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 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. In an estimated DSGE model with sticky prices and wages, Christiano et al. (2014) emphasized borrowers' credit frictions and found an empirical role for news shocks in the riskiness of the entrepreneur.[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

[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) envisaged risk shocks to the marginal efficiency when converting raw capital into effective capital, but they understood that it is difficult to distinguish risk shocks from IST shocks when converting investment into installed capital, an issue studied by Justiniano et al. (2010). Using a baseline model, Christiano et al. (2014) 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, 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.

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 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 seventeen 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, to labor supply, to monetary policy, and to two sectoral price markups. We carry out variance decompositions to each of the eighteen 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 output, consumption, investment, and real wages, followed by non-news shocks to IST that account for about 25 percent of the fluctuations, while each of the remaining 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 eighteen shocks at different forecast horizons. In comparison with Sims (2016)'s results, for all variables, the variance shares attributable to IST news shocks are in a majority for the periods after news

[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.

shocks are realized.

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 response to IST news shocks, even if there are no 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 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 on 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.

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 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.

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[7] Investment adjustment costs play a role to reconcile boom-bust cycles in response to IST news shocks in our baseline model, with or without a boom-bust cycle when there is not or there is an investment adjustment cost.

[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. 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.

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 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

[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.

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 groups: patient and impatient. Patient households have the lowest time preference rate and are savers. 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 groups 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

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

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 ($\mathcal{N}(0,\ \sigma_\mu^2)$).[15] The term $v_{\mu,t-\tau}$ is a preference news shock to durables, which provides τ-period-ahead news about an expected shift in future preferences. The news shock $v_{\mu,t-\tau}$ is *i.i.d.* with $\mathcal{N}(0,\ \sigma_{\mu v}^2)$ and uncorrelated with the contemporaneous innovation $e_{\mu,t}$. We

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

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 available in t.[16] The discount factor is $\beta_b \in (0, 1)$, which is smaller than patient households' discount factor, $\beta_s \in (0, 1)$. 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 groups 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

[16] Like Monacelli (2009) and Chen and Liao (2014) with two groups 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 which nests the two classes of utility functions characterized in King et al. (1988) and Greenwood et al. (1988).

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

where $\pi_{d,t} \equiv P_{d,t}/P_{d,t\text{-}1}$, 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 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 one more unit of 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. A higher $\psi_{b,t}$ 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 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 assembles 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.

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

where $\varepsilon_{j,t}>1$ is the time-varying elasticity of substitution between intermediates in sector j, and $\varepsilon_{j,t}/(\varepsilon_{j,t}-1) =$

$1+\epsilon_{j,t}$, where $\epsilon_{j,t}$ is a shock to price markup, which is assumed to follow an AR(1) process given by

$$\ln(1+\epsilon_{j,t}) = (1-\rho_{pj})\ln(1+\epsilon_j) + \rho_{pj}\ln(1+\epsilon_{j,t-1}) + e_{pj,t} + v_{pj,t-\tau},\ \ j=c,\ d,$$

where $\epsilon_j = 1/(\varepsilon_j - 1)$ is the steady-state value. The parameter $\rho_{pj} \in (0, 1)$ measures the persistence of shocks. The innovations $e_{pj,t}$ and $v_{pj,t-\tau}$ are the contemporaneous and news shocks, which are assumed to be uncorrelated and *i.i.d.* with $\mathcal{N}(0, \sigma_{pj}^2)$ and $\mathcal{N}(0, \sigma_{pjv}^2)$, respectively.

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.

$$Y_{j,t}(z) = \left(\tfrac{P_{j,t}(z)}{P_{j,t}}\right)^{-\varepsilon_{j,t}} Y_{j,t}, \quad z \in [0, 1], \quad j=c, d, \tag{4}$$

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 $P_{j,t} = [\int_0^1 (P_{j,t}(z))^{1-\varepsilon_{j,t}} dz]^{1/(1-\varepsilon_{j,t})}$, $j=c, d$.

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.

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

where $K_{j,t}$ and $L_{j,t}$ 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 kinds of TFPs are assumed to follow AR(1) processes given by

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

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

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 $v_{A,t-\tau}$ and $v_{Aj,t-\tau}$ are the news shocks, which are assumed to be *i.i.d.* with $\mathcal{N}(0, \sigma_{Av}^2)$ and $\mathcal{N}(0, \sigma_{Ajv}^2)$, 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 the price $P_{j,t}(z)$.

As a consumer, an entrepreneur's expected lifetime utility is $E_0 \sum_{t=0}^{\infty} (\beta_j)^t \ln X_{j,t}$,[17] 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

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

where $P_{j,t}/P_{j,t}^{W}(z)$ is the price 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

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

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.[18] 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 $\mathcal{N}(0, \sigma_{Iv}^2)$. 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

[17] 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.
[18] 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).
[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).

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 confronts 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 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.

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

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 higher 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

$$MU_{j,t}^C = \lambda_{j,t}, \tag{6a}$$

$$\frac{P^W_{j,t}(z)}{P_{c,t}} MP^L_{j,t} = w_t, \tag{6b}$$

$$\frac{MU^D_{j,t}}{MU^C_{j,t}} = p_t - \beta_j(1-\delta)E_t\left(\frac{MU^C_{j,t+1}}{MU^C_{j,t}} p_{t+1}\right) - m_j(1-\delta)\psi_{j,t} p_t E_t(\pi_{d,t+1}), \tag{6c}$$

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

$$p_t q_{j,t} = \beta_j E_t\left[MU^C_{j,t+1} \frac{P^W_{j,t+1}(z)}{P_{c,t+1}} MP^K_{j,t+1} + p_{t+1}q_{j,t+1}(1-\delta)\right] + m_j(1-\delta)MU^C_{j,t}\psi_{j,t}E_t[p_{t+1}\pi_{c,t+1}], \tag{6e}$$

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

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, $\frac{q_{j,t}}{\lambda_{j,t}}$. 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 level, which is the real price of 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 signifies 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

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

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

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

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

$$\tilde{\pi}_{j,t} = \frac{\varepsilon_{j,t} - 1}{\vartheta_j} \tilde{\kappa}_{j,t} + \beta_s E_t(\tilde{\pi}_{j,t+1}), \quad (8)$$

where $\kappa_{j,t} \equiv P_{j,t}{}^W/P_{j,t}$ is the real marginal cost. 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 price markup $P_j/P_j{}^W=\varepsilon_j/(\varepsilon_j-1)$ is a constant.

2.5 Equilibrium

In equilibrium, nondurable and durable final goods markets clear.

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

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

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.

$$K_t = K_{c,t} + K_{d,t}, \quad (10a)$$

$$L_{c,t} + L_{d,t} = L_{s,t} + L_{b,t}. \quad (10b)$$

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

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

$$\frac{R_t}{R} = (\frac{R_{t-1}}{R})^{\rho_R} [(\frac{\pi_t}{\pi})^{\phi_\pi} (\frac{Y_t}{Y})^{\phi_Y}]^{1-\rho_R} \varsigma_t, \quad \rho_R \in (0,1),\ \phi_\pi > 0,\ \phi_Y > 0, \tag{11}$$

where $\pi_t \equiv (\pi_{c,t})^{1-\mu_t} (\pi_{d,t})^{\mu_t}$ is a composite inflation index with the weight for durables being the share of consumer durables in the composite consumption index, and $Y_t \equiv Y_{c,t} + p_t Y_{d,t}$ is real gross domestic product (GDP). The parameters R, π, and Y are steady-state values. Policy parameter ς_t is a shock which evolves according to

$$\ln \varsigma_t = \rho_M \ln \varsigma_{t-1} + e_{M,t} + v_{M,t-\tau},$$

where the parameter $\rho_M \in (0, 1)$ measures the persistence of shocks. The innovations $e_{M,t}$ and $v_{M,t-\tau}$ are the contemporaneous and news shocks, which are assumed to be uncorrelated and *i.i.d.* with $\mathcal{N}(0, \sigma_M^2)$ and $\mathcal{N}(0, \sigma_{Mv}^2)$, respectively.

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 1954Q3-2020Q1 on nine real and nominal variables. The observable variables are output, nondurable consumption, consumer durables, hours worked, business investment, real wage, business debts, inflation in the consumption sector, and nominal interest rate.[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, deflated by the consumption deflators, expressed in logarithms, and detrended by the one-sided Hodrick-Prescott filter with a smoothing parameter of 1,600 (see Stock and Watson, 1999; Born and Pfeifer, 2021).[21] The prior distributions of parameters are set by the standard DSGE literature, such as Smets and Wouters (2007), Justiniano et al. (2010), Schmitt-Grohé and Uribe (2012), and Görtz and Tsoukalas (2017). In particular, the prior distributions of Calvo probability and investment adjustment cost parameters are set following Görtz and Tsoukalas (2017). The prior distribution of the entrepreneur's loan-to-value ratio parameter is set as a beta distribution with mean 0.80 and standard deviation 0.15. The prior mean is based on the maximum regulatory loan-to-value ratio of conventional mortgages in the US. The estimation results are summarized in Table 1.[22]

[20] The series of observables are 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, commercial and industrial loans, inflation measured by the consumption deflator, and effective federal funds rate, respectively. The consumption deflator is the deflator for personal consumption expenditures on nondurable goods and services.

[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] We use the Dynare software to estimate the posterior distributions. In the estimation, we choose a high value for the jscale parameter (jscale=1.5) and a Monte-Carlo based optimization routine for the mode computation by specifying mode_compute=6. In the Appendix, we report four figures. First, we illustrate both series of the nine actually observed data and the estimates of these smoothed variables, which indicate that both series are exactly the same and fluctuate

[Insert Table 1 here]

First, the posterior modes of the Calvo probability of not resetting nondurable and durable prices are estimated to be about 0.76 and 0.22, respectively, 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=4.12 and φ_d=4.02, which are within the estimates in the standard DSGE literature. The posterior estimates of the entrepreneur's loan-to-value ratios are m_c=0.79 and m_d=0.82, so the entrepreneur's loan-to-value ratio is higher than the household's ratio, as in Iacoviello (2005). As for the monetary policy rule, the posterior distributions of the parameters lie within the standard range in the literature regarding Taylor rules.[24]

Next, 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 U.S. 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 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. 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

around zero. Next, we depict the estimates of the smoothed structural shocks, which are the best guess for the structural shocks given all observations, derived from the Kalman smoother at the posterior mean, according to Pfeifer (2020). The figure suggests that all estimates fluctuate around zero, and particularly, the IST news shock has the largest volatility among all shocks. Moreover, following Pfeifer (2020), we report graphs produced by identification, in which the top panel displays the identification strength and the bottom panel exhibits the identification sensitivity of the parameters. The figure suggests that all parameters are identified except for the Calvo probability. Finally, we plot the Brooks and Gelman (1998) convergence diagnostic, in which the top panel depicts one line that shows the 80% interval/quantile range, and the other line shows the mean interval range, based on the range of the posterior likelihood function. The middle and the bottom panels show the estimates of the same statistics for the second and the third central moments, respectively. The figure indicates that both lines have stabilized toward the same value.

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

[24] We also test different prior means and standard deviations and use different sample periods with alternative observables, and we find that the results of the small standard errors of some posterior distributions are robust.

spending in total private spending in the US. The steady-state 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 price 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 $\phi_s=\phi_b=1$, which is within the range of values used in the existing literature.

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 $\theta_c=0.76$, which implies $1/(1-\theta_c)=4.1$ and thus, a frequency of nondurable price adjustments of about four 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.[25] Equating these two slopes gives $\vartheta_j=(\varepsilon_j-1)\theta_j/[(1-\theta_j)(1-\beta_s\theta_j)]$. Given $\varepsilon_c=6$ and $\beta_s=0.99$, we pin down the value for the degree of nominal price rigidities in nondurables to $\vartheta_c=61.24$. As for the degree of durable-price stickiness, our estimate gets $\theta_d=0.22$, which implies $1/(1-\theta_d)=1.3$ and thus, a frequency of durable price adjustments of over one quarter. Then we obtain $\vartheta_d=1.74$ in the same way.

Finally, 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 $v_b=10.84$. In the same fashion, we obtain $v_s=5.25$ for patient households.

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 U.S. economy. Besides, Table 3 exhibits business cycle moments for the postwar U.S. data and those generated by the baseline model with multiple shocks.[26] The model generated moments match with those in the data reasonably well. Consumption is less volatile than output, investment is more volatile than output, and the wage is slightly more volatile than output. Moreover, real aggregate variables are procyclical. Therefore, our baseline model is capable of generating business cycle properties in the US.

[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

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

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

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 Tobin's Q goes down (cf. Panel K). A decrease in Tobin's Q indicates that a good news shock to IST leads to a decline in firm's value, which is inconsistent with the data. 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 impulse responses of macro variables consistent with the data.

4.2 The Model with Sticky Prices

Next, 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 $\vartheta_c= 61.24$ and $\vartheta_d=1.74$, 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), and Tobin's Q remains falling (cf. Panel K), similar to Figure 1. Hence, in response to an IST news shock, the model with sticky prices without financial constraints still cannot produce impulse responses consistent with the data.

4.3 The Baseline Model: Sticky Prices and Financial Constraints

Finally, 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=61.24 and ϑ_d=1.74 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). Due to binding collateral constraints, the magnitude of the response of consumption is increased by more than 0.6% in Figure 3 (cf. Panel B), as compared to -0.2% in Figure 2. The magnitudes of the responses of output and investment in Figure 3 are about the same as those in Figure 2 (cf. Panels A and D). In addition, real debts also rise (cf. Panel G). As a result of a positive news shock to IST, Tobin's Q goes up (cf. Panel K), which is in line with the data. 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 (cf. Panels D and E). 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. Hence, a positive IST news shock causes the business cycle comovement.

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 positive 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),[27] 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 period 1982Q3-2016Q4.

To facilitate comparison of whether the source of aggregate fluctuations is from IST news shocks or other shocks, we perform variance decompositions to each of the eighteen 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, to labor supply, to monetary policy, and to two sectoral price markups. Table 4 presents the variance decomposition of the macro variables accounted for by all these shocks in our baseline model.

[Insert Table 4 here]

As seen from the table, IST news shocks are the dominant source of volatility and account for over 50 percent of the fluctuations in output, consumption, investment, and real wages. IST contemporaneous shocks account for about 25 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 hours.[28] 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.[29]

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[27] 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 housing and durables.

[28] 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 0.8 percent of the fluctuations in output and thus, are not the main source of volatility.

[29] Table 4 indicates that the consumption volatility is explained more by TFP news shocks in the durable sector than by TFP news shocks in the nondurable consumption sector. To see the intuition, we note that entrepreneurs consume. Moreover, as durable prices are less sticky than nondurable prices, TFP shocks in the durable sector change durable prices. Thus, a change in entrepreneur's cash flows influences entrepreneur's consumption. As a result, consumption volatility is explained more by TFP shocks in the durable sector than by TFP shocks in the nondurable sector.

The unconditional forecast error variance decomposition in Table 4 is constructed at an infinite forecast horizon. In a recent paper, Sims (2016) has argued that the forecast horizon also 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 eighteen shocks under concern at different forecast horizons. In comparison with Sims (2016)'s results, for all variables, the variance shares attributable to IST news shocks are in a majority for the periods after news shocks are realized. In particular, IST news and non-news shocks are always dominant sources of volatility in real aggregates for all forecast horizons in our baseline model.

[Insert Table 5 here]

5. Sensitivity Analysis

This section carries out sensitivity analyses for the results of our baseline model. We have underlined the role of sticky prices and financial constraints, and the coefficients of the price adjustments are not identified. To understand the sensitivity of sticky prices and financial constraints, firstly, we investigate the robustness of the results if nondurable prices are adjusted in more than four quarters. Moreover, the durable price is less sticky than the nondurable price 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 intriguing to understand the robustness of the results if entrepreneurs are risk neutral. Finally, TFP news shocks will also be explored.

5.1 Price Stickiness of Nondurables

In our baseline estimation, the frequency of nondurable price adjustments is about four quarters, which lies within the range in the standard New Keynesian literature. 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 stickier. We employ the probability of resetting nondurable prices, $1-\theta_c$=0.24, to pin down ϑ_c=61.24. To see how the result changes when nondurable prices are stickier, we decrease the probability of resetting nondurable prices, and thus raise the cost of nondurable price adjustments, ϑ_c. We envisage the impulse responses, when the probability of resetting nondurable prices decreases from 0.24 to 0.2 and then to 0.17, which implies that the nondurable consumption price is reset less frequently from every four quarters to every five quarters and then to every six quarters, respectively, with the corresponding adjustment cost parameter value of ϑ_c being increased from 61.24 to 96.15 and then to 142.80, respectively. The impulse responses are displayed in Figure 4.

[Insert Figure 4 here]

With stickier nondurable prices, less firms raise nondurable prices in response to a positive IST news shock. Then, the durable price relative to the nondurable price increases more than that in the baseline model on impact (cf. Panel H), so the real debt is influenced more by collateral prices on impact (cf. Panel G). Therefore, the wealth effect of the collateral value becomes stronger, and real aggregate variables also rise by more.

The simulation indicates that our results of comovement are robust as long as the stickiness of nondurable price is higher than two 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, $1-\theta_d$=0.78, so ϑ_d=1.74. 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 0.78 to 0.5 and then to 0.33, which implies that durable prices are reset less frequently from every 1.3 quarters to every 2 quarters and then to every 3 quarters, respectively, with the corresponding adjustment cost parameter value of ϑ_d being increased from 1.74 to 9.90 and then to 30.15, respectively. The impulse responses are shown in Figure 5.

[Insert Figure 5 here]

Figure 5 indicates that, with nondurable prices being reset every four quarters, real aggregates comove when durable prices are reset every two and three 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 higher than that of the nondurable price adjustment, as evidenced by Bils and Klenow (2004).

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 to a positive IST news shock 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 consumption, real wages, and real debts are mitigated (cf. green dashed lines). However, when entrepreneurs' collateral constraints are not binding, with binding households' collateral constraints, consumption falls and Tobin's Q goes down on impact (cf. red long-dashed lines), which is against the empirical evidence. In particular, entrepreneurs no longer have to rely on the relaxation of the collateral constraint to raise their funding (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 intriguing 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. green dashed lines), despite the larger percentage fluctuations of real variables than the baseline model with hump-shape responses. Besides, Tobin's Q declines as compared to the baseline model with risk-averse entrepreneurs. Thus, our baseline model has a better fit to the data than the model with risk-neutral entrepreneurs.

[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 less than 1 percent of the fluctuations in output are driven by TFP news shocks, it is also worthwhile to check if TFP news shocks can cause comovement in our model. As reported in Figure 8, in response to a positive aggregate TFP news shock, Tobin's Q rises (cf. Panel K), and the relative price of investment increases (cf. Panel H).

[Insert Figure 8 here]

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. In addition, TFP news shocks also generate deflation (cf. Panel I), which is consistent with those identified in the data using the VAR model, such as Görtz et al. (2021). Therefore, our mechanism applies to not only IST news shocks but also TFP news shocks.

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, rather than 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 real macroeconomic variables in our model. By contrast, positive IST news shocks lead to a decline in consumption in an otherwise identical model except either sticky prices or 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	5%	95%
θ_c	Calvo probability of nondurable-sector prices	Beta	0.80	0.10	0.7554	0.7567	0.7527	0.7613
θ_d	Calvo probability of durable-sector prices	Beta	0.20	0.10	0.2154	0.2138	0.2089	0.2175
φ_c	Investment adjustment cost in nondurable sector	Gamma	4.00	1.00	4.1150	4.1184	4.1075	4.1294
φ_d	Investment adjustment cost in durable sector	Gamma	4.00	1.00	4.0164	4.0176	4.0108	4.0230
m_c	Entrepreneur's loan-to-value ratio in nondurable sector	Beta	0.80	0.15	0.7919	0.7923	0.7903	0.7940
m_d	Entrepreneur's loan-to-value ratio in durable sector	Beta	0.80	0.15	0.8178	0.8180	0.8169	0.8194
ρ_R	Taylor rule inertia	Beta	0.50	0.20	0.5200	0.5205	0.5186	0.5228
ϕ_π	Taylor rule inflation	Normal	1.70	0.30	1.7037	1.7012	1.6942	1.7091
ϕ_Y	Taylor rule output	Normal	0.125	0.05	0.3358	0.3365	0.3327	0.3430
Shocks: Persistence								
ρ_I	IST	Beta	0.60	0.20	0.4531	0.4509	0.4447	0.4566
ρ_A	Aggregate TFP	Beta	0.60	0.20	0.6959	0.6933	0.6832	0.7011
ρ_{Ac}	TFP in nondurable sector	Beta	0.50	0.20	0.4583	0.4616	0.4588	0.4645
ρ_{Ad}	TFP in durable sector	Beta	0.50	0.20	0.6265	0.6275	0.6189	0.6351
ρ_μ	Preference	Beta	0.60	0.20	0.5702	0.5704	0.5653	0.5743
ρ_ω	Labor supply	Beta	0.60	0.20	0.6657	0.6600	0.6575	0.6623
ρ_M	Monetary policy	Beta	0.60	0.20	0.4608	0.4602	0.4555	0.4639
ρ_{pc}	Price markup in nondurable sector	Beta	0.60	0.20	0.5973	0.6038	0.6019	0.6079
ρ_{pd}	Price markup in durable sector	Beta	0.60	0.20	0.7040	0.7064	0.7029	0.7101
Contemporaneous Shocks: Volatilities								
σ_I	IST	Inv Gamma	0.005	2.00	0.1777	0.1805	0.1776	0.1846
σ_A	Aggregate TFP	Inv Gamma	0.005	2.00	0.0031	0.0029	0.0026	0.0032
σ_{Ac}	TFP in nondurable sector	Inv Gamma	0.005	2.00	0.0013	0.0012	0.0010	0.0015
σ_{Ad}	TFP in durable sector	Inv Gamma	0.005	2.00	0.0048	0.0047	0.0037	0.0056
σ_μ	Preference	Inv Gamma	0.001	2.00	0.0292	0.0296	0.0277	0.0309
σ_ω	Labor supply	Inv Gamma	0.001	2.00	0.0005	0.0006	0.0003	0.0009
σ_M	Monetary policy	Inv Gamma	0.001	2.00	0.0010	0.0010	0.0009	0.0011
σ_{pc}	Price markup in nondurable sector	Inv Gamma	0.001	2.00	0.0220	0.0211	0.0194	0.0226
σ_{pd}	Price markup in durable sector	Inv Gamma	0.001	2.00	0.0078	0.0078	0.0072	0.0089
News Shocks: Volatilities								

σ_{Iv}	IST	Inv Gamma	0.0035	2.00	0.2267	0.2269	0.2212	0.2319
σ_{Av}	Aggregate TFP	Inv Gamma	0.0035	2.00	0.0014	0.0017	0.0012	0.0023
σ_{Acv}	TFP in nondurable sector	Inv Gamma	0.0035	2.00	0.0010	0.0010	0.0007	0.0014
σ_{Adv}	TFP in durable sector	Inv Gamma	0.0035	2.00	0.0056	0.0050	0.0038	0.0062
$\sigma_{\mu v}$	Preference	Inv Gamma	0.0007	2.00	0.0003	0.0006	0.0002	0.0011
$\sigma_{\omega v}$	Labor supply	Inv Gamma	0.0007	2.00	0.0051	0.0050	0.0046	0.0053
σ_{Mv}	Monetary policy	Inv Gamma	0.0007	2.00	0.0013	0.0013	0.0012	0.0014
σ_{pcv}	Price markup in nondurable sector	Inv Gamma	0.0007	2.00	0.0151	0.0174	0.0135	0.0209
σ_{pdv}	Price markup in durable sector	Inv Gamma	0.0007	2.00	0.0003	0.0005	0.0002	0.0007

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
steady-state elasticity of substitution between intermediates for nondurable/durable sector	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/impatient households	L_s, L_b	0.3
impatient households' loan-to-value ratio	m_b	0.77
parameter of labor in utility for patient households	v_s	5.25
parameter of labor in utility for impatient households	v_b	10.84

Table 3. Business cycle moments

	Data (1947Q1-2021Q4)	Model
SD of consumption (relative to output)	0.67	0.91
SD of investment (relative to output)	4.44	8.13
SD of wage (relative to output)	1.07	1.09
Corr (consumption, output)	0.76	0.67
Corr (consumption, investment)	0.46	0.39
Corr (investment, hours)	0.76	0.53
Corr (wage, output)	0.86	0.90
Corr (consumption, wage)	0.67	0.84

Table 4. Variance decomposition in the baseline model (%)

Variable	IST shock		Aggregate TFP shock		TFP shock in C-sector		TFP shock in D-sector		Durables preference shock	
	News	Non-news	News	Non-news	News	Non-news	News	Non-news	News	Non-news
Output	73.27	22.25	0.22	0.58	0.02	0.02	0.62	0.20	0.00	0.06
Consumption	51.94	29.55	0.04	1.00	0.01	0.01	0.74	1.30	0.00	2.82
Hours	35.12	20.45	0.07	0.84	0.09	0.29	6.21	0.81	0.00	2.10
Investment	80.20	18.69	0.01	0.15	0.00	0.00	0.09	0.08	0.00	0.08
Real wage	67.82	20.81	0.04	0.25	0.01	0.02	0.49	0.08	0.00	0.07
Real debt	67.01	27.05	0.02	0.50	0.00	0.01	0.44	0.56	0.00	0.30
Relative price of investment goods	70.59	14.08	0.04	0.43	0.02	0.01	1.54	1.00	0.00	1.42
Inflation	73.37	21.36	0.15	0.94	0.02	0.04	0.21	0.20	0.00	0.09
Nominal interest rate	74.33	20.66	0.19	0.65	0.02	0.03	0.52	0.11	0.00	0.10

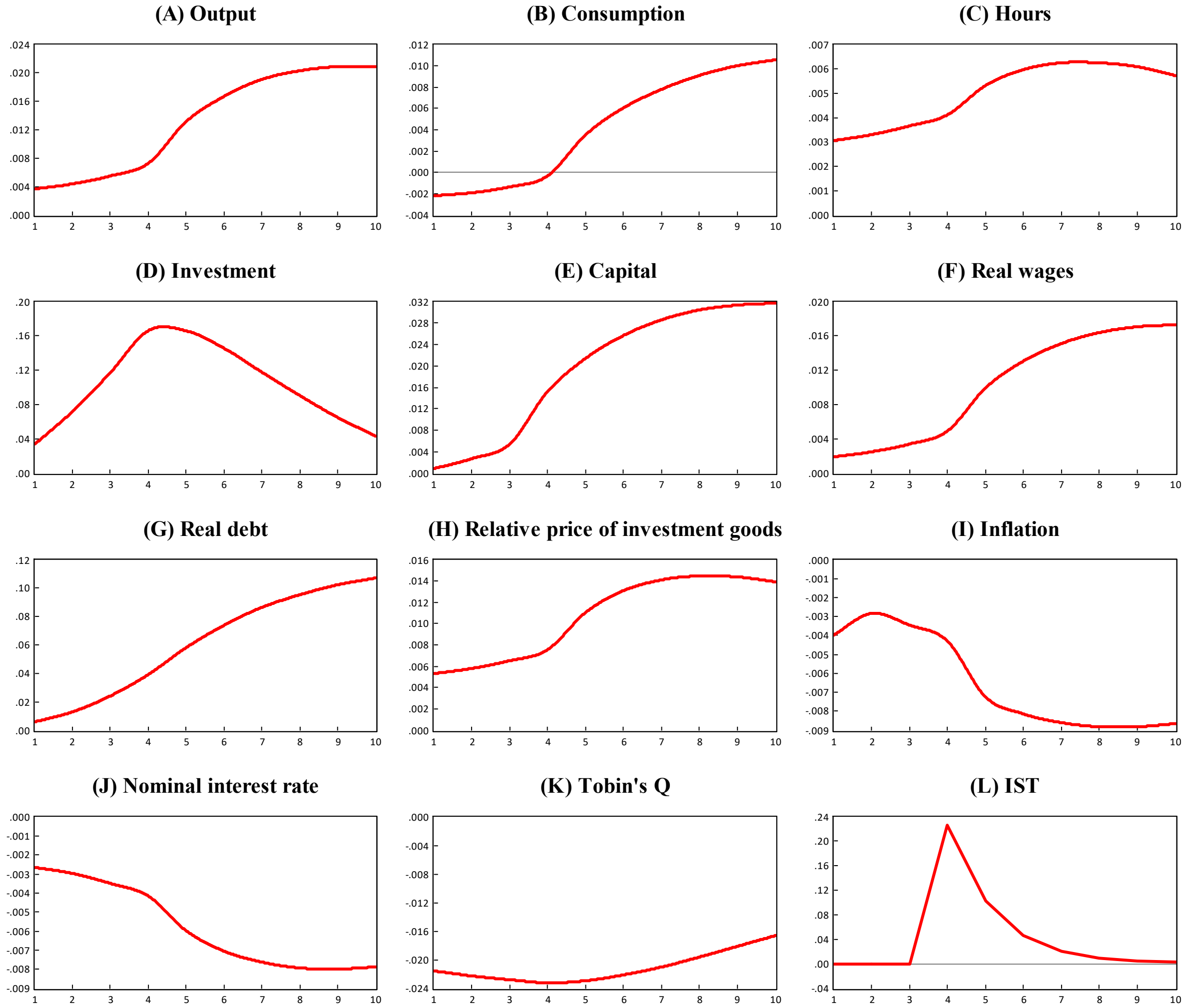
Table 4. (Cont.) Variance decomposition in the baseline model (%)

Variable	Labor supply shock		Monetary policy shock		Price markup shock in C-sector		Price markup shock in D-sector	
	News	Non-news	News	Non-news	News	Non-news	News	Non-news
Output	0.25	0.00	0.27	0.42	0.88	0.85	0.00	0.08
Consumption	0.05	0.00	1.18	3.51	2.86	3.89	0.00	1.10
Hours	9.32	0.06	1.73	4.85	4.46	6.09	0.02	7.49
Investment	0.01	0.00	0.11	0.22	0.16	0.13	0.00	0.07
Real wage	0.33	0.01	0.87	1.92	3.27	3.84	0.00	0.18
Real debt	0.03	0.00	0.44	1.15	0.89	1.07	0.00	0.54
Relative price of investment goods	0.07	0.00	0.83	0.73	4.06	3.37	0.00	1.81
Inflation	0.15	0.00	0.94	0.85	0.84	0.70	0.00	0.12
Nominal interest rate	0.20	0.00	1.60	0.29	0.69	0.46	0.00	0.15

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

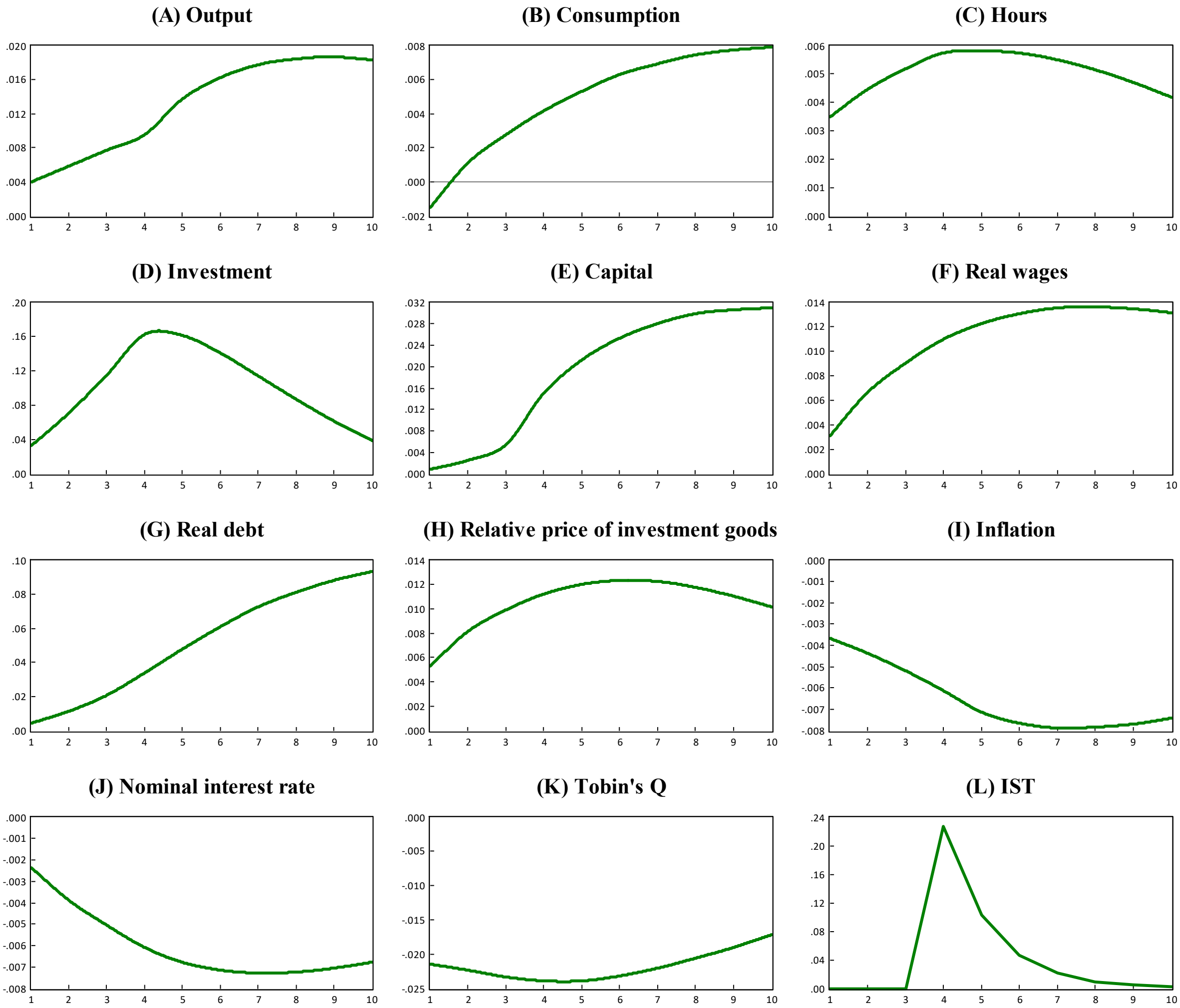
		Forecast Horizon								
Variable	Shock	1	2	3	4	5	8	16	32	∞
Output	IST news	16.63	18.66	24.58	33.01	45.92	65.04	73.11	73.17	73.27
	IST non-news	24.78	40.74	47.69	43.98	37.98	27.50	22.26	22.26	22.25
	Others	58.59	40.6	27.73	23.01	16.1	7.46	4.63	4.57	4.48
Consumption	IST news	13.03	16.15	22.05	32.22	37.12	40.39	41.83	47.17	51.94
	IST non-news	41.01	42.07	39.79	34.34	31.73	30.40	31.31	30.98	29.55
	Others	45.96	41.78	38.16	33.44	31.15	29.21	26.86	21.85	18.51
Hours	IST news	12.05	13.26	17.11	22.55	24.04	23.70	25.05	27.40	35.12
	IST non-news	31.76	30.33	27.59	20.01	17.99	17.68	18.39	19.95	20.45
	Others	56.19	56.41	55.3	57.44	57.97	58.62	56.56	52.65	44.43
Investment	IST news	27.01	42.12	58.24	72.20	78.08	80.63	79.80	80.21	80.20
	IST non-news	71.07	56.26	40.53	26.95	21.23	18.64	19.10	18.68	18.69
	Others	1.92	1.62	1.23	0.85	0.69	0.73	1.1	1.11	1.11
Real wage	IST news	23.71	29.73	38.53	49.32	55.46	63.76	67.45	67.48	67.82
	IST non-news	37.14	37.30	34.03	27.92	24.99	21.77	20.46	20.77	20.81
	Others	39.15	32.97	27.44	22.76	19.55	14.47	12.09	11.75	11.37
Real debt	IST news	12.74	13.10	14.73	35.12	47.96	61.53	66.05	66.26	67.01
	IST non-news	48.36	56.99	60.35	47.66	39.17	30.18	27.36	27.46	27.05
	Others	38.90	29.91	24.92	17.22	12.87	8.29	6.59	6.28	5.94
Relative price of investment goods	IST news	23.01	31.94	41.06	49.17	55.57	66.44	69.05	70.56	70.59
	IST non-news	11.72	16.24	19.06	18.98	18.29	15.54	14.13	13.91	14.08
	Others	65.27	51.82	39.88	31.85	26.14	18.02	16.82	15.53	15.33
Inflation	IST news	0.06	9.44	20.60	31.90	46.44	66.46	73.43	73.26	73.37
	IST non-news	0.11	20.01	34.39	37.85	34.35	25.28	21.11	21.32	21.36
	Others	99.83	70.55	45.01	30.25	19.21	8.26	5.46	5.42	5.27
Nominal interest rate	IST news	4.12	3.65	11.93	25.02	40.15	65.02	74.51	74.26	74.33
	IST non-news	2.92	5.62	18.27	29.87	32.41	25.53	20.25	20.55	20.66
	Others	92.96	90.73	69.80	45.11	27.44	9.45	5.24	5.19	5.01

Note: Other shocks include contemporaneous (non-news) and news shocks from aggregate TFP, two sectoral TFPs, durables preference, labor supply, monetary policy, and two sectoral price markups. The column corresponding to forecast horizon 4 means news shocks become realized.



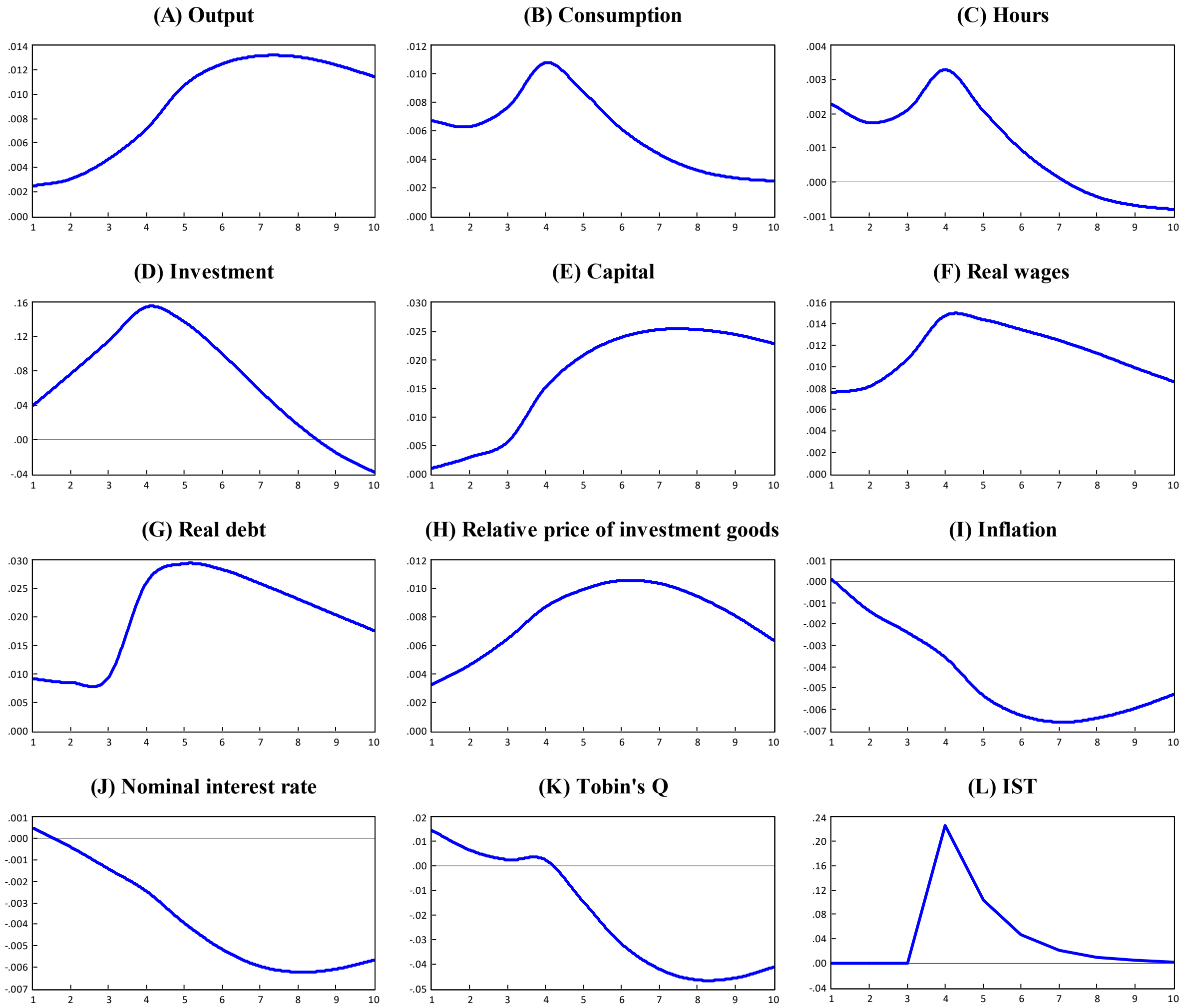
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for K_{t+1}, so the value of K_2 is in period 1.

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



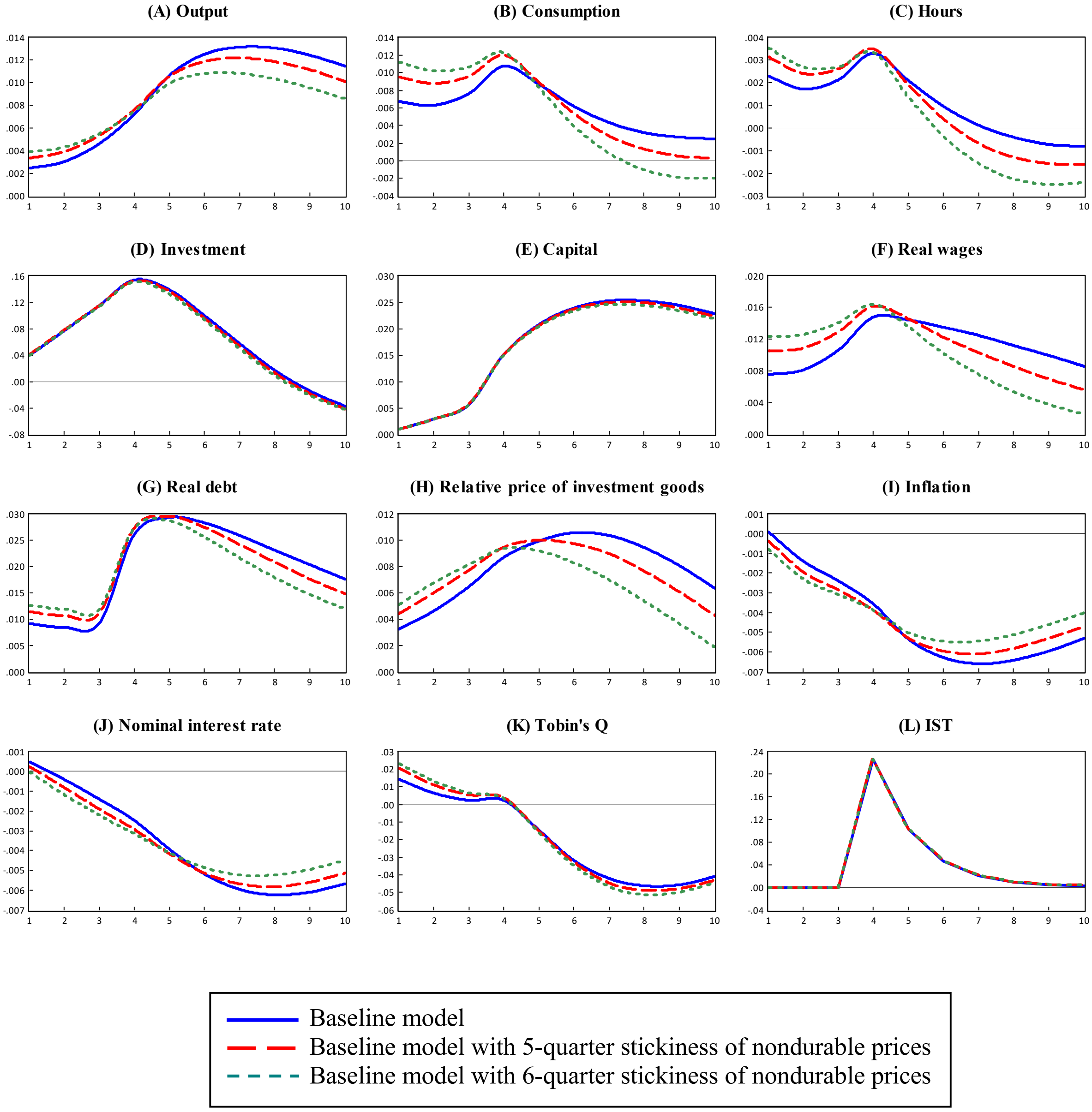
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for K_{t+1}, so the value of K_2 is in period 1.

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



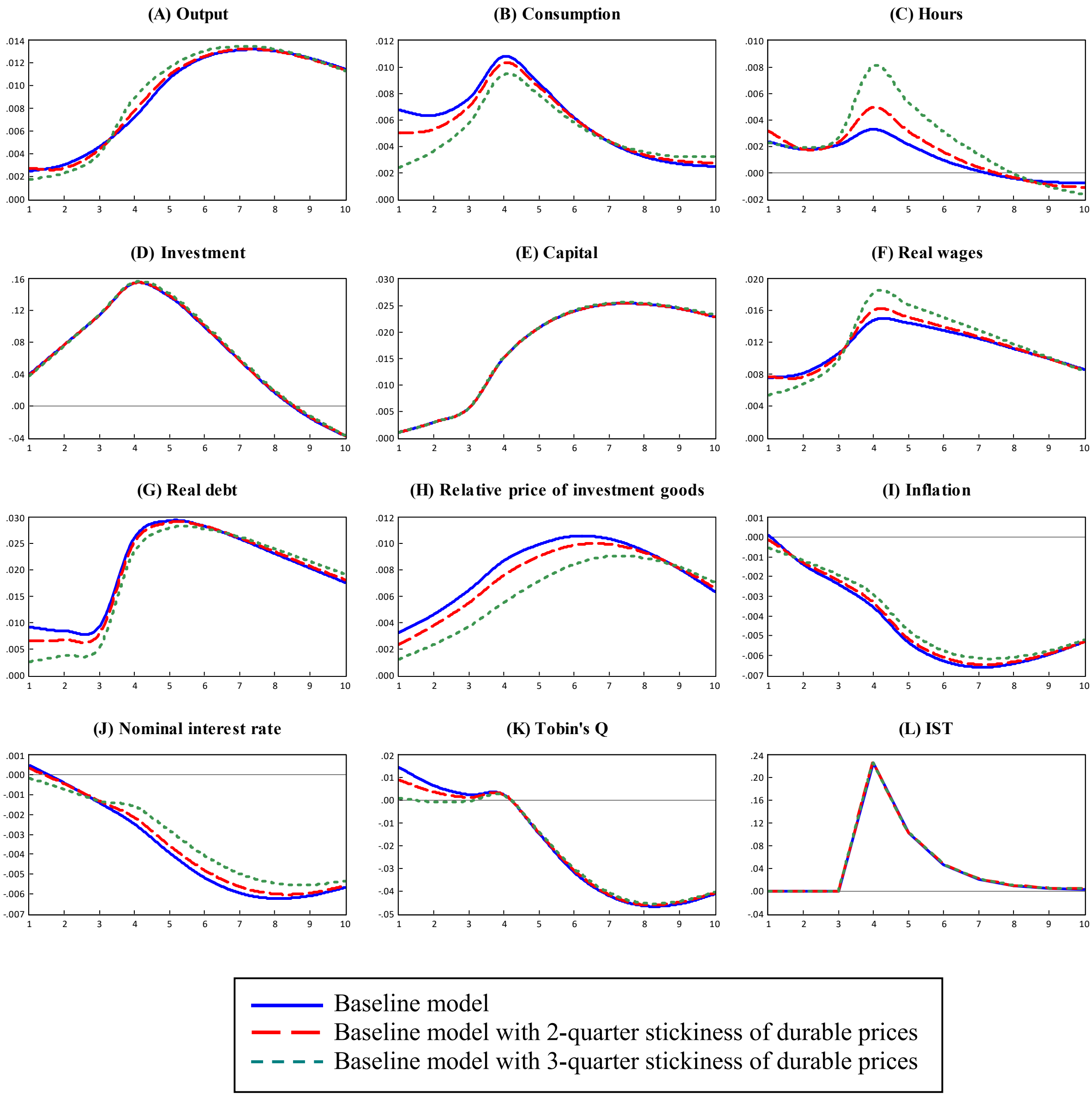
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for K_{t+1}, so the value of K_2 is in period 1.

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



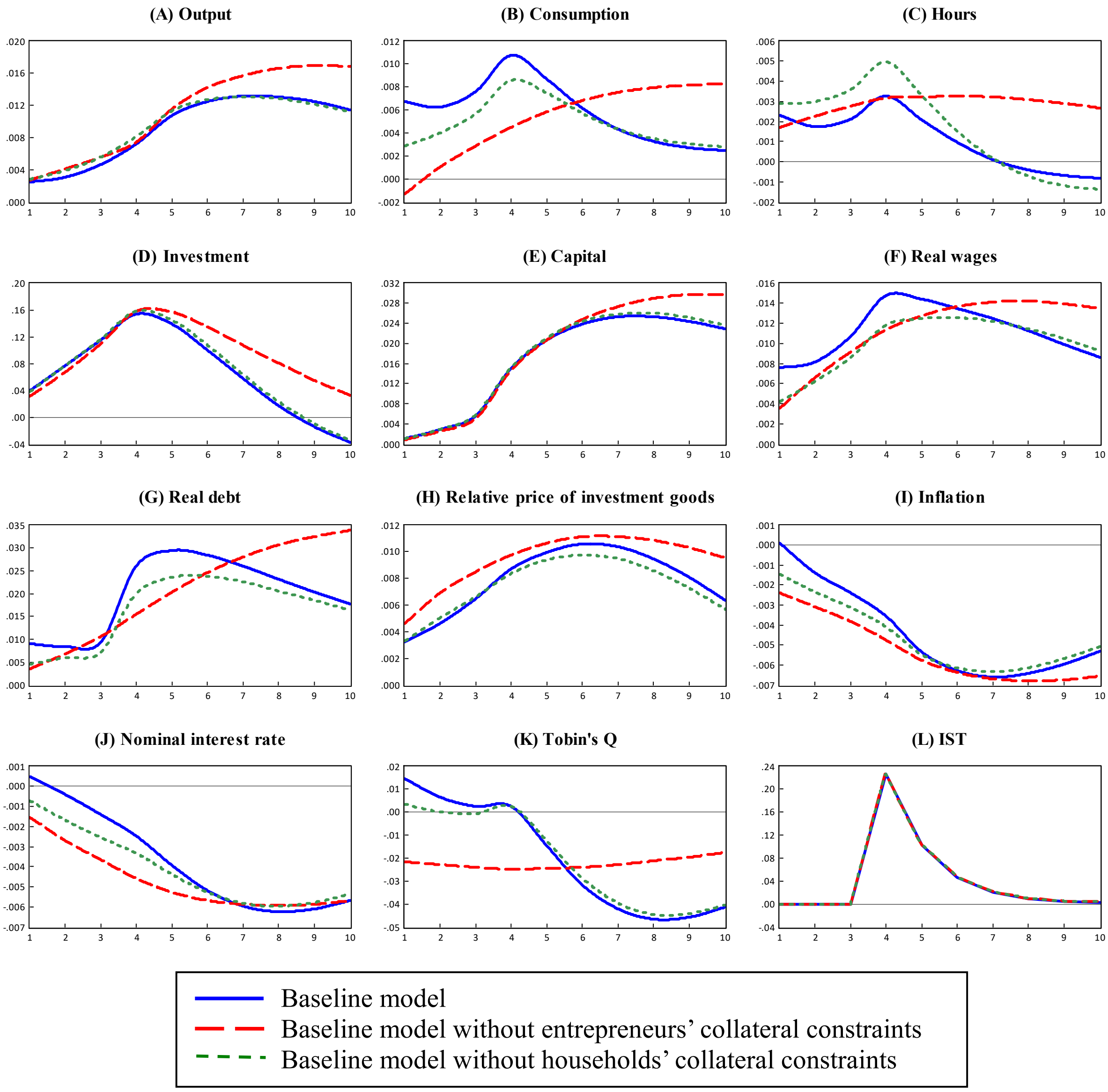
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for K_{t+1}, so the value of K_2 is in period 1.

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.



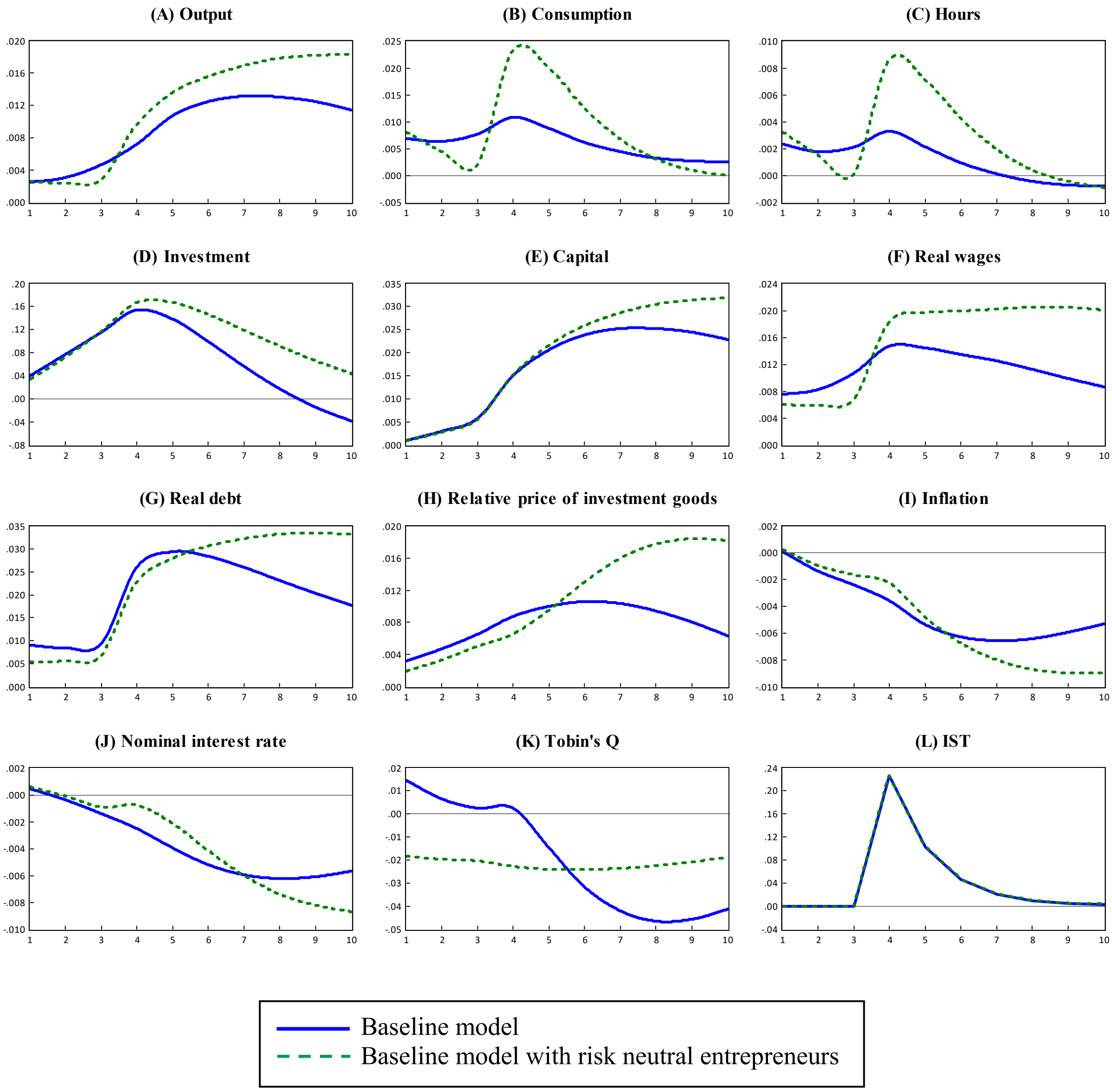
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for K_{t+1}, so the value of K_2 is in period 1.

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



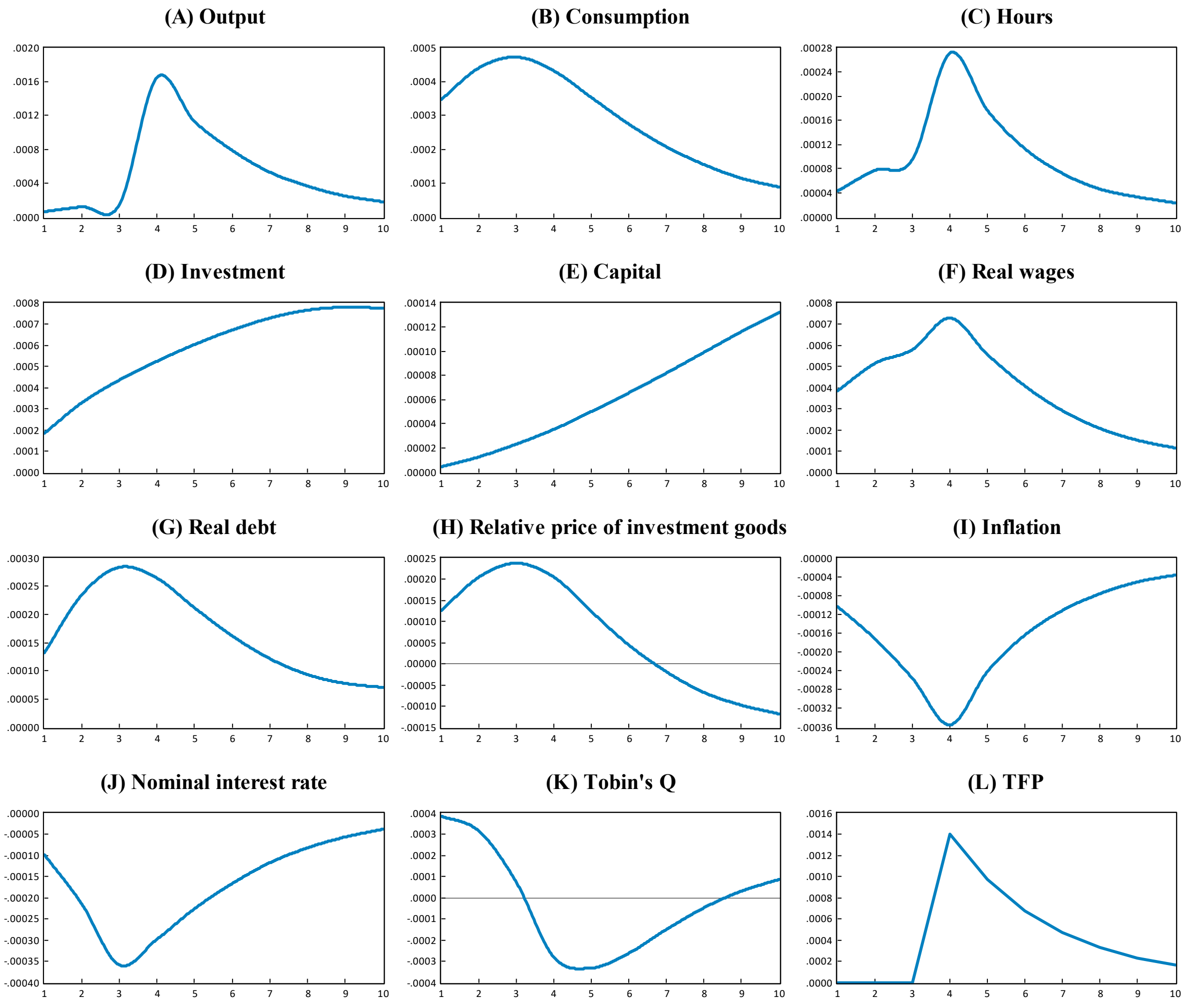
Note: The horizontal axis is quarters; the vertical axis is percentage deviations from the steady state. Panel (E) Capital is expressed for K_{t+1}, so the value of K_2 is in period 1.

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 TFP news shock