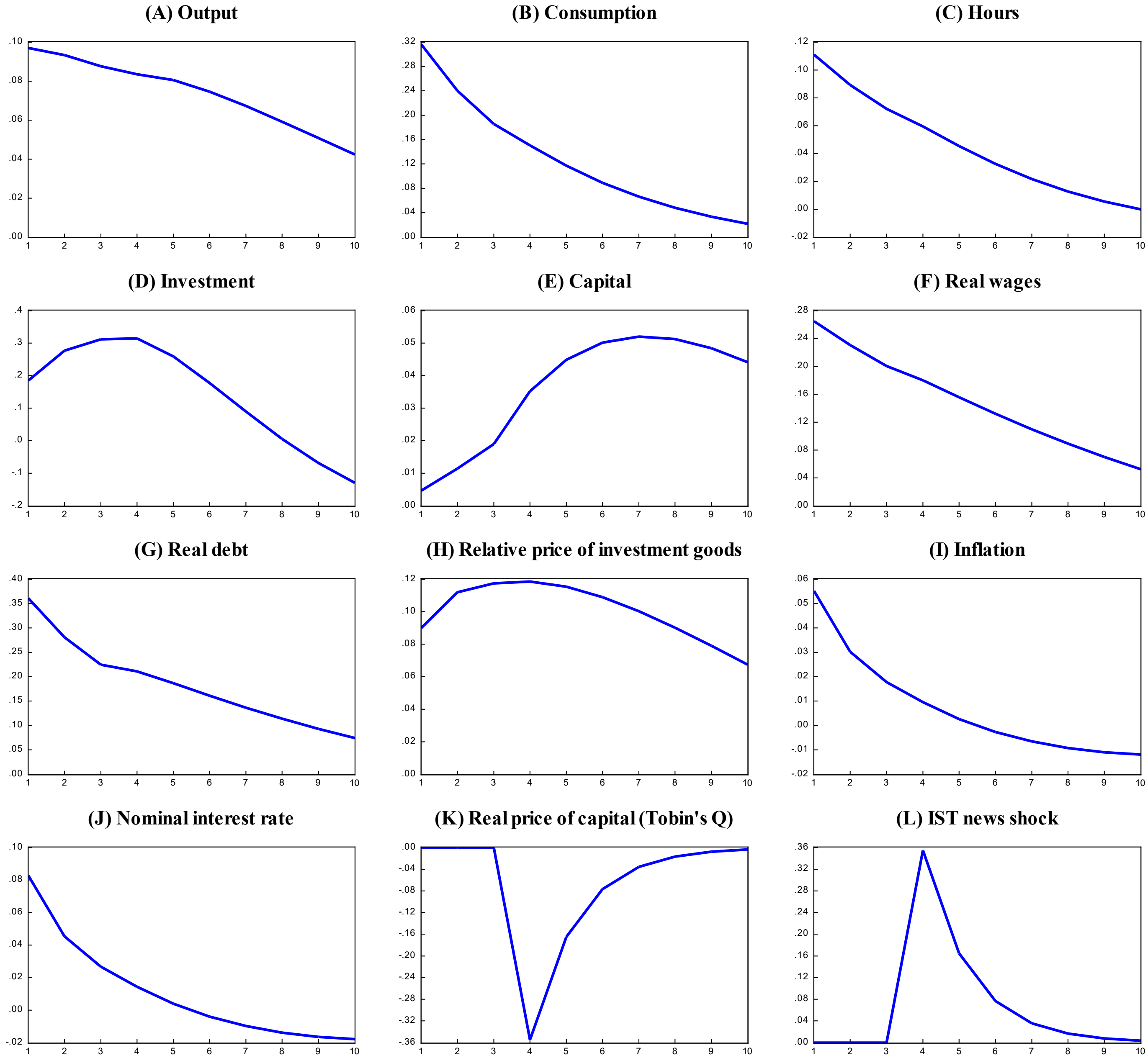
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 1. Impulse responses to a positive IST news shock in a model without sticky prices and financial frictions



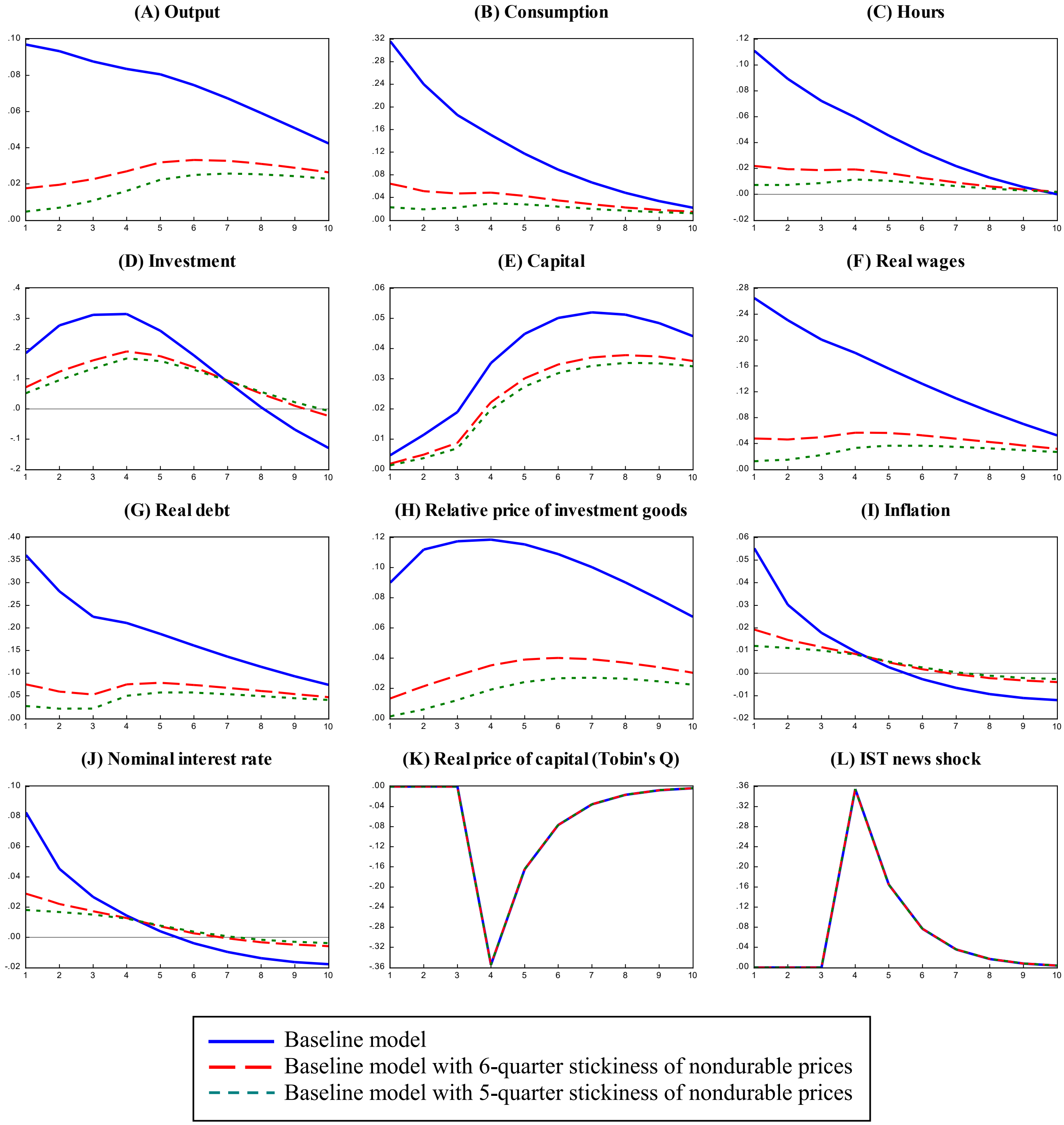
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 2. Impulse responses to a positive IST news shock in a model, which adds sticky prices into the model in Figure 1.



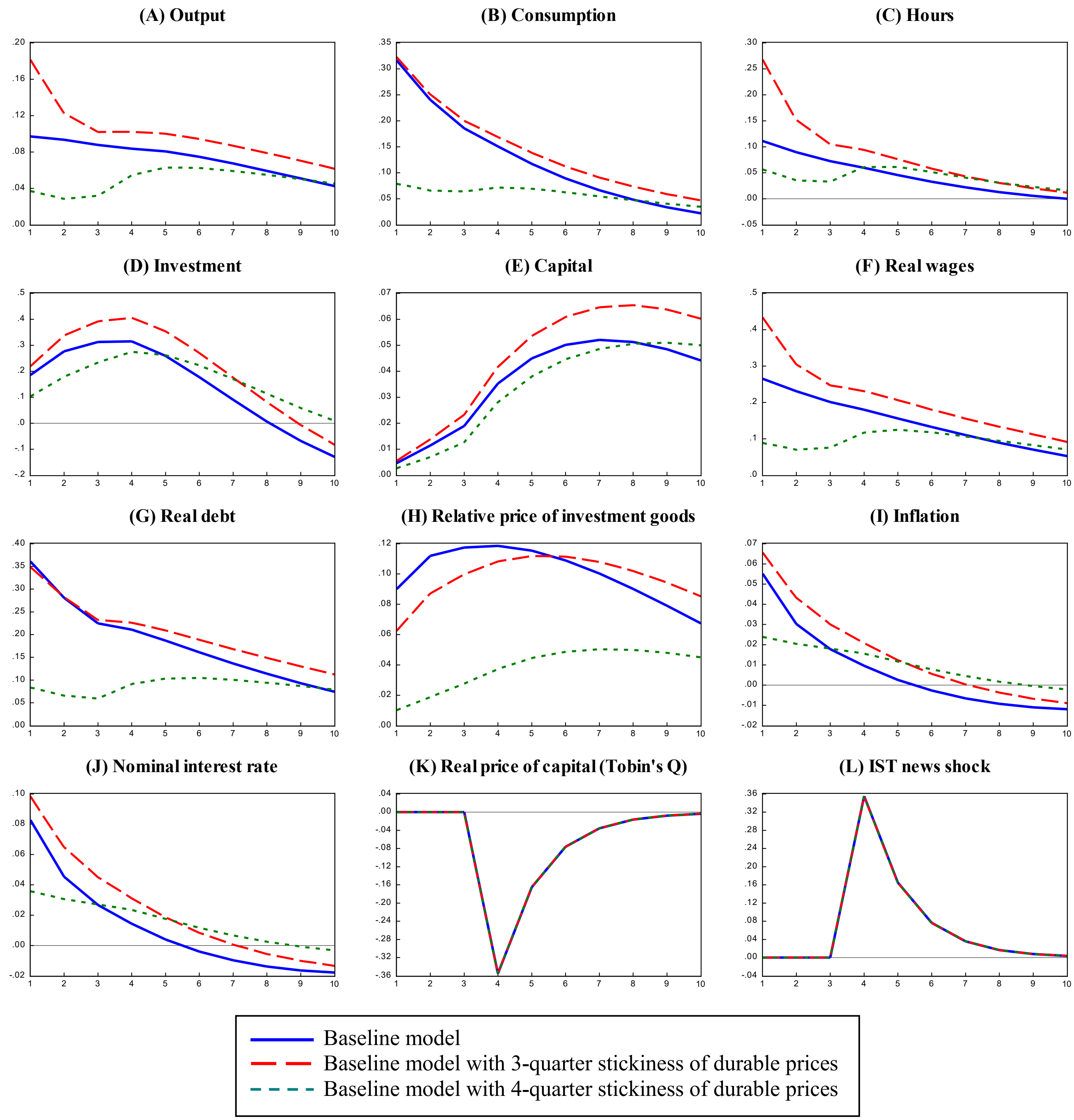
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 3. Impulse responses to a positive IST news shock in the baseline model, which adds financial constraints into the model in Figure 2.



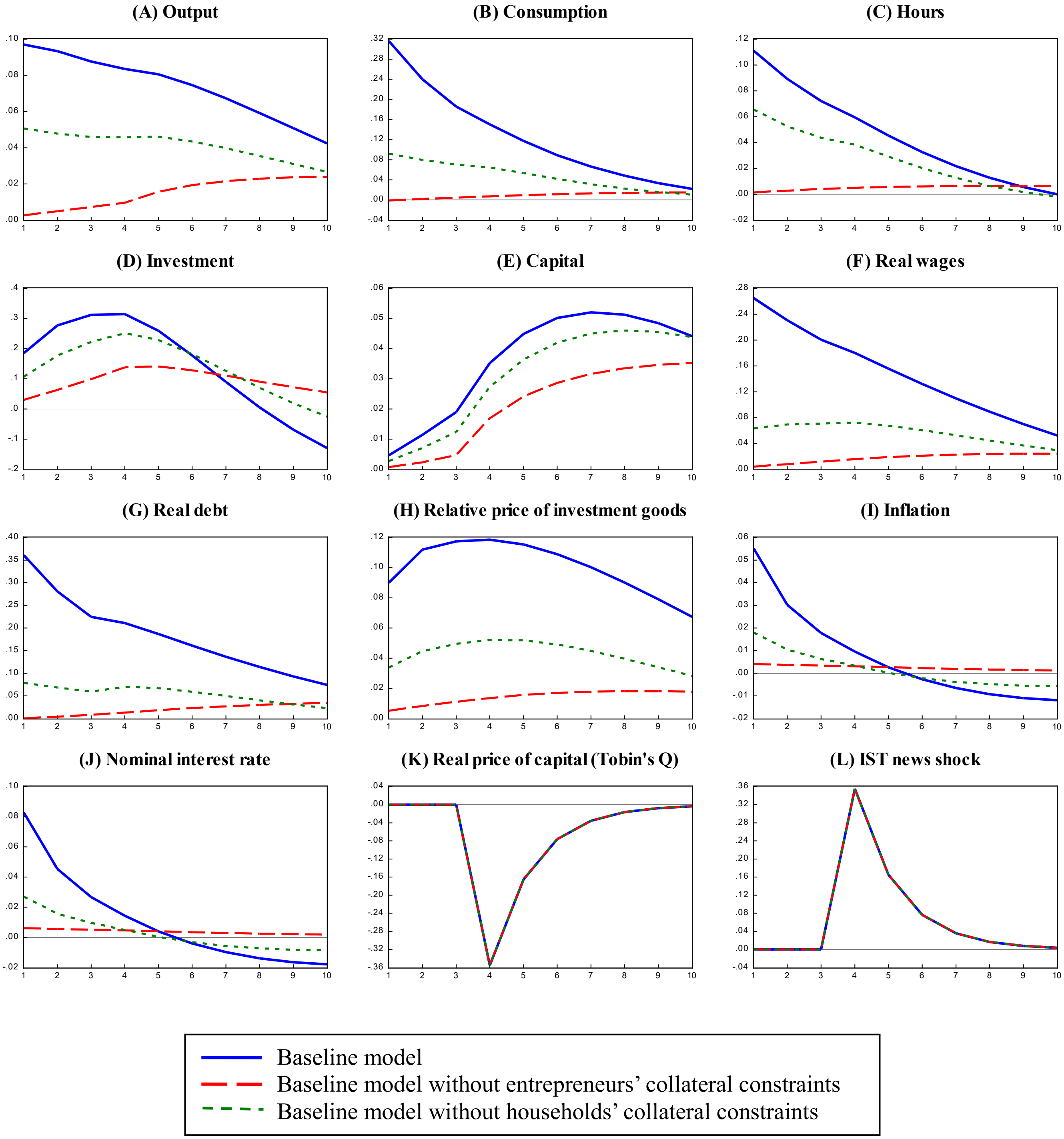
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 4. Sensitivity: impulse responses to a positive IST news shock in the baseline model and otherwise identical models except for varied degrees of nondurable price stickiness.



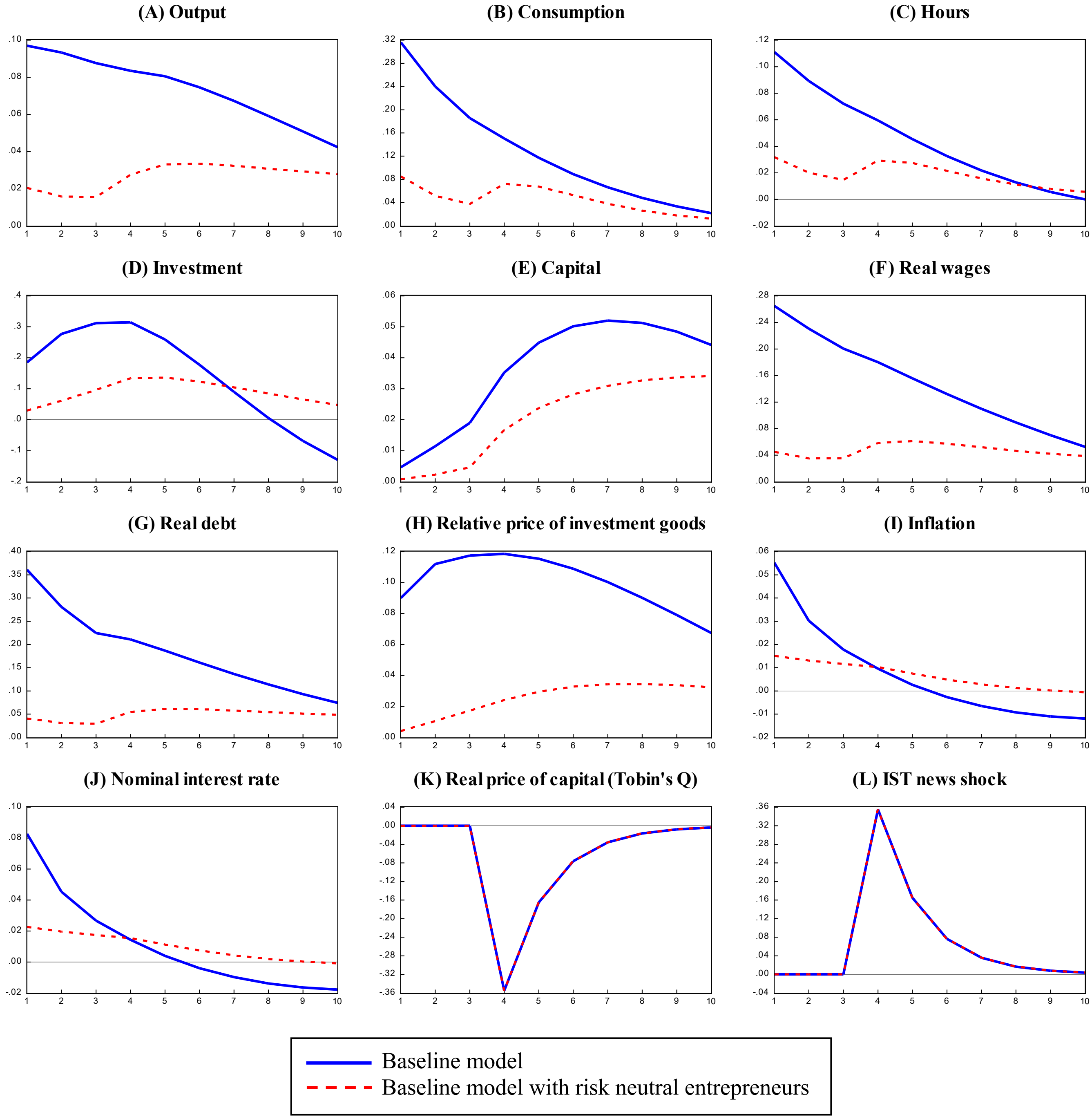
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 5. Sensitivity: impulse responses to a positive IST news shock in the baseline model and those with varied degrees of durable price stickiness.



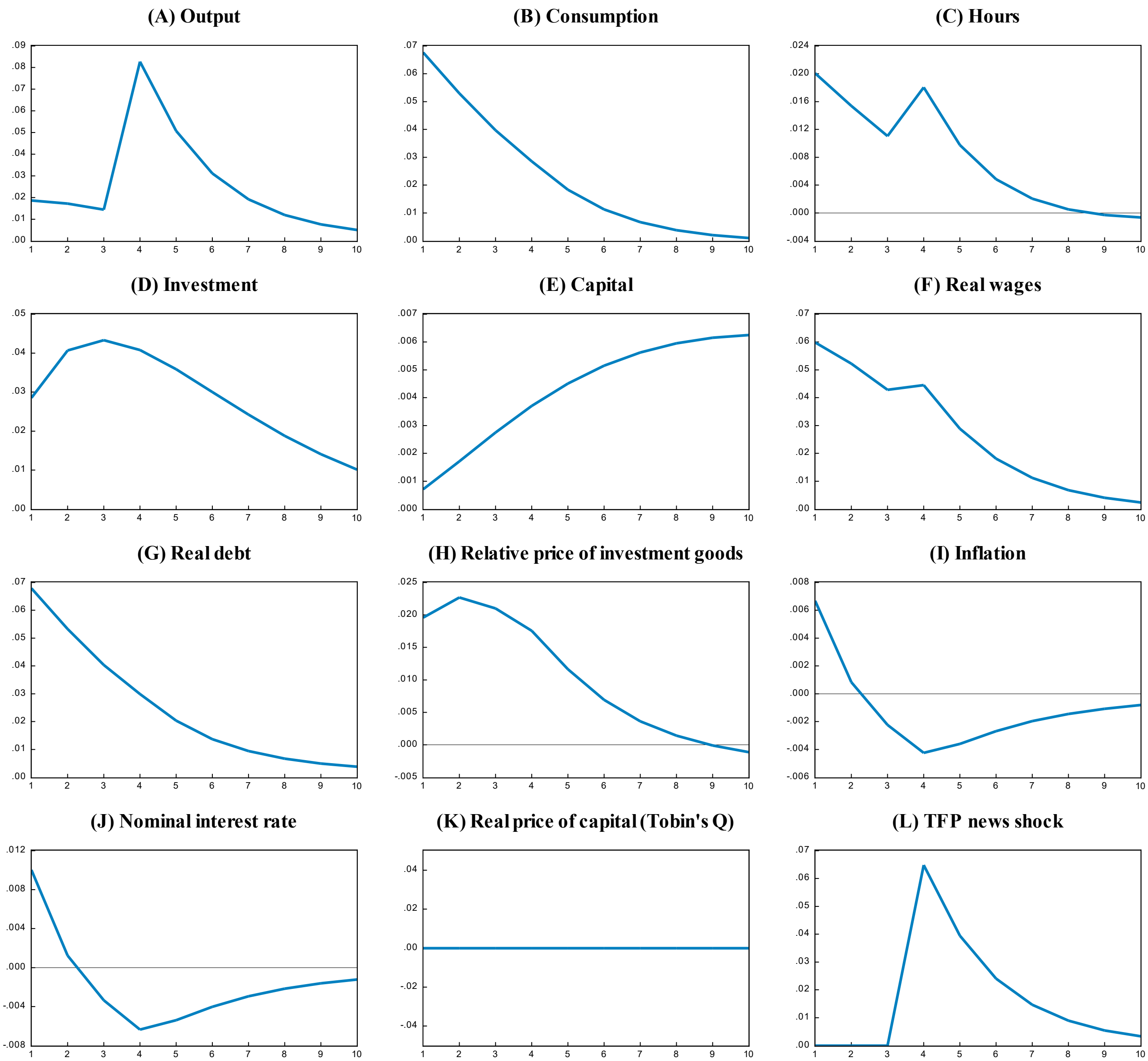
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 6. Sensitivity: impulse responses to a positive IST news shock in the baseline model and otherwise identical models without households' or entrepreneurs' collateral constraints.



Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 7. Sensitivity: impulse responses to a positive IST news shock in the baseline model and the otherwise identical model when entrepreneurs are risk neutral.



Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for k_{t+1}, so the value of k_2 is in period 1.

Figure 8. Impulse responses to a positive aggregate TFP news shock in the baseline model