A Tale of Two Volatilities:

Sectoral Uncertainty, Growth, and Asset-Prices

Gill Segal*

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Abstract

What is the impact of higher technological volatility on asset-prices and macroeconomic aggregates? I find the answer hinges on its sectoral origin. I document several novel empirical facts: Volatility that originates from the consumption sector plays the "traditional" role of depressing the real economy and stock prices, whereas volatility that originates from the investment sector boosts prices and growth; Investment (consumption) sector's technological volatility has a positive (negative) market-price of risk; Investment sector's technological volatility helps explain return spreads based on momentum, past profitability, and Tobin's Q. I show that a standard DSGE two-sector model fails to fully explain these findings, while a model that features monopolistic power for firms and sticky prices, as well as early resolution of uncertainty, can quantitatively explain the differential impact of sectoral volatilities on real and financial variables. In all, the sectoral decomposition of volatility can reconcile existing competing evidence related to the impact of volatility shocks.

*Gill Segal (segalg@wharton.upenn.edu), The Wharton School, University of Pennsylvania, 3620 Locust Walk, Philadelphia, PA 19104, USA. I thank my advisors Amir Yaron, João Gomes, Itay Goldstein, Ivan Shaliastovich, and the participants at the Wharton Macro Seminar for their helpful comments. All mistakes are my own.

1 Introduction

It is a common notion, especially among policymakers, that uncertainty played an important role in inhibiting economic recovery from the Great Recession. Consequently, there has been a growing research effort in macroeconomics and in finance to understand the implications of volatility shocks, yielding mixed evidence. In macroeconomic studies, it is debatable whether volatility, particularly in general equilibrium, lowers or increases investment. In asset-pricing, most studies argue that volatility drops asset-valuation ratios, while others claim it is a mechanism that boosts stock prices.[1] Corporate finance studies show that higher volatility increases the cost of capital, thus lowering investment and leverage.

In this study I show that it is possible to reconcile the mixed evidence about the implications of volatility by decomposing the source of uncertainty into sectoral origins. Specifically, I ask what is the impact of technological (TFP) volatility on asset-prices and aggregate cash-flows? I shed new light on this question, and find that the answer depends empirically and theoretically on the sector from which the volatility emanates. I split the economy into two super-sectors: the consumption sector and the investment sector. I study the pricing and the macroeconomic implications of sectoral innovations (first-moment sectoral TFP shocks), as well as sectoral volatility shocks (second-moment sectoral TFP shocks), of these two sectors.

I document a novel empirical regularity: the TFP-volatilities of the investment sector and the consumption sector have *opposite* impact on the real and financial economy. Contrary to the typical view of policymakers, TFP-volatility is not always contractionary empirically. The market's fear of uncertainty is well-justified when the productivity of the consumption sector is more uncertain. The TFP-volatility of the consumption sector depresses stock prices and aggregate investment. By contrast, uncertainty about the productivity of investment-good producers boosts aggregate cash-flows, raises equity valuations, and lowers credit spreads. Moreover, investment TFP-volatility helps explain return spreads based on momentum and Tobin's Q, beyond the ability of first-moment sectoral TFP innovations.

I explain the empirical findings using a quantitative general-equilibrium production-based model. The model features two-sectors, consumption and investment, whose production is subject to sectoral TFP shocks with time-varying volatility. While a standard perfect-competition model fails to fully explain the data, I show that a model that features monopolistic power for firms and sticky prices, as well as early resolution of uncertainty under Epstein and Zin (1989) and Weil (1989) preferences, is capable of explaining the differential impact of sectoral volatilities on real and financial variables.

[1] See a comprehensive discussion related to the implications of volatility shocks for economic growth and asset-prices in existing literature in Section 2.

The implications of this study contribute to several disciplines. On the macroeconomic front, this paper shows that higher uncertainty should not be suppressed if it stems from investment firms. On the asset-pricing front, my work highlights that sectoral volatility shocks, in particular in the investment sector, can go beyond first-moment innovations in explaining return spreads. On the corporate-finance front, I demonstrate that sectoral volatilities lead to differential impact on credit spreads, and on firms' incentive to take leverage.

A starting-point of my study is that uncertainty takes many different forms, and therefore, can lead to the mixed findings in the literature regarding its effect on economic growth and valuations. Focusing on the consumption versus the investment sector's TFP-volatility, stems from a voluminous macro-finance literature which divides the economy to these two classifications. This literature stresses the importance of innovations to the level of investment TFP (*first-moment* shocks) for the business-cycle, the equity premium, and certain return spreads.[2] To the best of my knowledge, my work is the first to examine the differential role of consumption and investment TFP-volatility (*second-moment* shocks) for prices and growth.

The focus on the TFP-volatility of the two sectors can be motivated economically. In a reduced form manner, higher investment TFP-volatility could be thought of as a bundle of R&D growth options, which raises uncertainty. Some of these options would turn out to be bad, but some in the right tail would be successful. Future exercising of successful options could be manifested in improved productivity and welfare. For example, uncertainty about the productivity of a firm like "Delta Airlines", classified as consumption-producing firm (service producer), can be quite different than uncertainty about "Pratt & Whitney" productivity (a large aircraft engine producer), classified under the investment sector.[3] Perhaps, creative R&D work done at "Pratt & Whitney", which is a source for higher uncertainty, would generate the next technological advancement (e.g. fuel efficient engine), from which "Delta Airlines" could also benefit? Interestingly, I find results along this intuition.

Empirically, using measures of sectoral innovations and volatility shocks, I document four novel stylized facts:[4] (1) While consumption-sector's TFP-volatility is associated with lower investment, output, and consumption, investment-sector's TFP-volatility is associated with boosting these quantities; (2) Investment TFP-volatility risk has a positive market-price, and

[2]These innovations are commonly termed investment-specific technological shocks, or IST. IST shocks refer to the Hicks-neutral technical changes of the investment sector (that are orthogonal to the consumption sector's technology shocks). In my work, I examine the total Solow residual in both sectors. For symmetry, I use the terms investment-TFP and consumption-TFP innovations. Both terms in my paper refer to *sectoral* Hicks-neutral technology shocks.

[3]I follow here the classification suggested by Gomes, Kogan, and Yogo (2009), of SIC codes into industries.

[4]I measure the TFP-volatility of the consumption and investment sectors via the predictable component of sectoral TFP realized variances. For more details, see discussion in Section 3.2.

consumption TFP-volatility has a negative market-price. The sectoral volatilities also affect the default spread in opposite directions: investment TFP-volatility lowers it; (3) By and large, equities are exposed in a similar fashion to the sectoral volatilities. Investment TFP-volatility increases firms' stock-prices (positive exposures, or positive "betas"), while firms' beta to consumption TFP-volatility is negative; (4) I show that investment TFP-volatility is important for the market risk-premium, and for explaining the momentum spread.

Why does investment TFP-volatility impact differ from consumption TFP-volatility? Using a quantitative DSGE theory, my work explains the impact of sectoral volatilities on aggregate cash-flows and aggregate valuations. The model features a consumption sector, and an investment sector, and builds on Smets and Wouters (2007), Liu, Fernald, and Basu (2012), and Garlappi and Song (2013b). The output of the consumption sector is a final-good used for consumption only, and it is subject to a consumption TFP shock. The output of the investment sector is the economy's aggregate investment, and it is subject to an investment TFP shock. It flows to both consumption firms, and investment firms that wish to invest.

Given the economy's structure, a consumption TFP innovation is a multiplicative shock that only rescales consumption, and thus has a transitory impact. By contrast, an investment TFP innovation affects multi-period stock of aggregate capital, and thus has a prolonged impact. As a result, consumption TFP-volatility resembles pure short-run capital risk, while investment TFP-volatility resembles more long-run income risk. As discussed below, this implies that the strength of the motive to save (invest) in order to hedge against higher uncertainty differs between the two volatilities.

When TFP-volatility of the investment sector rises, it implies that in future periods the probability of having sub-optimal amount of investment goods rises. In this case, the household has a strong incentive to invest more, and consume less, due to "precautionary saving". Investing more ensures higher aggregate capital in the future. Capital can be used for both consumption and investment production. Hence, it acts as a buffer of savings. If a bad investment TFP shock is realized, the buffer can be used to smooth consumption.

By contrast, I show that under early resolution of uncertainty preferences, more consumption TFP-volatility makes the household more impatient. This triggers more consumption, and less investment. Intuitively, under early resolution of uncertainty case, the agent dislikes uncertainty. To minimize her exposure to volatility build-up in the future, she shifts her consumption profile as much as possible to the present, which implies lower investment.

The former discussion demonstrates that consistently with the data, a model with perfect competition leads investment expenditures to rise (drop) with investment (consumption) TFP-volatility. However, because consumption and investment are substitutes, with perfectly competitive firms, a sectoral TFP-volatility shock would cause consumption and aggregate investment to counterfactually diverge.[5] The model therefore features time-varying markups, which builds upon monopolistic competition and sticky prices.[6] Time-varying markups make consumption and aggregate investment comove in response to sectoral volatility shocks, consistently with the data.[7] Consequently, sticky prices play an important role in explaining macroeconomic facts and volatility risk premia.

As is common in production models, aggregate investment and stock prices comove. Consequently, the two sectoral TFP-volatilities have opposite impact on stock prices. In particular, since higher investment TFP-volatility increases investment, it increases the demand for capital goods, and also their relative price. As a result, the value of firms' capital rises, and stock prices appreciate. This implies, as in the data, a positive beta to investment TFP-volatility. The opposite logic applies to consumption TFP-volatility, and implies negative betas to consumption TFP-volatility, consistently with the data.

The behavior of the market-prices of risk is derived from consumption dynamics and preferences. Consumption TFP-volatility depresses aggregate consumption, and generates a more volatile consumption profile. Both effects, under early resolution of uncertainty, increase the marginal utility of the investor, and imply a negative market-price of risk. Investment TFP-volatility increases consumption's volatility on one hand. On the other hand, this volatility has a prolonged effect on the economy through capital build-up. This capital build-up leads to a rise in long-run consumption. Quantitatively, the latter channel can dominate the first, implying a positive market-price of risk for investment TFP-volatility, as in the data.

The rest of this paper is organized as follows. In Section 2, I review related literature. Section 3 documents the novel empirical facts regarding sectoral TFP volatilities. In Section 4, I present the general-equilibrium model, and discuss its intuition in Section 5. Section 6 presents the quantitative results. Section 7 provides concluding remarks.

[5]This divergence implies that consumption TFP-volatility would counterfactually boosts consumption, not only contemporaneously but also in the future. Counterfactual consumption behavior could also adversely affect the market-price of consumption TFP-volatility risk.

[6]Markups in the model are countercyclical: They increase with consumption TFP-volatility. As higher consumption TFP-volatility has a contractionary impact, this is consistent with some empirical evidence suggesting that markups are countercyclical (see e.g. Barsky, Solon, and Parker, 1994; and Chevalier and Scharfstein, 1996).

[7]See related discussion in Basu and Bundick (2012), and Fernández-Villaverde, Guerrón-Quintana, Kuester, and Rubio-Ramírez (2015).

2 Related Literature

My paper relates to three main strands of literature. *First, my study is related to the growing literature discussing the implications of volatility shocks for macroeconomic growth, and asset-prices.* I contribute to this line of works by documenting and rationalizing novel channels, through which fundamental volatilities can interact both positively and negatively with macro-aggregates and prices. Volatility in this work refers to the time-series conditional volatility of shocks, to an economic variable of interest (in my case, TFP).

Empirically, the typical relation between volatility and the macroeconomy is *negative*. This negative link is documented in the early work of Ramey and Ramey (1995), Martin and Rogers (2000), and more recently by Engel and Rangel (2008), Bloom (2009), and Baker and Bloom (2013). Fewer empirical works, document a positive impact of volatility, such as Kormendi and Meguire (1985) on output, and Stein and Stone (2013) on R&D expenditures.[8]

From a theoretical perspective, there is an on-going debate regarding the impact of volatility on investment. *On one hand,* some studies highlight a negative impact on investment. The works of McDonald and Siegel (1986), Dixit and Pindyck (1994), and recently Bloom (2009), use real-option effects to explain why volatility suppresses investment and hiring. The work of Fernandez-Villaverde, Guerrón-Quintana, Rubio-Ramirez, and Uribe (2011) discusses uncertainty in an open-economy, showing that volatility lowers domestic investment. Other works argue that volatility increases the cost of capital, or credit spreads, making investment more costly (see e.g. Christiano, Motto, and Rostagno, 2014; Arellano, Bai, and Kehoe, 2012; and Gilchrist, Sim, and Zakrajsek, 2014). Basu and Bundick (2012) and Fernández-Villaverde et al. (2015) rely on nominal rigidities to show that both consumption and investment drop in response to volatility shocks. *On the other hand,* other studies rely on economic forces which yield a positive link between volatility and investment, including precautionary savings, time-to-build, and investment irreversibility.[9]

Most asset-pricing studies argue for a *negative* effect of volatility on financial variables. Focusing first on the impact of aggregate-fundamental's volatility, Bansal, Khatchatrian, and Yaron (2005) show that higher aggregate volatility depresses asset-valuation ratios. Related,

[8]Related, the work of Imbs (2007) shows that on average, within-industry volatility of value-added is non-negatively (or weakly positively) related to the same industry's growth. Yet, average within-sector volatility across industries, relates negatively to aggregate growth. Differently from my work, Imbs does not identify which sectors' volatility interact positively or negatively with *aggregate* growth, or why.

[9]see e.g. Abel and Eberly, 1996; Bar-Ilan and Strange, 1996; Gilchrist and Williams, 2005; Jones, Manuelli, Siu, and Stacchetti, 2005; Malkhozov, 2014; and Kung and Schmid, 2014. Related, Johnson (2007) highlights that higher uncertainty, accompanied with technological revolutions, encourages investment as a mean of optimal learning. For an excellent survey of uncertainty impact on macroeconomic quantities, the reader may also refer to Bloom (2014).

Drechsler and Yaron (2011), and Shaliastovich (2015), show that higher aggregate volatility increases risk premia. Bansal, Kiku, Shaliastovich, and Yaron (2014) find that the market-price of aggregate volatility risk is negative. In the context of real options, Ai and Kiku (2012) argue that higher aggregate volatility may decrease the value of growth options, as the volatility is priced, and affects discount rates.

Other works, argue also for a *negative* impact, yet of *different* facets of volatility. Croce, Nguyen, and Schmid (2012), and Pastor and Veronesi (2012), demonstrate the negative impact of policy uncertainty on prices. In the context of learning, Van Nieuwerburgh and Veldkamp (2006), show that slower learning and higher belief uncertainty in bad times, generates slow recoveries and countercyclical movements in asset prices.[10]

Some financial studies argue for a more *positive* link between volatility and valuations. Campbell, Giglio, Polk, and Turley (2012) analyze aggregate volatility in an extended version of the intertemporal capital asset-pricing model (ICAPM), and find that in a recent-sample, equities have positive exposure to volatility. Pastor and Veronesi (2009) show that stock prices of firms rise as a result of higher uncertainty during times of technological revolutions.[11]

Different frameworks exhibit a more *ambivalent* link between volatility and returns. Segal, Shaliastovich, and Yaron (2015) show that the positive and negative semivariances of industrial-production have opposite impact on stock and bond prices. Patton and Sheppard (2015) show that negative semivariances of returns leads to higher future return volatility.[12]

The second strand of literature related to my paper, discusses the role of investment TFP innovations for the business cycle and asset prices. Yet, the focus of this literature so far evolved around first-moment TFP innovations, as opposed to second-moment TFP shocks, which are at the focus of the current work. A long strand of macroeconomic works stress the importance of investment technology innovations for business-cycle fluctuations.[13]

[10] Related, Fajgelbaum, Schaal, and Taschereau-Dumouchel (2015) also show that higher belief uncertainty discourages investment. Herskovic, Kelly, Lustig, and Van Nieuwerburgh (2015) show that the common component of idiosyncratic volatility among firms raises the households marginal utility, and is negatively priced. Krishnan, Petkova, and Ritchken (2009), show that correlation risk carries a significant negative price of risk.

[11] Other related papers include Johnson and Lee (2014), which highlight that the the common component of firm-specific cash-flow volatility increases equity valuation ratios, especially for levered equity claims. In the context of executive compensation, Cohen, Hall, and Viceira (2000) argue that since executive options increase in stock's volatility, they provide incentives for managers to take actions that increase firm risk, thus pursuing more projects.

[12] Other related papers include Feunou, Jahan-Parvar, and Tédongap, 2013; Bekaert and Engstrom, 2009; Bekaert, Engstrom, and Ermolov, 2015; Colacito, Ghysels, and Meng, 2013; McQuade, 2014; and Feunou, Jahan-Parvar, and Okou, 2015.

[13] see e.g. Greenwood, Hercowitz, and Krusell, 1997; Greenwood, Hercowitz, and Krusell, 2000; Fisher, 2006; Jaimovich and Rebelo, 2009; Justiniano, Primiceri, and Tambalotti, 2010; and Basu, Fernald, and Kimball, 2006.

In the context of asset-pricing, the works of Christiano and Fisher (2003), Papanikolaou (2011), and Garlappi and Song (2013a) among others, highlight the ability of investment shocks to explain the equity premium puzzle. Nonetheless, while Papanikolaou (2011) finds that investment innovations carry a negative beta and a negative market-price of risk, while Garlappi and Song (2013a) and Li, Li, and Yu (2013) find that these shocks carry a positive beta and a positive market-price. Consistently with Papanikolaou (2011), I document a negative beta to investment (first-moment) innovations. In-line with the controversy, I document that the sign of the market-price of risk of investment first-moment TFP innovations, is not a strictly robust feature of the quarterly data. In my benchmark analysis, I find a positive market-price for investment first-moment TFP innovations, though this market-price turns negative in some of the robustness checks. More relevant, the market-prices of sectoral TFP-*volatility* shocks are robust features of the quarterly data.

Investment innovations are shown to be helpful in explaining certain return spreads: Value spread (see Papanikolaou, 2011), spreads based on past-investment, market-betas and idiosyncratic volatility (see Kogan and Papanikolaou, 2014; and Kogan and Papanikolaou, 2013), and commodity-based spreads (see Yang, 2013). Li (2014) argues that investment innovations can explain the momentum spread, though Garlappi and Song (2013a) find that the magnitude of this spread captured by these shocks is low, in particular at quarterly frequency. My work documents that investment TFP-*volatility* shocks, are capable of explaining a significant fraction of the momentum spread at quarterly frequency.

The last voluminous literature that my paper is more broadly related to, are production/investment based asset-pricing papers. These works, study the role of (neutral) technological innovations for the joint dynamics of asset-prices and macroeconomic quantities.[14] For example, Liu, Whited, and Zhang (2009), find that conditional expectations of stock returns are positively correlated with expectations of investment returns. Belo, Lin, and Bazdresch (2014), provide an investment-based model to explain why firms with high hiring rates earn lower returns, while Jones and Tuzel (2013) offer an investment-based framework to explain why firms with higher inventory growth earn lower returns, relying on adjustment costs channels. Lastly, Gârleanu, Kogan, and Panageas (2012) study "displacement risk", that is, that innovation works to the advantage of new generations of innovators at the expense of older generations, helping to rationalize the value premium.[15]

[14] For a survey of this comprehensive literature, the reader may also refer to Kogan and Papanikolaou (2012).

[15] Other works discussing asset-pricing moments in a general-equilibrium production models include Jermann, 2010; Berk, Green, and Naik, 1999; Tallarini, 2000; Boldrin, Christiano, and Fisher, 2001; Gomes, Kogan, and Zhang, 2003; Carlson, Fisher, and Giammarino, 2004; Zhang, 2005; Croce, 2014; Kaltenbrunner and Lochstoer, 2010; Gomes and Schmid, 2010; Favilukis and Lin, 2013; Eisfeldt and Papanikolaou, 2013; Lustig, Roussanov, and Verdelhan, 2011; Lin, 2012; and Ai, Croce, and Li, 2013, to name a few.

3 The Facts

In this section I empirically examine the implications of sectoral first-moment TFP innovations and volatility shocks. Sections 3.1 and 3.2, describe the data and the methodology used to construct first- and second- moment sectoral TFP shocks empirically. In Section 3.3, I analyze the effects of sectoral shocks, and in particular volatility shocks, on aggregate macro quantities such as output, consumption, and investment. In Section 3.4, I examine the implications of sectoral shocks for cross-sectional risk-premia. I further highlight the asset-pricing role of sectoral TFP-volatility shocks, above and beyond sectoral first-moment TFP shocks, in Section 3.5. In the robustness section, Section 3.7, I show that the key results are maintained for alternative methods of extracting TFP-volatility shocks from the data.

3.1 Data

In my benchmark analysis I use quarterly data from 1947-Q1 to 2014-Q4. Consumption and output data come from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA) tables. Consumption corresponds to the real per capita expenditures on non-durable goods and services and output is real and per capita gross domestic product. Capital investment data are from the NIPA tables; Data on average weekly hours worked, and average hourly earnings, of production and nonsupervisory employees in good-producing industries are from BLS. Quarterly sales, capital-expenditures, and net-earnings for publicly traded firms are taken from Compustat. All nominal time-series are adjusted for inflation using Consumer-Price Index from BEA. Data on price deflators of non-durables and services, and on equipment and software goods, are from NIPA tables as well. Total-factor productivity data, are taken from the Federal Reserve Bank of San-Fransisco. I elaborate more on the TFP data used in section 3.2.

Aggregate asset-prices data include 3-month Treasury bill rate, the stock price and dividend on the broad market portfolio from the Center for Research in Security Prices (CRSP). I adjust the nominal short-term rate by the expected inflation to obtain a proxy for the real risk-free rate. Additionally, I collect data on equity portfolios sorted on key characteristics, such as size, book-to-market ratio, momentum, operating profitability and idiosyncratic return volatility from the Fama-French Data Library. To measure the default spread, I use the difference between BAA and AAA corporate yields, obtained from the Federal Reserve Bank of St. Louis.

3.2 Construction of Sectoral Shocks

I obtain quarterly aggregate and sectoral TFP data (Solow residual) from Fernald (2012). In computing the TFP, labor includes an adjustment for "quality" or composition. Capital services are also adjusted for changes in composition over time. I further obtain capacity-utilization adjusted TFP data from Basu et al. (2006). Using the relative prices of investment-goods, the aggregate TFP series is decomposed into separate sectoral TFP series, for the (non-structures, non-residential) "investment" sector, and "consumption" sector. "Consumption" in this context means everything that is not in the investment sector, i.e., everything other than private business equipment (e.g. non-durables and services).[16]

The use of the relative price of investment goods to obtain investment TFP innovations was originally proposed by Greenwood et al. (1997). It can be shown that if producers in both sectors have equal factor shares of capital and labor, pay the same factor prices (i.e., wages and capital rents), have similar markups, and capital flows freely between the two-sectors intra-temporally, then changes in relative TFP of both sectors equal changes in the relative price of investment.

In my benchmark case, I use the sectoral TFP time-series proposed by Fernald (2012). The sectoral TFP data of Fernald (2012) account for the time-varying output share of the investment-sector, and capture the overall TFP in each of the sector. As such, these data correspond well with my general-equilibrium setup, in which sectors' sizes are also time-varying. Yet, in section 3.7, I demonstrate that the empirical results are robust to other proxies as well.[17]

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[16]See Fernald (2012) for details. To be specific, the log-growth in aggregate TFP is defined as:

$$\Delta TFP_t = \Delta Y_t - \alpha_t \Delta K_t - (1-\alpha_t)(\Delta \text{hours}_t + \Delta \text{labor-productivity}_t)$$

where ΔY is the log-growth in gross value-added, ΔK is the log-growth in perpetual inventory stocks (calculated from disaggregated quarterly NIPA investment data), and α is capital's share of output. Let $\Delta \tilde{P}_{i,t}$ be the log-growth in the *relative* price of investment (equipment):

$$\Delta \tilde{P}_{i,t} = log(P_i/P_c)_t - log(P_i/P_c)_{t-1},$$

where P_i is the price deflator of investment-goods, and P_c is the price deflator of non-equipment goods and services. Let $w_{i,t}$ be equipment share of business output. Then consumption TFP log-growth ΔC-TFP, and investment TFP log-growth ΔI-TFP are computed by solving:

$$\begin{aligned} \Delta TFP_t &= w_{i,t}\Delta \text{I-TFP}_t + (1-w_{i,t})\Delta \text{C-TFP}_t \\ \Delta \tilde{P}_{i,t} &= \Delta \text{C-TFP}_t - \Delta \text{I-TFP}_t. \end{aligned}$$

[17]In particular, the results are robust when sectoral TFPs are adjusted for capacity-utilization, as in Basu et al. (2006). Furthermore, it is very common in the investment literature to use only the relative investment price deflator as a proxy for investment-*specific* shocks (see e.g. Greenwood et al. (1997), Fisher (2006), and

As is common in the investment literature, the log-growth in consumption TFP and investment TFP are the respective sectoral *first-moment* innovations.[18] I denote these innovations as ΔC-TFP and ΔI-TFP, respectively, where C is a short for consumption, and I is a short for investment.

To obtain second-moment (volatility) TFP shocks I follow four steps. First, I filter the sectoral TFP growth rates using an AR(k) filter, where k is chosen by Akaike Information Criterion. I do so, in order to remove any potential conditional mean from the time series, and obtain sectoral TFP residuals, denoted $\{\varepsilon_{j,t}\}, \quad j \in \{C, I\}$.

Second, I construct sectoral realized variances $RV_j, \quad j \in \{C, I\}$, from the sectoral TFP residuals, over a window of W quarters:

$$RV_{j,t-W+1\to t} = \Sigma_{k=t-W+1}^{t} \varepsilon_{j,k}^{2} \tag{3.1}$$

These realized variances capture ex-post (or backward-looking) volatility in each sector. Third, to make the volatilities forward-looking, in-line with the model, I project future sectoral log-realized variances on a set of predictors, denoted by Γ_t:

$$\log(RV_{j,t+1\to t+W}) = b_0 + b'\Gamma_t + error \tag{3.2}$$

The exponentiated fitted value of these projections are the sectoral ex-ante TFP-volatilities ($V_j = exp(\hat{b}_0 + \hat{b}'\Gamma), \quad j \in \{C, I\}$). The log transformation ensures that the ex-ante volatility measures remain strictly positive, in a similar fashion to Segal et al. (2015).

Lastly, I use the logarithm first-difference of the sectoral ex-ante TFP-volatility series, as the sectoral TFP-volatility shocks. I consider this step as a reduced-form way to obtain a proxy of second-moment shocks, that is both in-line with the construction of the first-moment innovations, and does not require further filtering. Taking the first-difference of the volatility series, also reduces their auto-correlation, and thus, alleviates potential Stambaugh (1986) biases in predictive projections. However, the results are still robust when the total ex-ante volatilities are used as well in the various projections, instead of their first-difference.

Garlappi and Song (2013a)). The results are robust to the use of the relative-price of investment deflator proxy instead. Other proxies considered are described in section 3.7.

[18] The construction of first-moment TFP innovations via log growth is identical to the empirical construction of TFP innovations in the works of Garlappi and Song (2013a) and of Kogan and Papanikolaou (2014). It is also consistent with the fact that in the model, the sectoral TFPs are random walks. However, the results are robust to filtering the sectoral TFP growth series using an $AR(k)$ filer, and using the residuals as the first-moment TFP innovations.

In the benchmark case, I set $k = 3$, and $W = 8$ quarters. Motivated by the general-equilibrium setup, the benchmark predictors I use, Γ_t, are the four variables which from a production perspective, are sufficient describe the economy's evolution: consumption and investment TFP growth, and the two sectoral realized variances. However, the results are robust to exclusion or inclusion of other predictors. Following these steps, I obtain four shocks: ΔC-TFP and ΔI-TFP, capturing (first-moment) sectoral TFP innovations, and ΔC-TFP-VOL and ΔI-TFP-VOL capturing second-moment sectoral TFP shocks. With these four shocks, I obtain a set of novel empirical facts, as illustrated in sections 3.3 - 3.5.

As the TFP of the consumption and the investment sectors comove, their volatilities are also correlated. To emphasize the distinction between the two sectoral volatilities, Figure 1 shows the component of investment TFP-volatility which is orthogonal to consumption TFP-volatility. The orthogonal component is obtained from the projection of investment TFP-volatility on consumption TFP-volatility. The residual investment TFP-volatility is procyclical. Specifically, we can see a decrease in the residual investment TFP-volatility during the Great Recession. On the other hand, the residual volatility rises during the high-tech revolution of mid to late 1990s.

3.3 Sectoral Shocks and The Macroeconomy

In this section, using the empirical proxies for sectoral volatility shocks, I document the first stylized fact, related to the interaction of sectoral volatilities and the macroeconomy.

Fact I: *Investment-sector's TFP-volatility predicts positively both the* growth rates *and the* business-cycle *component of key macroeconomic variables: consumption, output, investment, and labor; Consumption-sector's TFP-volatility predicts these quantities negatively.*

I first project contemporaneous and future cumulative macroeconomic growth rates, for horizon h quarters, on the current proxies for sectoral shocks: first-moment sectoral TFP innovations of the two-sectors, and second-moment TFP shocks of the two-sectors. In other words, I run the following regressions:

$$\begin{cases} \Delta y_t = \beta_0 + \beta_0'[\Delta\text{C-TFP}_t, \Delta\text{I-TFP}_t, \Delta\text{C-TFP-VOL}_t, \Delta\text{I-TFP-VOL}_t] + error & \text{if } h = 0 \\ \frac{1}{h}\sum_{j=1}^{h} \Delta y_{t+j} = \beta_{0,h} + \beta_h'[\Delta\text{C-TFP}_t, \Delta\text{I-TFP}_t, \Delta\text{C-TFP-VOL}_t, \Delta\text{I-TFP-VOL}_t] + error & \text{if } h > 1. \end{cases}$$

The variable y is a macroeconomic log-variable of interest, and the forecast horizon h varies between $h \in \{0, 1, 4, 12, 20\}$ quarters. Table 1 shows the slope coefficients, along with the adjusted R^2 of the regressions, for aggregate cash-flow (macroeconomic) growth variables – consumption, GDP, corporate sales and earnings. Table 2 shows the evidence for inputs growth measures – capital inputs: non-residential capital investment, corporate capital expenditures, and the relative-price of investment, as well as labor inputs: average hours worked and wages.

It is evident from these two tables that across the various macroeconomic growth rates and across all the horizons, the slope coefficient on consumption TFP innovation is always positive and almost always significant (with the exception of an insignificant negative slope for sales growth contemporaneously). This evidence is consistent with the notion that higher productivity is associated with higher growth, and increased economic activity.

With some contrast, investment TFP innovation's loadings are positive contemporaneously (and also in shorter predictive horizons), but turn negative for medium and long-run predictive projections. Investment innovations also have strictly negative loadings in aggregate prices projections: wages and the relative-price of investment. As shown in Panel A of Table 2, investment TFP innovations increase capital investment growth contemporaneously. This finding is in-line with the empirical evidence of Kogan and Papanikolaou (2014) and Kogan and Papanikolaou (2013), that investment-specific shocks (measured via the relative price of investment, or via investment-minus-consumption portfolio returns), raise firms' investment-rates contemporaneously. Yet, some of the negative loadings on investment TFP innovations, in particular for consumption and GDP, are consistent with recent empirical evidence of Basu et al. (2006) and Liu et al. (2012), that investment technology shocks can be contractionary.

Consumption TFP-volatility carries always a negative slope coefficient. It is statistically significant mostly in shorter horizons of zero quarters up to one year. This is the typical negative interaction of volatility and growth, documented by Bloom (2009) and others. By sharp contrast, investment TFP-volatility has always a positive correlation with contemporaneous and future growth. This positive interaction is also statistically significant at horizons of one-year, and three-years ahead. However, in the case of capital investment, the positive loading on investment TFP-volatility is also significant contemporaneously.

It is worth noting that the adjusted R^2s for the contemporaneous projections of GDP and capital investment are quite substantial. For GDP growth the adjusted R^2 is close to 50%, and for capital investment it is 36%. Generally, the R^2s decline with the forecast horizon.

The positive interaction of investment TFP-volatility is not limited to growth rates. In Table 3, I repeat the same projections of the former Tables, but now the dependent variable is the business-cycle component of an economic variable of interest y, averaged over the predictive horizon h. The business-cycle component is obtained via filtering the level data using a one-sided HP-filter, with a smoothing parameter of 1600. Averaging the business-cycle component is made to reduce the amount of noise, and extract the "long-term" business-cycle component of the variables of interest. For brevity, I consider in Table 3 a subset of macroeconomic variables, including consumption, GDP, capital investment, hours, and the relative-price of investment.

The Table conveys a similar message to the growth-rate evidence. Consumption TFP-volatility shocks predict negatively, while investment TFP-volatility shocks predict positively, the cyclical component of macroeconomic variables. The significance of the volatilities generally drops with the predictive horizon. For some variables, such as hours-worked, the significance of the volatility loadings is stronger in the business-cycle evidence, than in the growth-rate evidence.[19]

Though the projections in Tables 1 - 3 are multivariate, and account for the correlations between the factors, I further illustrate the impact of TFP-volatility shocks via impulse-responses, shown in Figure 2. The impulse-response functions are computed from a first-order vector autoregression (VAR(1)) that includes investment TFP-volatility, consumption TFP-volatility, investment TFP innovation, consumption TFP innovation, and the *detrended* macroeconomic variable of interest. The detrended macroeconomic variable is also standardized. I plot one-standard deviation Cholesky TFP-volatility shock responses, to detrended consumption, output and capital investment.

Figure 2 illustrates again the expansionary pattern for investment TFP-volatility, and the contractionary pattern for consumption TFP-volatility. Panels (a), (b) and (c), demonstrate that a one-standard deviation of consumption TFP-volatility shock, drops the cyclical component of consumption, investment and output by 0.13, 0.16 and 0.24 standard deviations, respectively, one-quarter after the shock hits. The negative impact persists up to ten quarters ahead. In particular for investment, the negative response is persistent up to 20 quarter ahead.

By contrast, Panels (d), (e), and (f) show that one standard-deviation shocks to investment TFP-volatility increase one-quarter ahead detrended consumption, investment and output by 0.04, 0.12, and 0.13 standard deviations, and the positive impact persists up to

[19]From the fact that the sectoral TFP volatilities impact both growth rates and cyclical components similarly, one may learn that the impact of TFP-volatilities on macroeconomic variables is not only persistent, but even tends to amplify some period after the volatility shock hits. This pattern is theoretically consistent with the existence of adjustment costs, that prevent firms from fully responding to the volatility shocks upon impact.

20 quarters onwards. Economically, the negative impact of consumption TFP-volatility is somewhat larger than the positive impact of investment TFP-volatility.

3.4 Sectoral Shocks and The Cross-Section of Returns

In this section I show the implications of sectoral first-moment TFP innovations and TFP-volatility shocks for the cross-section of stock returns. To the extent that sectoral volatilities interact with aggregate consumption growth in an opposite way, it may suggest that the marginal utility of the household is affected differently by sectoral volatilities. In-line with this conjecture, my empirical analysis yields the second stylized fact:

Fact II: *Consumption TFP-volatility has a negative market price of risk, while the market price of investment TFP-volatility is positive. Hence, the high-risk states for the investors are associated with low investment uncertainty, and high consumption uncertainty.*

Generally, a portfolio risk premium is given by the product of the market prices of fundamental risks $\Lambda = (\lambda_{\text{C-TFP}}, \lambda_{\text{I-TFP}}, \lambda_{\text{C-TFP-VOL}}, \lambda_{\text{I-TFP-VOL}})$, the variance-covariance matrix of the risk-factors, denoted by Ω, which captures the quantity of risk, and the exposure of the portfolio to the underlying macroeconomic risk β_i:

$$E[R_{i,t+1} - R_{f,t}] = \Lambda' \Omega \beta_i. \tag{3.3}$$

Given a cross-section of returns, and the risk-factors' shocks, I can estimate the equity exposures and the market prices of risks using a standard Fama and MacBeth (1973) procedure, described below.

First, I obtain the return betas by running a multivariate regression of each portfolio returns on the sectoral shocks[20]:

$$\begin{aligned} r_{i,t} \;=\; & \text{const} + \beta_{i,C-TFP} \Delta\text{C-TFP}_t \\ & + \beta_{i,I-TFP} \Delta\text{I-TFP}_t \\ & + \beta_{i,C-TFP-VOL} \Delta\text{C-TFP-VOL}_t \\ & + \beta_{i,I-TFP-VOL} \Delta\text{I-TFP-VOL}_t \\ & + \text{error}. \end{aligned} \tag{3.4}$$

[20] I obtain similar results when I use excess returns, or first-difference of the returns as a dependent variable, as a reduced-form return innovation.

The slope coefficients in the above projection, represent the portfolio's exposures to sectoral TFP innovation risks and sectoral TFP-volatility risks. Next, I obtain factor risk premia $\tilde{\Lambda}$ by running a cross-sectional regression of average excess returns on the estimated betas:

$$\overline{R_i^e} = \tilde{\lambda}_{\text{C-TFP}}\beta_{i,\text{C-TFP}} + \tilde{\lambda}_{\text{I-TFP}}\beta_{i,\text{I-TFP}} + \tilde{\lambda}_{\text{C-TFP-VOL}}\beta_{i,\text{C-TFP-VOL}} + \tilde{\lambda}_{\text{I-TFP-VOL}}\beta_{i,\text{I-TFP-VOL}} + \text{error}. \tag{3.5}$$

I impose a zero-beta restriction in the estimation and thus run the regression without an intercept. The implied factor risk premia, $\tilde{\Lambda} = (\tilde{\lambda}_{\text{C-TFP}}, \tilde{\lambda}_{\text{I-TFP}}, \tilde{\lambda}_{\text{C-TFP-VOL}}, \tilde{\lambda}_{\text{I-TFP-VOL}})$, encompass both the vector of the underlying prices of risks Λ, and the quantity of risks Ω :

$$\tilde{\Lambda} = \Omega\Lambda.$$

To compute the underlying prices of risk Λ, I pre-multiply the factor risk premia $\tilde{\Lambda}$ by the inverse of the quantity of risk matrix Ω.To obtain standard errors, I embed the two-state procedure into Generalized Method of Moments (GMM), which allows to capture statistical uncertainty in estimating jointly asset exposures and market-prices of risk.

In the benchmark implementation, the menu of cross-sectional assets includes the market return, the cross-section of ten portfolios sorted on size, ten portfolios sorted on book-to-market, and ten portfolios sorted on momentum. Panel A of Table 4 shows the market prices of risks estimates along with their t-statistics.

Panel A documents that consumption sector's TFP first-moment innovations have a positive and significant market price. This is in-line with several works (e.g. Garlappi and Song (2013a)).

The market-price of risk of investment TFP first-moment innovations is positive yet not statistically significant. While Papanikolaou (2011) and Kogan and Papanikolaou (2013) find that investment-specific innovations are negatively priced, Garlappi and Song (2013a) and Li et al. (2013) both find that these shocks carry a positive market-price. In-line with the on-going debate, I document that the market-price of risk of investment innovations, is not a strictly robust feature of the data – at least not at quarterly frequency. Though the benchmark analysis yields a positive market-price for investment innovations, as in Garlappi and Song (2013a), this market-price turns negative in some of the robustness checks. For example, when ten industry portfolios are added to the cross-section, this market price turns negative, yet with a very low t-statistic. In my model, I choose to adopt the view that investment innovations are positively priced. In *most* of the robustness checks this market price is positive. A positive sign is also consistent with an intertemporal elasticity of substitution greater than one, which is important for explaining the impact of sectoral volatilities on investment. More importantly, the market-prices of sectoral TFP-volatility shocks, as I discuss next, are robust features of the data.

Panel A also shows that the market price of investment TFP-volatility is positive, while the market-price of consumption TFP-volatility is negative. Both market prices are statistically significant. This is consistent with the effect of sectoral volatilities on the evolution of aggregate cash-flows (and consumption in particular).

The next stylized fact is evident from Panel B of Table 4:

Fact III: *For most equities, the risk exposures (betas) to consumption TFP-volatility are negative, and the risk exposures to investment TFP-volatility are positive.*

All assets have a positive exposure to consumption TFP first-moment innovations, and a negative exposure to investment TFP first-moment innovations. The latter is consistent with Papanikolaou (2011) and Kogan and Papanikolaou (2013) findings.

In addition, all equities except for portfolios comprised of very small stocks, are exposed in a similar fashion to sectoral TFP-volatility shocks. By and large, consumption TFP-volatility lowers equity valuations (negative betas), while investment TFP-volatility raises equity valuations (positive betas). Table 4 reports exposures without t-statistics to save space. In Table 5, I report industry (sectoral) portfolios' exposures to the sectoral shocks, along with t-statistics, obtained from running projection (3.4). Sorting stocks into industry portfolios is based on Gomes et al. (2009) SIC classifications for sectors.

Similarly to Panel B of Table 4, Table 5 shows that all sectors' exposures to sectoral shocks share the same pattern described earlier. In particular, the non-durables, services, and investment portfolios have positive exposure to investment TFP-volatility, and a negative one to consumption TFP-volatility. Except for two-cases in the Table, all betas are statistically significant.

3.5 The Pricing Role of Sectoral Volatilities

Section 3.4 demonstrates that the sectoral TFP-volatility shocks are priced in the cross-section of returns. Consequently, a production-based stochastic discount factor that excludes the volatility shocks is misspecified. Yet, is this misspecification also *economically* important for matching asset-pricing moments? In this section I argue that sectoral volatility shocks, and in particular in the investment sector, contribute positively and significantly to the equity premium, and can also explain a significant variation of the momentum spread, and of investment-based spreads.

To highlight the importance of the TFP-volatility shocks, I compare two factor model specifications. In the first specification, I include four risk factors: consumption and investment (first-moment) TFP innovations, and consumption and investment TFP-volatility shocks. The second model specification excludes the sectoral volatilities, and only includes two risk factors: the first-moment TFP innovations of the two-sectors. I tabulate a summary of the asset-pricing implications for the two models – in Table 6, for the four-factor model, and in Table 7, for the two-factor model.

Panel A of Tables 6 and 7 reports the *adjusted* R^2 of the second-stage projection in the Fama-Macbeth procedure (i.e., mean excess returns on cross-sectional risk exposures, as in equation (3.5)), performed separately for each of the models. The cross-sectional assets in each case are identical to those used in Section 3.4, and include ten portfolios sorted on size, ten portfolios sorted on book-to-market, and ten portfolios sorted on momentum. The fit of the four-factor model is significantly better than the two-factor specification. The adjusted R^2 rises from about 50% with only sectoral first-moment innovations, to 70% when volatilities are included.[21]

Furthermore, panel B of Tables 6 and 7 reports the factor model-implied quantile based quarterly return spreads, of several cross-sections, against their data counterpart. The dimensions tabulated include size, book-to-market, momentum, lagged firm value to capital value (Tobin's Q), operating profitability, and idiosyncratic return volatility spreads.[22]

The fit of the four-factor model is significantly improved along the momentum, Q, operating profitability, and idiosyncratic volatility dimensions, in comparison to the two-factor specification. In the data, the quarterly momentum spread amounts to 2.65%. When volatilities are included, the factor model-implied spread amounts to 0.83%. While this is only 30% of the data-spread's magnitude, in the model without volatilities, the model-implied spread bears the wrong sign (that is, low momentum portfolio earns a higher return than high momentum portfolio), and amounts to -0.50%. Similarly, model-implied spreads based on operating profitability and idiosyncratic volatility bear the opposite sign compared to the empirical counterparts when the sectoral volatilities are excluded, but become close to the empirical estimates once the volatility shocks are included. The model-implied quarterly

[21] The Akaike Information Critertion of the second-stage projection also rises from the two- to four- factor specification.

[22] Tobin's Q is measured as Market-to-Book ratio as in Hennessy, Levy, and Whited (2007). Operating profitability is measured via operating profits divided by book equity. Idiosyncratic volatility is measured via the variance of the residuals from the Fama-French three-factor model over 60 days.

Q-spread is 1.28% when volatilities are included, but only 0.41% without volatilities, while the data-spread is 0.98%.

The investment literature documents that investment first-moment TFP shocks are helpful in explaining the Value spread (see Papanikolaou, 2011), and commodity-based spreads (see Yang, 2013). Li (2014) argues that investment first-moment TFP innovations can explain the momentum spreads at annual frequency. Yet, the ability of investment first-moment innovations to explain the momentum spread is disputed in the literature. Garlappi and Song (2013a) find that the fraction of the momentum spread, captured by investment first-moment TFP innovations is low at *quarterly* frequency. Table 7 is also consistent with the notion that investment TFP first-moment innovations alone are not enough to explain the momentum spread. By sharp contrast, I find that the ability of investment TFP-*volatility* shocks to explain the momentum spread is large and economically significant.

Panel B of Table 6 shows the decomposition of the model-implied momentum spread to the contribution of each risk factor.[23] The momentum spread, emanating from investment TFP-volatility risk channel, is 2.43% compared to 2.65% in the data (90% of the momentum spread's magnitude).

In Panel C of Tables 6 and 7, I tabulate the model-implied market excess return, along with its decomposition to the risk-premia contributions coming from the different risk factors. The model-implied quarterly market excess return, when volatilities are included, is 1.63%, strikingly close to the empirical counterpart of 1.64%. For comparison, the model-implied market excess return in a model without volatilities is 1.39%. Panel C of Table 6 shows that most of the market risk premium stems from consumption TFP innovation risk, and investment TFP-*volatility* risk.

Tables 6 and 7 thus lead to the following stylized fact:

Fact IV: *Investment TFP-volatility shocks are important for the market risk premium, and explaining the magnitude of the momentum spread.*

Lastly, I examine the differential impact of sectoral TFP volatilities on the default spread in Panel A of Table 8. I project contemporaneous and future cumulative log growth rates of the default spread, on the current proxies of sectoral shocks, as specified in projection (3.3). Interestingly, I find that while consumption TFP-volatility raises the spread, investment TFP-volatility significantly *lowers* it, in predictive horizons of up to three years ahead. This

[23] The contribution of a risk factor to a model-implied return includes the risk-premium from the factor's own quantity of risk, as well as one-half of the risk-premium from the covariance terms between the risk factor and other shocks in the model.

evidence may suggest that investment TFP-volatility lowers the cost of capital for firms, thus spurring investment, consistently with the evidence of Section 3.3. The differential impact of the volatilities on the economy-wide default spread seems to be translated into an opposite incentive of firms to issue debt. Panel B of Table 8 shows that consumption TFP-volatility drops total debt growth, whereas investment TFP-volatility raises it.

3.6 Volatility Feedback to Technological Growth

Section 3.3 shows that the sectoral TFP volatilities have a significant impact on the growth of aggregate cash-flows. In this section I examine whether the sectoral volatilities also affect the evolution of production technology itself, positively or negatively. I project one-quarter ahead consumption- and investment- TFP growth rates on the current level of the four factors: two sectoral first-moment TFP innovations, and two sectoral TFP-volatilities. The results are reported in Table 9.

Table 9 shows that investment and consumption TFP growth rates depend significantly (and positively) only on their own lagged value. Beyond that, there is a positive and significant feedback between investment TFP-volatility today to one-quarter ahead consumption TFP growth. I denote this feature the 'volatility feedback'. This is the only significant interaction between second-moment shocks to first moment TFP innovations predictively.

Although not micro-founded, one can think of this volatility feedback as delayed culmination of growth options in the investment sector. In a reduced form manner, higher investment TFP-volatility could be thought of as a bundle of R&D growth options, which raises uncertainty. Some of these options would turn out to be bad, but some in the right tail would be successful. Because higher volatility also causes a delay in exercising growth options, the positive impact of the successful growth options would not be seen immediately today. But in the future (one quarter), these successful growth options are exercised. This could be manifested as improved productivity in the final good sector one quarter ahead.

The economic significance of this finding will be clarified in the model section. The empirical feedback of investment TFP-volatility to future consumption productivity would be used to quantitatively explain the positive market-price of risk of investment TFP-volatility.

3.7 Robustness

I consider various robustness checks regarding the construction of the ex-ante sectoral volatilities in the data. First, I consider different predictors for predicting future realized variances, as in projection (3.2). I add to the benchmark predictors additional variables such as the risk-free rate and the market-price dividend ratio. The summary of the key results are shown in Table 12. In unreported results, I consider different sets of predictors as well: including the default-spread as an additional predictor, or including *only* the lagged sectoral realized-variances as predictors. In all cases, the results are broadly unchanged. I also consider a different window for the realized variances construction, as in equation (3.1). In Table 13, I tabulate a summary of the results when the window is expanded to three years. The results are also largely robust when the window is shortened to just four quarters.

Next, I consider the usage of the total ex-ante volatilities as risk-factors in the various projections, as opposed to their first-difference (referred to in this work as their reduced-form shocks). The results are reported in Table 10. Similarly, I also replace the ex-ante volatilities by their realized-variance counterparts (i.e., backward-looking volatilities) in Table 14. In both cases, by and large, the findings are qualitatively similar to those reported in the benchmark specification. It is worth noting that the only feature that alters between the specifications is the market price of risk of investment TFP first-moment innovations. In the benchmark case it is positive (consistently with Garlappi and Song (2013a)), but in some of these robustness checks it turns negative (consistently with Papanikolaou (2011)). More relevant to this work, the signs of the TFP volatilities' betas and market-prices are robust.

I also consider the usage of a different proxy for sectoral volatilities. Specifically, I split the universe of Compustat firms into consumption and investment sectors, according to the classifications of Gomes et al. (2009). I then consider the dispersion of sales growth for consumption firms, versus the dispersion of sales for investment firms, as proxies for the two-sectors' technological volatilities. The summary results are reported in Table 11. Notably, dispersion differs conceptually from time-series conditional volatility of aggregate shocks. Yet, I obtain qualitatively the same results as with the benchmark proxies. Sales dispersion of consumption firms generates a contractionary impact, while sales dispersion of investment firms an expansionary one.

Lastly, I consider other modifications: (1) Filtering the sectoral TFP growth rates using an $AR(k)$ filter, and using the residuals as first-moment TFP innovations; (2) Using capacity-utilization adjusted TFPs, as in Basu et al. (2006), for sectoral productivity shocks; (3) I consider projecting the benchmark second-moment shocks on the same-sector first-moment innovations, in order to orthogonalize the volatility shocks, and alleviate concerns that the results are mechanically driven by the correlation structure of the shocks; (4) I consider using the relative-price of investment goods as an investment *specific* technology shock, against a neutral TFP. In the interest of space, I do not report these additional tables but note that across all of these modifications of the benchmark specification, I broadly confirm the key empirical results: the interactions of sectoral volatilities with growth and business-cycle of macro variables, and the asset-pricing implications of the sectoral volatility shocks.

4 The Model

Why is consumption TFP-volatility contractionary for macroeconomic quantities and prices, while investment TFP-volatility expansionary? I rationalize the findings using a quantitative framework. This section describes the general-equilibrium model. The model is quite rich, and I provide intuition regarding the role of the various model ingredients in Section 5.[24]

An overview of the economy follows below. Figure 3 provides a schematic illustration of the model players and their interactions.[25] The economy is populated by a continuum of identical households, deriving felicity from an Epstein and Zin (1989) and Weil (1989) utility over a stream of consumption-goods and leisure. The household supplies labor to two good-producing sectors: a "consumption" sector and an "investment" sector.

In each sector, there is a mass of intermediate good producers, who produce *differentiated* products: either differentiated-intermediate consumption goods or differentiated-intermediate investment goods. The intermediate good producers produce their output using a Cobb-Douglas production function over capital and labor, which is subject to sectoral TFPs, that also feature stochastic volatilities. The intermediate good producers face monopolistic competition in the product markets. They pick their nominal product price, but face adjustment costs in doing so.

In each sector, a representative aggregator converts the intermediate goods to a final composite good. The consumption-sector's aggregator sells the final consumption-good to the household for consumption. The investment aggregator produces final investment goods (capital), and sells them back to the intermediate-good producers in both sectors, who buy these goods when they wish to invest. In the economy a monetary policy authority also operates, and sets the nominal interest rate according to a Taylor (1993) rule. This Taylor

[24] Only a subset of the model assumptions are needed to rationalize the impact of volatility shocks on investment behavior. Namely, even without monopolistic competition and nominal rigidities, a two-sector of perfect competition is sufficient to explain volatilities' impact on investment, as I illustrate in section 5. Other model ingredients are placed to generate *comovement* of consumption and investment in response to volatility shocks (see Basu and Bundick (2012)), and to *quantitatively* amplify the impact of volatility shocks on real and financial quantities.

[25] The economy structure builds on the two-sector production economies of Papanikolaou (2011), Liu et al. (2012), and Garlappi and Song (2013b), but also features Epstein and Zin (1989) utility and stochastic volatility in the productivity of both sectors.

rule, along with the pricing kernel of the household, endogenously pins down inflation. Next, I describe in more detail each model ingredient.

4.1 Aggregation

The aggregator in the consumption (investment) sector produces composite or "final" consumption (investment) goods, denoted $Y_{c,t}$ ($Y_{i,t}$). $Y_{c,t}$ will be used for consumption by the household, while $Y_{i,t}$ will be equal to aggregate investment in the economy. Production of the composite consumption (investment) good requires a continuum of differentiated intermediate goods as inputs, denoted by $\{y_{c,t}(n)\}_{\{n\in[0,1]\}}$ ($\{y_{i,t}(n)\}_{\{n\in[0,1]\}}$). The aggregation technology in both sectors is symmetric, so I describe it below jointly.

The production of the final composite $Y_{j,t}$, in sector $j \in \{c,i\}$, converts the intermediate goods of sector j into a final-good using a constant elasticity of substitution (CES) technology:

$$Y_{j,t} = \left[\int_0^1 (y_{j,t}(n))^{\frac{\mu_j - 1}{\mu_j}} dn \right]^{\frac{\mu_j}{\mu_j - 1}}, \quad j \in \{c,i\}. \tag{4.1}$$

The parameter $\mu_j, \quad j \in \{c,i\}$, measures the degree of substitutability among the intermediate goods. Perfect competition among the intermediate good producers implies $\mu_j \to \infty$. Under finite μ_j, the intermediate goods in sector j are not perfect substitutes, and thus each intermediate good producer possesses some monopolistic power.

Each intermediate good producer of variety n in sector j sells its intermediate good to the aggregator at a nominal price $p_{j,t}(n)$. Each final good producer (aggregator) in sector j, sells its composite output $Y_{j,t}$ at nominal price $P_{j,t}$. The aggregator in each sector $j \in \{c,i\}$ faces perfectly competitive market, thus solving:

$$\max_{\{y_{j,t}(n)\}} P_{j,t} Y_{j,t} - \int_0^1 p_{j,t}(n) y_{j,t}(n) dn, \quad j \in \{c,i\}, \tag{4.2}$$

where $Y_{j,t}$ is given by (4.1), and the prices are taken as given. The first-order condition of (4.2) yields the demand for differentiated intermediate good of type n in sector j:

$$y_{j,t}(n) = \left[\frac{p_{j,t}(n)}{P_{j,t}} \right]^{-\mu_j} Y_{j,t}, \quad j \in \{c,i\}. \tag{4.3}$$

As the market for final goods is perfectly competitive, the final-good producing firm (aggregator) in sector j earns zero profits in equilibrium. This condition, along with equations (4.2) and (4.3), yields the aggregate price index in sector j, given by:

$$P_{j,t} = \left[\int_0^1 (p_{j,t}(n))^{1-\mu_j} dn \right]^{\frac{1}{1-\mu_j}}, \quad j \in \{c, i\}. \tag{4.4}$$

4.2 Intermediate Good Production

4.2.1 Sectoral Intermediate-Good Producers

This section describes the production and price-setting decisions of intermediate goods. To save space, and since the description of production in the consumption sector and investment sector is symmetric, I describe them jointly.

Intermediate goods in sector $j \in \{c, i\}$ are differentiated, and each variety is denoted by $n \in [0, 1]$. Each intermediate-good producer n in sector j rents labor $n_{j,t}(n)$ from the household, and owns capital stock $k_{j,t}(n)$. The intermediate-good producer n in sector j produces an intermediate good $y_{j,t}(n)$, using a constant returns-to-scale Cobb-Douglas production function over capital and labor, and subject to sectoral TFP shocks $Z_{j,t}$:

$$y_{j,t}(n) = Z_{j,t} k_{j,t}(n)^{\alpha_j} n_{j,t}(n)^{1-\alpha_j}, \quad j \in \{c, i\}, \tag{4.5}$$

where α_j is the capital share of output of intermediaries in sector j, and $Z_{j,t}, \quad j \in \{c, i\}$, are the sectoral TFPs. Each intermediate good producer who wishes to invest an amount $i_{j,t}(n)k_{j,t}(n)$, where $i_{j,t}(n)$ is the investment-rate, must purchase $\Phi_k(i_{j,t}(n))k_{j,t}(n)$ units of capital goods, under an equilibrium price of investment goods $P_{i,t}$. Following Papanikolaou (2011) and Garlappi and Song (2013b), the convex adjustment cost function $\Phi_k(i)$ is given by:

$$\Phi_k(i) = \frac{1}{\phi}(1 + i)^{\phi} - \frac{1}{\phi}. \tag{4.6}$$

The parameter ϕ captures the degree of adjustment cost. When $\phi = 1$ there are no adjustment costs. When $\phi = 2$, adjustment costs are quadratic. Capital of each producer of type n in sector j, depreciates at rate δ, and evolves according to:

$$k_{j,t+1}(n) = (1 - \delta + i_{j,t}(n))k_{j,t}(n). \tag{4.7}$$

Intermediate good producers in both sectors are price takers in the input market, and monopolistic competitors in the product market. They face a quadratic costs of changing their nominal output price $p_{j,t}(n)$ each period, similarly to Rotemberg (1982), given by:

$$\Phi_{P,j}(p_{j,t}(n), p_{j,t-1}(n)) = \frac{\phi_{P,j}}{2}\left[\frac{p_{j,t}(n)}{\Pi_j p_{j,t-1}(n)} - 1\right]^2 p_{j,t-1}(n) Y_{j,t}, \quad j \in \{c, i\}, \tag{4.8}$$

where $Y_{j,t}$ is the final composite good in sector j, Π_j is the steady-state inflation in the j sector, and $\phi_{P,j}$ governs the degree of nominal rigidity in sector j. The assumption of Rotemberg (1982), as opposed to Calvo (1983) pricing, implies that I can model the intermediate good production in each sector as a single representative intermediate goods-producing firm. In all, the period nominal dividend of intermediate good producer of type n in sector j, $d^{\$}_{j,t}(n)$, in terms on nominal consumption goods, is given by:

$$d^{\$}_{j,t}(n) = p_{j,t}(n)y_{j,t}(n) - W_t n_{j,t}(n) - P_{i,t}\Phi_k(i_{j,t}(n))k_{j,t}(n) - \Phi_{P,j}(p_{j,t}(n), p_{j,t-1}(n)), \quad j \in \{c, i\}. \tag{4.9}$$

Each intermediate good producer n, chooses optimal hiring, investment, and nominal output price, to maximize the firm's market value, taking as given nominal wages W_t, the nominal price of investment goods $P_{i,t}$, the demand for differentiated intermediate good n in sector j given by (4.3), and the nominal stochastic discount factor of the household $M^{\$}_{t,t+1}$. Specifically, the intermediate good-producers maximize:

$$V^{\$}_{j,t}(n) = \max_{\{n_{j,s}(n), k_{j,s}(n), p_{j,s}(n)\}} \quad E_t \Sigma_{s=t}^{\infty} M^{\$}_{t,t+s} d^{\$}_{j,t+s}(n), \tag{4.10}$$

subject to (4.7), (4.9), and the demand constraint:

$$\left[\frac{p_{j,t}(n)}{P_{j,t}}\right]^{-\mu_j} Y_{j,t} \leq Z_{j,t} k_{j,t}(n)^{\alpha_j} n_{j,t}(n)^{1-\alpha_j}, \quad j \in \{c, i\}. \tag{4.11}$$

Notice that $V^{\$}_{j,t}(n), \quad j \in \{i, c\}$, is measured in nominal consumption units. Define the real firm value $V_{j,t}(n)$, and real dividend $d_{j,t}(n)$ (in terms of real consumption goods), for firm n in sector j, by:

$$V_{j,t}(n) = V^{\$}_{j,t}(n)/P_{c,t}; \quad d_{j,t}(n) = d^{\$}_{j,t}(n)/P_{c,t}. \tag{4.12}$$

Lastly, define the real *growth* rate in aggregate investment expenditures (in terms of real consumption goods) as $\Delta I_t = \frac{(P_{i,t}/P_{c,t})Y_{i,t}}{(P_{i,t-1}/P_{c,t-1})Y_{i,t-1}}$, and the *growth* rate in the *relative* price of investment goods by $\Delta P_{i,t} = \frac{P_{i,t}/P_{c,t}}{P_{i,t-1}/P_{c,t-1}}$.

4.2.2 Productivity Shocks

The production in the investment sector is subject to a sectoral TFP shock, denoted $Z_{i,t}$, and similarly, the production in the consumption sector is subject to a sectoral TFP shock denoted $Z_{c,t}$. The sectoral TFP growth rates are characterized as follows:

$$\frac{Z_{i,t}}{Z_{i,t-1}} = \mu_{z,i} + \tilde{\varepsilon}_{i,t}, \tag{4.13}$$

$$\frac{Z_{c,t}}{Z_{c,t-1}} = \mu_{z,c} + \tilde{\varepsilon}_{c,t}, \tag{4.14}$$

where $\tilde{\varepsilon}_{i,t} = \sigma_{zi,t-1}\varepsilon_{i,t}$, and $\tilde{\varepsilon}_{c,t} = \tau(\sigma^2_{zi,t-1} - \sigma^2_{zi,0}) + \sigma_{zc,t-1}\varepsilon_{c,t}$. The shocks $\varepsilon_{i,t}$ and $\varepsilon_{c,t}$ are orthogonal, and are i.i.d. standard Normal.[26] Driven by the empirical findings of Section 3.6, equation (4.14) shows that I incorporate a positive volatility feedback from investment-technology volatility, $\sigma^2_{zi,t-1}$ to one-period-ahead consumption TFP growth, which is governed by the parameter $\tau > 0$. The processes $\sigma_{zc,t}$ and $\sigma_{zi,t}$ capture time-variation in the volatility of sectoral growth shocks. They follow independent AR(1) processes:

$$\sigma^2_{zi,t} = (1 - \rho_{\sigma,zi})\sigma^2_{zi,0} + \rho_{\sigma,zi}\sigma^2_{zi,t-1} + \sigma_{w,i}\varepsilon_{\sigma,i,t}, \tag{4.15}$$

$$\sigma^2_{zc,t} = (1 - \rho_{\sigma,zc})\sigma^2_{zc,0} + \rho_{\sigma,zc}\sigma^2_{zc,t-1} + \sigma_{w,c}\varepsilon_{\sigma,c,t}, \tag{4.16}$$

where the volatility shocks $\varepsilon_{\sigma,i,t}$ and $\varepsilon_{\sigma,c,t}$ are i.i.d. over time and are standard Normal.

4.3 Household

The economy is populated by a mass of identical households, or alternatively, by a one representative household. The representative household supplies total labor N_t, which flows to the consumption and investment sectors. It derives utility from an Epstein and Zin (1989) and Weil (1989) utility over a stream of consumption-goods C_t and disutility from labor N_t:

$$U_t = \left\{(1-\beta)\left[C_t(1-\xi N_t^{\eta})\right]^{1-1/\psi} + \beta\left(E_t U_{t+1}^{1-\gamma}\right)^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}}, \tag{4.17}$$

[26] Notice that I do not exponentiate the right-hand side of the sectoral growth rates in equations (4.13), and (4.14). Thus, TFP growth rates are normal, instead of log-normal. The motivation for this modeling choice is to exclude any hard-wired Jensen effect that can mechanically yield an impact of volatility on the *mean* growth rate. Moreover, the parameters μ_{zc} and μ_{zi} will be set to values above one, while the shocks are small, ensuring the growth rate is never negative in any population simulation. However, exponentiating the growth rates to ensure positivity does not change the qualitative or quantitative results of this work.

where β is the time discount-rate, γ is the relative risk aversion, ψ is the intertemporal elasticity of substitution (IES), ξ is the amount of disutility from labor, and η is the sensitivity of disutility to working hours. When $\gamma = \frac{1}{\psi}$, the utility becomes time-separable power utility. When $\gamma > (<) \frac{1}{\psi}$ the household has preferences exhibiting early (late) resolution of uncertainty. The preferences nest a class of multiplicative preferences over consumption and labor, as discussed in King, Plosser, and Rebelo (1988).

The household derives income from labor, as well as from the dividends of well-diversified portfolio of intermediate consumption and investment good producers. She chooses the labor supply and consumption to maximize her lifetime utility, subject to the following budget constraint:[27]

$$\max_{\{C_s, N_s\}} \quad U_t, \quad \text{s.t. } P_{c,t}C_t = W_tN_t + \int_0^1 d_{c,t}^{\$}(n)dn + \int_0^1 d_{i,t}^{\$}(n)dn, \tag{4.18}$$

where $P_{c,t}$ is the nominal price of final consumption goods, and W_t is the nominal market wage.

From the consumer problem, I can obtain the nominal SDF used to discount the nominal dividend of intermediate-good producing firms in *both* sectors:

$$M_{t+1}^{\$} = \beta \left(\frac{C_{t+1}}{C_t}\right)^{-1/\psi} \left(\frac{1-\xi N_{t+1}^{\eta}}{1-\xi N_t^{\eta}}\right)^{1-1/\psi} \left(\frac{U_{t+1}}{\left(E_t U_{t+1}^{1-\gamma}\right)^{\frac{1}{1-\gamma}}}\right)^{1/\psi-\gamma} \frac{P_{c,t}}{P_{c,t+1}}. \tag{4.19}$$

4.4 Monetary Authority

The economy is cashless. The monetary authority sets the nominal log-interest rate $r_t^{\$}$ according to a Taylor (1993) rule. Thus, $r_t^{\$}$ evolves as follows:

$$r_t^{\$} = \rho_r r_{t-1}^{\$} + (1-\rho_r)(r_{ss}^{\$} + \rho_\pi(\pi_t - \pi_{ss}) + \rho_y(\Delta y_t - \Delta y_{ss})) \tag{4.20}$$

where π_t is log inflation (in the consumption sector) defined as $\pi_t = \log\left(\frac{P_{c,t}}{P_{c,t-1}}\right)$, and where Δy_t is log-growth of real total output, $\Delta y_t = \log\left(\frac{Y_{c,t}+P_{i,t}/P_{c,t}Y_{i,t}}{Y_{c,t-1}+P_{i,t-1}/P_{c,t-1}Y_{i,t-1}}\right)$. $r_{ss}^{\$}$, π_{ss}, and Δy_{ss} are the steady-state log-levels of nominal interest rate, inflation, and output growth.

[27] This is a simplified budget constraint. I implicitly imposed the market-clearing condition that the nominal bond holding of the household is zero every period ($B_t = B_{t+1} = 0$), and the household is the owner of all shares for all firms ($\omega_{j,t}(n) = \omega_{j,t+1}(n) = 1, \quad j \in \{i,c\}, n \in [0,1]$, where $\omega_{j,t}(n)$ is the fraction of firm n in sector j held by the household).

4.5 Equilibrium

In equilibrium, (nominal) wage W_t, price of investment goods $P_{i,t}$, and consumption-sector inflation π_t, are set to clear all markets:

- Labor market clearing:

$$\int_0^1 n_{c,t}(n)dn + \int_0^1 n_{i,t}(n)dn = N_t. \tag{4.21}$$

- Consumption-good market clearing:

$$C_t = Y_{c,t}. \tag{4.22}$$

- Investment-good market clearing:

$$\int_0^1 \Phi_k(i_{c,t}(n))K_{c,t}(n)dn + \int_0^1 \Phi_k(i_{i,t}(n))K_{i,t}(n)dn = Y_{i,t}. \tag{4.23}$$

- Zero net supply of nominal bonds:

$$\frac{1}{R_t^{\$}} = E_t[M_{t+1}^{\$}] \tag{4.24}$$

An equilibrium consists of prices and allocations such that (i) taking prices and wage as given, each household's allocation solves (4.18); taking aggregate prices and wage as given, firm's allocations in each sector $j \in \{c, i\}$ solve (4.10); (iii) labor, consumption-good, investment-good and bond markets clear.

I am looking for a symmetric equilibrium, in which all intermediate good firms, in both sectors, choose the same price $P_{j,t}(n) = P_{j,t}$, employ the same amount of labor $n_{j,t}(n) = n_{j,t}$, and choose to hold the same amount of capital $k_{j,t}(n) = k_{j,t}$.

5 Model Intuition

To understand the model intuition, in this section I shut down certain channels, to highlight the core economic forces of the model. As I illustrate below, even in a stripped-down perfect-competition model, I am able to rationalize the impact of volatility shocks on investment, and the risk-exposures of firms to the sectoral shocks. Yet, the simplified model described below generates divergence of investment and consumption in response to volatility shocks, and hence, cannot rationalize the impact of volatility shocks on consumption. This could also result in counterfactual market-prices of volatility risks. The layers of monopolistic competition and nominal rigidities address this matter.

To facilitate the discussion, assume a two-sector economy under perfect competition, inelastic labor supply, and without adjustment costs.[28] Under these assumptions, I can collapse the model of Section 4 to a representative agent problem, as follows:

$$V_t(k_{ct}, k_{it}, z_{ct}, z_{it}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} \left\{(1-\beta)C_t^{1-1/\psi} + \beta\left(E_t V_{t+1}(k_{ct+1}, k_{it+1}, z_{ct+1}, z_{it+1})^{1-\gamma}\right)^{\frac{1-1/\psi}{1-\gamma}}\right\}^{\frac{1}{1-1/\psi}} \quad (5.1)$$

s.t.

$$C_t = z_{ct} k_{ct}^{\alpha} n_{ct}^{1-\alpha} \quad (5.2)$$

$$Y_{i,t} = z_{it} k_{it}^{\alpha} n_{it}^{1-\alpha} \quad (5.3)$$

$$k_{c,t+1} = (1-\delta)k_{ct} + I_{ct} \quad (5.4)$$

$$k_{i,t+1} = (1-\delta)k_{it} + I_{it} \quad (5.5)$$

$$I_{ct} + I_{it} = Y_{i,t} \quad (5.6)$$

$$n_{ct} + n_{it} = 1, \quad (5.7)$$

[28] Specifically, I assume that (1) There is no disutility from labor $\xi = 0$, so labor supply is inelastic; (2) $\mu_j \to \infty, \quad j \in \{c, i\}$, implying perfect competition in both sectors; (3) Assume $\tau = 0$, that is, no volatility feedback to future TFP growth; (4) $\phi = 1$, so there are no capital adjustment costs ; (5) The capital share of output is the same in both sectors $\alpha_c = \alpha_i = \alpha$.

where $\frac{z_{jt}}{z_{j,t-1}} = \sigma_{zj,t-1}\varepsilon_{j,t}, \quad j \in \{c,i\}$.[29] In appendix A, I show that the solution to program (5.1) is equal to the solution of the maximization program (5.8), given by:

$$\tilde{V}_t(k_{ct}, k_{it}, z_{it}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} \Bigg\{ (1-\beta)\left(k_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} + \underbrace{\beta \left(E_t \left(\frac{z_{ct+1}}{z_{ct}} \right)^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}}}_{\tilde{\beta}_t} \left(E_t \tilde{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}} \tag{5.8}$$

s.t.

(5.3), (5.4), (5.5), (5.6), and (5.7),

$$\frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t}\varepsilon_{zc,t+1},$$

$$\frac{z_{it+1}}{z_{it}} = \mu_{zi} + \sigma_{zi,t}\varepsilon_{zi,t+1}.$$

The equivalence of programs (5.1) and (5.8) relies on the fact that the detrended value function of the social planner is homogeneous of degree one in consumption TFP growth. Homogeneity of degree one in consumption TFP growth stems from the fact that z_{ct} is random walk, and from the fact that an Epstein-Zin utility is a homogeneous of degree one function.

5.1 Sectoral Volatilities and Investment Implications

To understand the impact of consumption TFP-volatility on investment, it is constructive to realize that higher consumption TFP-volatility, $\sigma_{zc,t}$, increases the social planner's effective impatience, under the case of early resolution of uncertainty. To see this, notice first that in maximization program (5.8), the ex-ante expectation of consumption TFP growth (that is, the expression $\tilde{\beta}_t = \beta \left(E_t \left(\frac{z_{ct+1}}{z_{ct}} \right)^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}}$) acts like a time "preference shock" that changes in the effective time-discount rate of the planner.

When $\gamma > 1$, $(\cdot)^{(1-\gamma)}$ is a convex function. With more consumption TFP-volatility (higher σ_{zc}), $E_t \left(\frac{z_{ct+1}}{z_{ct}} \right)^{1-\gamma}$ increases by Jensen's inequality. When the agent has *early resolution of*

[29] In program (5.1) the sectoral volatilities, $\sigma_{zc,t}$ and $\sigma_{zi,t}$, are also carried as state variables. For brevity of notation, I omitted them from the vector of state variables.

uncertainty preferences, $\psi > 1$, and the expression $\frac{1-1/\psi}{1-\gamma}$ is negative. Thus, higher σ_{zc} translates into a *lower* effective discount factor $\tilde{\beta}$. In other words, the representative agent puts lower weight on the continuation value. This implies a more impatient agent. Moreover, consumption TFP-volatility only affects impatience, as the growth of z_c appears nowhere else in the program, except for its *ex-ante* impact on $\tilde{\beta}_t$.

As a result of greater impatience, when σ_{zc} rises, the agent decides to shift her consumption profile to the present.[30] To implement such policy, the agent would shift labor to the consumption sector, to increase consumption today; she would also increase investment in the consumption sector, to ensure higher consumption in near-future. Consequently, investment sector's labor drops ($n_{i,t} \downarrow$), and investment sector's investment drops. Since capital in the investment sector is predetermined, but investment's labor drops, *higher consumption TFP-volatility lowers aggregate investment, in-line with the empirical findings.*

Notice, that the impact of σ_{zc} on the agent's patience depends on the preference parameters. When $\gamma = 0, 1$, there is no Jensen effect, and so consumption TFP-volatility would not impact $\tilde{\beta}_t$. If $\psi < 1$ (late resolution of uncertainty preferences), consumption technology volatility would boost investment, as the agent becomes more patient (higher $\tilde{\beta}_t$).[31]

The program (5.8) shows that consumption TFP *ex-ante* expectations change the effective discount rate. Beyond that, under the specification for z_c growth, consumption TFP shocks have no other effect ex-post except for being a multiplicative shock that "rescales" consumption (see equation (5.2)). This is a transitory (short-run) impact.[32] By contrast, investment innovations z_i affect multi-period stock of aggregate capital dynamics, which flows to *both* sectors. Investment innovations, consequently, have a long-run and persistent impact. When these shocks become more volatile, they induce a strong *precautionary saving* motive.[33]

[30] An alternative intuitive argument for this claim, is that under early resolution of uncertainty case the agent dislikes uncertainty. To minimize her exposure to volatility build-up in the future, and void capital loss, she prefers shifting her consumption profile as much as possible to the present.

[31] The dependence of investment's response to consumption TFP-volatility on the value of IES is consistent with the works of Levhari and Srinivasan (1969), Sandmo (1970), and Obstfeld (1994). In a one-sector context, these studies analyze the impact of higher volatility of multiplicative shocks, which only affect the riskiness of capital (similarly to consumption TFP). These models share the prediction that for high values of IES, the substitution effect dominates, and higher volatility induces less investment.

[32] The notion that consumption TFP has a short-run impact, that is, rescales consumption traces back to Kimball (1994).

[33] A necessary condition for precautionary saving is Decreasing Absolute Risk Aversion (see e.g. Leland, 1968 ;Kimball and Weil, 2009), satisfied by Epstein and Zin (1989) utility. Quantitatively, I find that the motive to hedge against low consumption states, in response to higher investment TFP-volatility, prevails the substitution effect for both high and low IES values. This is consistent with the study of Jones et al. (2005), who show that in a one-sector economy, and under most realistic calibrations, higher volatility raises savings and growth in equilibrium.

When TFP-volatility of the investment sector rises (higher σ_{zi}), it implies that in the future the probability of having sub-optimal amount of investment-goods rises. This would inhibit the ability to smooth consumption, as aggregate investment goods flow to both sectors, much like total output in a one-sector economy. The household has a strong incentive to invest more in the investment sector, and consume less, by shifting labor to the investment sector ($n_{i,t} \uparrow$). Implementing such a policy, ensures higher aggregate capital in the future. Capital can be used for both consumption and investment production. Hence, it acts as a buffer of savings. If a bad investment TFP shock is realized, the buffer of capital can be used to smooth consumption. Higher investment partially hedges the investment TFP-volatility shock. Consequently, *higher investment TFP-volatility increases aggregate investment, in-line with the empirical findings.*

5.2 Sectoral Volatilities and Pricing Implications

The illustrated logic shows that investment TFP-volatility, σ_{zi}, increases the demand for investment goods, while consumption TFP-volatility, σ_{zc}, lowers the demand for investment goods (when IES is greater than one). As a result, the relative price of new investment goods (in the decentralized economy) intuitively increases when σ_{zi} rises, but drops when σ_{zc} rises. To see this more formally, let $q_{c,t}$ be the Lagrange multiplier of constraint (5.4), let $q_{i,t}$ be the Lagrange multiplier of constraint (5.5), and let $P_{i,t}$ be the Lagrange multiplier of constraint (5.3).[34] From first-order conditions of program (5.1), and in particular, from equating the marginal productivity of labor in both sectors, one obtains:

$$P_{i,t} = q_{i,t} = q_{c,t}, \tag{5.9}$$

$$P_{i,t} = \frac{z_{c,t}}{z_{i,t}} \left(\frac{k_{c,t}}{k_{i,t}} \frac{n_{i,t}}{n_{c,t}} \right)^{\alpha}. \tag{5.10}$$

Since higher consumption TFP-volatility σ_{zc} lowers $n_{i,t}$ and raises $n_{c,t}$, the price of new investment goods $P_{i,t}$ (measured here in real consumption units) must fall by equation (5.10). Likewise, higher investment TFP-volatility σ_{zi} increases $n_{i,t}$ and lowers $n_{c,t}$, causing the price $P_{i,t}$ to rise.

Generally, the marginal value of assets in place (i.e., Tobin's Q: q_c or q_i), should equal the marginal cost of new capital (P_i), times the marginal adjustment cost (installation cost). In the absence of adjustment costs, we obtain equation (5.9), which implies that the price of installed capital is equal in the consumption and investment sectors. Thus, consumption

[34] I normalize all multipliers by the marginal utility from consumption at time t, to parallel the multipliers with prices of the decentralized economy

TFP-volatility lowers $q_{c,t}$ and $q_{i,t}$, and the opposite happens in response to investment TFP-volatility.

Firms in the model exhibit constant returns to scale in capital and labor. By a standard argument, Tobin's Q is a sufficient statistic for the (ex-dividend) firm values. Higher σ_{zi} increases $P_{i,t}$ and so increases both $q_{i,t}$ and $q_{c,t}$. This implies that higher investment TFP-volatility increases firms' values in both sectors, and by definition, $\beta_{\text{j,I-TFP-VOL}} > 0, \quad j \in \{c, i\}$. The exact opposite logic applies to consumption TFP-volatility, and implies $\beta_{\text{j,C-TFP-VOL}} < 0, \quad j \in \{c, i\}$. *The risk-exposure patterns with respect to sectoral volatility shocks, are consistent with the data.*

5.3 Sectoral Volatilities and The Role of Nominal Rigidities

The intuition of sections 5.1 and 5.2 demonstrates that in the perfect-competition model, investment expenditures rise in response to investment TFP-volatility, and drop in response to consumption TFP-volatility, in-line with the data. Yet, in the simplified setup, consumption and aggregate investment diverge in response to volatility shocks. As a result, consumption TFP-volatility counterfactually boosts consumption, not only contemporaneously but also in the future.[35] Counterfactual consumption behavior also induces a counterfactual impact on the market-price of consumption TFP-volatility risk.

The full version of the model features time-varying markups, that rely on monopolistic competition in the two sectors, along with sticky prices. As suggested in Basu and Bundick (2012) and Fernández-Villaverde et al. (2015), these model features make consumption and aggregate investment expenditures to commove with respect to sectoral volatility shocks. Specifically, when sticky prices are added (in particular, to consumption producing firms), consumption and investment expenditures *both* decrease in response to consumption TFP-volatility. The intuition is described below.

Section 5.1 shows that higher consumption TFP-volatility makes the agent more impatient. This increases the demand for consumption goods, and causes the agent to desire to supply more labor to the consumption sector. As a consequence, wages and the price of investment drop.[36] Thus, the marginal cost of producing consumption goods declines. When monopolistic competition is added, along with nominal price rigidity, higher consumption

[35] In the data, consumption TFP-volatility drops both consumption and investment. See Figure 2.

[36] Wages move in the simplified model in an opposite direction to consumption labor. The price of investment drops due to decreased demand for capital.

TFP-volatility causes the markups of consumption producing firms to rise, due to a drop in their marginal production costs.[37]

Higher markups of consumption producing firms lower the demand of these firms for labor at any given level of wages. This is because higher markups are equivalent to a higher degree of monopolistic power, which has a rationing impact on the quantity produced, and involves less utilization of labor.[38] Differently put, facing higher markups the consumption good producers would have optimally liked to reduce their prices, in order to drop markups, and increase their capacity. However, due to the nominal price rigidities, the consumption producing firms are limited in doing so. Since these firms cannot expand their capacity by lowering their output price, they demand less labor.

If the decline in labor demand from consumption producing firms (due to higher markups) is sufficiently strong, higher consumption TFP-volatility would cause these firms to hire less. Hence, *consumption drops upon a positive consumption TFP-volatility shock, which is consistent with the data.*

As labor flows out of the consumption sector, and into the investment sector, production of investment goods ($Y_{i,t}$) rises. The increased supply of investment goods (rise in $Y_{i,t}$), along with the reduced demand for these products from the household (due to higher effective impatience), causes their relative price P_i to decline even further.

If the decline in the relative price of investment P_i is strong enough, investment *expenditures*, defined as $I_t = P_{i,t}Y_{i,t}$, would drop in response to consumption TFP-volatility shock. This would happen simultaneously with a decline in consumption, as seen in the data.

6 Quantitative Model Results

6.1 Calibration

Table 15 shows the parameter choices of the model in the Benchmark case. The model is calibrated at quarterly frequency. There are three main parameter groups.

[37]With Rotemberg pricing, gross markup equals the inverse of the real marginal costs.

[38]The demand curve for labor from consumption producing firms is given by:

$$W_t = (1-\alpha)\frac{1}{\theta_{c,t}}k_{ct}^{\alpha}n_{ct}^{-\alpha},$$

where W_t is aggregate wage, and $\theta_{c,t}$ is the markup in the consumption sector. Thus, a higher markup $\theta_{c,t}$, shifts the labor demand curve of consumption producing firms downwards. As a result, consumption TFP-volatility shock makes consumption producing firms to demand less labor.

Production and technologies parameters. I set $\alpha_i = \alpha_c = 0.33$, so that the labor share in each sector is about 2/3. The quarterly depreciation rate is 0.015, which implies annual depreciation of 6%. Similarly to Papanikolaou (2011), the capital adjustment cost parameter is $\phi = 1.2$. I set the growth rates of the sectoral TFPs, μ_{zc} and μ_{zi}, to values that are consistent with the empirical estimates of Fernald (2012) and Basu et al. (2006), and such that the steady state growth rate of per-capita consumption is about 2%. The ratio between the log of μ_{zi} and μ_{zc} is about 2, which is consistnet also with the estimates obtained by Liu, Waggoner, and Zha (2011). This ratio also matches the model-implied growth rate for the relative price of investment to the data. The unconditional volatilities of the sectoral TFP shocks $\sigma_{zc,0}$ and $\sigma_{zi,0}$, are also close to the empirical estimates of Fernald (2012) and of Justiniano et al. (2010). They are set to match the volatility of consumption growth and investemnt growth. The ratio of $\sigma_{zi,0}$ to $\sigma_{zc,0}$ is 2, which is in-line with the calibration of Garlappi and Song (2013b). The peristence of the stochastic volatility in both sectors ρ_σ is set to 0.95, which is higher than Basu and Bundick (2012), but smaller than the estimate of Bansal and Shaliastovich (2013). The standard deviation of the volatility shock in each sector is set such that the ratio between the standard deviation of the sectoral volatility process to its unconditional mean is similar to the empirical estimate. The feedback from investment TFP-volatility to one quarter ahead consumption TFP growth is $\tau = 1.5$, which falls in the 90%-confidence interval of its empirical estimate.

Preference parameters. The time discount factor is $\beta = 0.997$, close to the value set in both Liu et al. (2012) and Garlappi and Song (2013b), and allows to closely match the value of the real risk-free rate. The relative risk aversion γ is set to 25. Though this number is quite high, it is consistent with and even smaller than some estimates at quarterly frequency (see e.g. Bansal and Shaliastovich, 2013; Van Binsbergen, Fernández-Villaverde, Koijen, and Rubio-Ramírez, 2012; and Rudebusch and Swanson, 2012). The intertemporal elasticity of substitution is set to 1.7, consistently with Bansal, Kiku, and Yaron (2012) and Bansal and Shaliastovich (2013). The sensitivity of disutility to working hours η is set to 1.4, consistently with Jaimovich and Rebelo (2009). The degree of disutility to working hours ξ is chosen such that in the deterministic steady state, the household works roughly 20% of their time.

Nominal rigidities and monetary policy parameters. Monetary policy parameters are consistent with Basu and Bundick (2012) and are standard in the literature. I set $\rho_r = 0.5$, $\rho_\pi = 1.5$, and $\rho_\pi = 0.5$. The nominal risk-free steady-state is set such that the deterministic steady-state inflation rate is 0.005 per quarter, or 2% per annum. I choose market power parameters of $\mu_c = \mu_i = 4$, which implies on average a 25% markup for firms in both sectors, and is identical to the market power set in the work of Garlappi and Song (2013b). Lastly, the nominal adjustment cost parameter is set to $\phi_C = 250$, and contributes to matching the volatility of the relative price of investment. This value is slightly higher, but of a similar magnitude to the parameter used in Basu and Bundick (2012) of 160.

I solve the model numerically via third-order perturbations method around the stochastic steady state, and using the above benchmark calibration. A characterization of the equilibrium conditions is specified in Appendix B.

6.2 Macroeconomic Moment Implications

I simulate the model at quarterly frequency and time-aggregate the model-implied time-series to form annual observations. The mean, standard deviation, and auto-correlation moments of annual real (log) consumption growth, investment expenditure growth, output growth, and the growth in the relative price of investment, are reported in Table 16, along with their empirical counterparts. Almost all data moments fall inside the model-implied 90%-confidence intervals.

Specifically, consumption growth mean is about 2% in the model and in the data. In the model, the standard deviation of consumption growth is about 2.2%, while the standard deviation of output growth is 3%. These estimates are slightly higher than the data counterparts of 1.52% and 2.53%, respectively, for the sample of 1947-2014. Yet, the model-implied standard deviations are consistent with the long-run sample (1930-2014) data volatilities. The auto-correlation of consumption growth is 0.54 in the model, versus 0.49 in the data. The standard deviation and auto-correlation of investment expenditure growth are 6.6% and 0.30 in the model, closely related to a standard deviation of 6.75% and autocorrelation of 0.18 in the data. The mean growth rate of the relative price of investment is -0.97% in the data, while it is -0.95% in the model. The model-implied volatility of the relative investment price growth is 3.48%, closely matching its empirical counterpart of 3.62%.

6.3 Sectoral Shocks and Macroeconomic Implications

In this Section I analyze the impact of sectoral first-moment and volatility TFP shocks on macroeconomic quantities in the model. I document in the benchmark case a positive impact of investment TFP-volatility on macro aggregates, and a negative impact of consumption TFP-volatility on macro aggregates, consistently with the data.

I plot impulse-responses from sectoral shocks to key macroeconomic variables.[39] The impulse-responses are computed for three separate model calibrations: (1) the benchmark case; (2) an identical calibration to the benchmark case, but in which there is no volatility feedback from investment TFP-volatility to future consumption TFP (i.e., $\tau = 0$); (3) an identical calibration to the benchmark case, but in which there is no volatility feedback, *and* no monopolistic competition or nominal rigidities (i.e., perfect competition).[40] Specifications (2) and (3) allow to highlight the role of volatility feedback and nominal rigidities in the model.

Since sectoral volatilities are the main focus of this work, I first analyze the implications of sectoral TFP-volatility shocks, $\varepsilon_{\sigma,c}$ and $\varepsilon_{\sigma,i}$. Figure 4 shows model-implied impulse responses from consumption TFP-volatility and investment TFP-volatility shocks, to aggregate consumption (Panels (a) and (d)), aggregate investment expenditures (Panels (b) and (e)), and aggregate output (Panels (c) and (f)). All variables are real and detrended using the model's stochastic trend. Each impulse-response is in units of percent change from the stochastic steady-state. Observing first Panels (b) and (e), one can see a negative impact of consumption TFP-volatility on investment, both at the time of the shock and up to 40 quarters ahead, and a positive impact of investment TFP-volatility on investment, that persists 40 quarters ahead as well, for all three model calibrations. This pattern aligns with the empirical findings. Though the magnitude and shape of the graphs may change somewhat between the specifications, the plots demonstrate that neither a volatility feedback, nor time-varying markups, are crucial to explain the impact of volatilities on investment. As discussed in section 5.1, it fundamentally stems from precautionary saving motive induced by investment TFP-volatility, and from higher effective impatience induced by consumption TFP-volatility.

[39]The impulse responses are computed by Monte-Carlo simulations. In each simulation $i \in \{1, 2, .., S\}$, I simulate the economy for 140 periods. Denote the simulated path of simulation i from period 100 onward by $\{p_i\}$. I then simulate the economy again, using the same shocks as were drawn before, but in period 100, I increase shock j by one standard deviation. Let the second simulated path from period 100 onward be $\{p'_i\}$. The impulse-responses of shock j are given by the matrix $\frac{1}{S}\Sigma_{s=1}^{S}(p'_i - p_i)$. I pick $S = 10,000$ simulations for the impulse-response computations.

Similar results are obtained by computing the impulse-responses using Vector Auto-regression of order one, as in the empirical section. In unreported results, I construct first- and second- moment TFP shocks from simulated model sample, in an identical fashion to the empirical construction. I then project detrended model variables on these shocks. Consistently, I obtain negative loadings on consumption TFP-volatility, and positive loadings on investment TFP-volatility. The quantitative magnitude of the model-implied loadings is similar to the data for detrended output and investment projections.

[40]Case 3 is almost identical quantitatively to the case in which there is monopolistic competition but no sticky prices, that is, constant markups. To save space, I do not report the results of the constant-markups case.

Panel (a) of Figure 4 shows that in the benchmark case, consumption TFP-volatility lowers consumption, contemporaneously and predictively, in-line with the data. The negative impact on consumption is a result of higher markups, which rise when consumption TFP-volatility rises. As discussed in Section 5.3, higher markups lower the demand of consumption good producers for labor at any given wage, causing them to hire less, and the production of the consumption sector falls. By contrast, and consistently with the data, Panel (d) shows that investment TFP-volatility generates in the benchmark case mostly a positive impact on consumption (a large overshoot), a few periods after the shock.[41] This is a consequence of prolonged capital build-up, which occurs upon the impact of this volatility shock. The build-up of capital translates into higher consumption in the future. Panel (a) shows that under perfect competition, consumption TFP-volatility shock increases consumption upon impact, and the response remains positive 20 quarters ahead. This feature is counterfactual to the empirical evidence. As explained in Section 5.3, in a perfect competition model consumption and aggregate investment diverge in response to volatility shocks. The layer of sticky prices, featured in the benchmark model, allows to flip the sign of consumption's response to consumption TFP-volatility, making it negative, consistently with the data.

Panels (c) and (f) show that output's response is strictly negative to consumption TFP-volatility, and strictly positive to investment TFP-volatility, for all three model configurations. This pattern is consistent with the empirical impulse-responses. Adding sticky prices *amplifies* in absolute value the magnitude of output's impulse-responses. This is a result of the fact that sticky prices cause consumption and investment expenditures, that comprise total output, to comove, instead of offsetting each other.

In figure 5, I plot impulse-responses from sectoral TFP-volatility shocks to hours, to detreded real wages, and the relative price of investment. In general, in the benchmark case, the Figure shows that investment TFP-volatility boosts these variables, while consumption TFP-volatility depresses these quantities. These volatility impacts are consistent with the data. In addition, all sub-plots illustrate that the volatility feedback is not qualitatively material for these macro responses. Observing Panels (c) and (f) of Figure 5, qualitatively, the price of investment-goods drops with consumption TFP-volatility, due to lower demand for investment goods (as the household is more impatience), and rises with investment TFP-volatility, due to higher demand for these goods (as the household desires to save more). Nominal rigidities amplify the magnitude of sectoral volatilities impulse-responses to investment-price. This feature arises as the price of investment-goods is inversely related in equilibrium to the markup of the consumption sector. This markup rises with consump-

[41] Panels (a) and (d) also show that the impulse-responses to consumption in a model without volatility feedback, closely track the benchmark plots. Thus, the volatility feedback is not responsible for qualitatively generating these results.

tion TFP-volatility, and drops with investment TFP-volatility.[42] A similar pattern arises for wages.

In all, figures 4 and 5 illustrate the ability of the benchmark model to rationalize the impact of sectoral TFP-volatilities on macro aggregates. The volatility feedback channel is not a (qualitative) driving force behind the macro results. The volatility feedback only plays a role in rationalizing the behavior of market-prices of investment volatility risk, as discussed in Section 6.4. Nominal rigidities can help reverse the shape of consumption's responses to volatility shocks, and quantitatively amplify other responses.

In figure 6, I plot the impulse-responses of sectoral first-moment TFP innovations to detrended consumption, investment expenditures and output. Panels (a)-(c) show that consumption TFP impact on these quantities is positive, at the time that the shock hits, but revert to zero shortly afterwards (or immediately afterwards, in the case of perfect-competition). Consumption TFP raises consumption by definition, and raises investment expenditures to the extent that it rescales positively the relative price of investment. Yet, all responses are short-lived. By contrast, investment TFP impact is very persistent on all three variables.[43] Panels (d)-(f) show that investment TFP raises investment, as the investment sector becomes more productive, and in absence of labor frictions, labor flows into the investment sector. As a result, investment TFP drops consumption, as resources are allocated to the investment sector.[44] Output's response to an investment TFP innovation is mixed: positive contemporaneously, but negative predictively, as is also the case in the data.

Next, I examine the role of IES in the model. In figure 7, I plot the impulse-responses of sectoral TFP-volatility shocks to consumption, aggregate investment and output, for two cases: (1) the benchmark calibration (IES = 1.7); (2) A calibration that is identical to the benchmark case, but in which there is no monopolistic competition or volatility feedback, and in which IES is calibrated to 0.8. When the IES is less than one, the impact of either consumption TFP-volatility or investment TFP-volatility on the macro quantities is qualitatively the same. The reason is that when the IES is less than one, higher consumption TFP-volatility acts as a preference shock that increases the household *patience* (see Section 5.1). As a result, with more consumption TFP-volatility, the household desires to invest more. Similarly, upon a positive shock to investment TFP-volatility, the household also de-

[42]Differently put, with sticky prices the supply of investment-goods increases in response to consumption TFP-volatility, while the demand for these goods drops by higher impatience. The increased supply amplifies the depreciation in investment price, compared to the perfect-competition case.

[43]As highlighted in Section 5.1, the persistent (long-run) nature of investment TFP innovations implies that when their volatility rises, it induces a strong desire to hedge against low consumption states (precautionary savings).

[44]In longer horizons, investment TFP generates an overshoot in consumption, as a result of a build-up in the amount of capital.

sires to invest more due to a strong precautionary saving motive. By sharp contrast, allowing the IES to be greater than one allows to obtain a *differential* volatility impact: positive for investment TFP-volatility, and negative for consumption TFP-volatility, consistently with the data.

6.4 Sectoral Shocks and Asset-Pricing Implications

In this Section I analyze the impact of sectoral TFP first-moment and second-moment shocks on asset-pricing quantities in the model. I show that the benchmark model is able to rationalize the signs of the market prices of risk, and the signs of cross-sectional exposures to the different sources of risk.

The model-implied log-returns for consumption firms', and investment firms', are defined as:

$$r_{c,t+1} = \log\left(\frac{V_{c,t+1}}{V_{c,t} - d_{c,t}}\right); \quad r_{i,t+1} = \log\left(\frac{V_{i,t+1}}{V_{i,t} - d_{i,t}}\right), \tag{6.1}$$

where $V_{j,t}$ is the cum-dividend real market firm values, defined in equation (4.12), for $j \in \{c, i\}$. At each time t, the aggregate market value is the sum of the market values for consumption and investment firms, $V_{m,t} = V_{c,t} + V_{i,t}$. The market log-return is given by:

$$r_{m,t+1} = \log\left(\frac{V_{m,t+1}}{V_{m,t} - d_{c,t} - d_{i,t}}\right). \tag{6.2}$$

In Table 17, I show the mean, standard deviation, and auto-correlation moments of annualized equity premium and real risk free rate, along with their empirical counterparts.[45] For the most part, the data moments fall inside the model-implied 90%-confidence intervals. In the model, the annualized (levered) equity premium is 6.6%, while it is 6.20% in the data for the period of 1947-2014.[46] The volatility of the equity premium is smaller compared to the data. This is an artifact of the relatively high value of risk aversion, coupled with the absense of investment efficiency shocks in the model.[47] The real risk free rate in the model

[45]Following Papanikolaou (2011), I multiply the model-implied market excess return by a factor of 5/3, to account for the fact the firms in the model are unlevered.

[46]A significant contribution to the equity premium stems from the volatility risks-premia, and in particular investment TFP-volatility risk-premium. This is a result of the fact that the volatilities are persistent processes, and the preferences are Epstein and Zin (1989). This resembles long-run volatility risk-premia in a Long-Run Risks model (see Bansal and Yaron, 2004).

[47]As demonstrated in Papanikolaou (2011), a model that does not include shocks to the efficiency of capital goods, in addition to investment TFP shocks, tends to generate too little quantity of risk in asset returns. I refrain from including such efficiency shocks in my model, in order to keep the number of shocks in the model the same as in the empirical section. This fasilitates a comparison between the model-implied signs of betas and market-prices of each shock against the data.

is 1.37%, while the data counterpart is slightly below 1%. The volatility and autocorrelation of the risk-free rate closely match their empirical counterparts.

Allowing for market-prices and betas to (potentially) time-vary, and using a log-linear approximation for the log-SDF and log-returns, the innovation to the real log-SDF ($m_{t,t+1}$), and real log-return of asset $k \in \{c, i, m\}$, ($r_{k,t+1}$), are given by:

$$m_{t,t+1} - E_t m_{t,t+1} = -\lambda_{zc,t}\sigma_{zc,t}\varepsilon_{c,t+1} - \lambda_{zi,t}\sigma_{zi,t}\varepsilon_{i,t+1} - \lambda_{\sigma,zc,t}\sigma_{w,c}\varepsilon_{\sigma,c,t+1} - \lambda_{\sigma,zi,t}\sigma_{w,i}\varepsilon_{\sigma,i,t+1}; \tag{6.3}$$

$$r_{k,t+1} - E_t r_{k,t+1} = \beta_{k,zc,t}\sigma_{zc,t}\varepsilon_{c,t+1} + \beta_{k,zi,t}\sigma_{zi,t}\varepsilon_{i,t+1} + \beta_{k,\sigma,zc,t}\sigma_{w,c}\varepsilon_{\sigma,c,t+1} + \beta_{k,\sigma,zi,t}\sigma_{w,i}\varepsilon_{\sigma,i,t+1}, \tag{6.4}$$

where $\lambda_{\mathbf{t}} = [\lambda_{zc,t}, \lambda_{zi,t}, \lambda_{\sigma,zc,t}, \lambda_{\sigma,zi,t}]'$ is the vector of market-prices of risk, and $\beta_{\mathbf{k,t}} = [\beta_{k,zc,t}, \beta_{k,zi,t}, \beta_{k,\sigma,zc,t}, \beta_{k,\sigma,zi,t}]'$ is the vector of risk-exposures of asset k, to consumption TFP, investment TFP, consumption TFP-volatility and investment TFP-volatility risks, respectively.

Consider a projection of long-sample simulated paths of log-SDF and log-returns, on long-sample paths of simulated shocks in the model:

$$m_{t,t+1} = m_0 + \tilde{\lambda}_{zc}\varepsilon_{c,t+1} + \tilde{\lambda}_{zi}\varepsilon_{i,t+1} + \tilde{\lambda}_{\sigma,zc}\varepsilon_{\sigma,c,t+1} + \tilde{\lambda}_{\sigma,zi}\varepsilon_{\sigma,i,t+1} + error; \tag{6.5}$$

$$r_{k,t+1} = r_{k,0} + \tilde{\beta}_{k,zc}\varepsilon_{c,t+1} + \tilde{\beta}_{k,zi}\varepsilon_{i,t+1} + \tilde{\beta}_{k,\sigma,zc}\varepsilon_{\sigma,c,t+1} + \tilde{\beta}_{k,\sigma,zi}\varepsilon_{\sigma,i,t+1} + error. \tag{6.6}$$

From identities (6.3) and (6.4), I define the model-implied *average* market-prices of risk, as the negative of the factor loadings of projection (6.5), dividend by the *average* quantity of risks that corresponds to each shock, as in the data. Similarly, I define the *average* exposures of asset k, as the factor loadings of projection (6.6), dividend by the *average* quantity of risks that corresponds to each shock, as in the data:

$$\lambda = \left[-\frac{1}{\sigma_{zc,0}}\tilde{\lambda}_{zc},\ -\frac{1}{\sigma_{zi,0}}\tilde{\lambda}_{zi},\ -\frac{1}{\sigma_{w,c}}\tilde{\lambda}_{\sigma,zc},\ -\frac{1}{\sigma_{w,i}}\tilde{\lambda}_{\sigma,zi}\right]', \tag{6.7}$$

$$\beta_k = \left[\frac{1}{\sigma_{zc,0}}\tilde{\beta}_{k,zc},\ \frac{1}{\sigma_{zi,0}}\tilde{\beta}_{k,zi},\ \frac{1}{\sigma_{w,c}}\tilde{\beta}_{k,\sigma,zc},\ \frac{1}{\sigma_{w,i}}\tilde{\beta}_{k,\sigma,zi}\right]'. \tag{6.8}$$

I simulate population paths of the log-SDF and log-returns, and project them onto the shocks paths', to obtain the market-prices of risk and exposures, as defined in (6.5) and (6.6). Importantly, in both projections, the R^2 is close to 99%. This indicates that the model-implied log-SDF and log-returns are almost *log-linear*, as specified in identities (6.3) and (6.4). Thus, I ignore any higher-order, non-linear SDF specifications. The model-implied market-prices and exposues are reported in Table 18. The Table shows the results for two model calibrations: (1) The benchmark case, in Panel A; (2) An identical calibration to the benchmark case, but without a volatility feedback ($\tau = 0$), and under perfect competition ($\mu_j \to \infty, \quad j \in \{c, i\}$), in Panel B.

6.4.1 Risk Exposures Implications

Panel A of Table 18 shows the risk exposures (betas) in the benchmark model. The risk exposures of the market, of consumption firms, and of investment firms to the sectoral shocks, are all consistent with the empirical findings. Namely, all assets have a positive exposure to consumption TFP, and investment TFP-volatility, and a negative exposure to investment TFP, and consumption TFP-volatility. For volatility risks, the exposures are also of roughly similar magnitude as their empirical counterparts, as can be seen in Table 5. Panel B of Table 18 shows the risk exposures in a simplified framework, in which firms are perfectly competitive. The signs of the risk exposures are unaltered.

The intuition behind the *signs* of the volatility exposures is explained in Section 5.2. For completeness, I briefly repeat it here. Since firms in the model exhibit constant returns to scale, the sign of an exposure is determined primarily by the impact of the volatility shock on the firm's Tobin's Q. In the model, Tobin's Q of firms, and the aggregate price of investment goods are positively related (they are identical in the absence of adjustment costs). Consumption TFP-volatility causes the household to be more impatient. This lowers the demand for investment goods, causing their price to drop, and consequently, depreciates the value of installed capital of firms. A reduction in the firms' value implies a negative exposure to consumption TFP-volatility ($\beta_{j,\text{C-TFP-VOL}} < 0, \quad j \in \{c, i, m\}$). By contrast, investment TFP-volatility raises the incentive of the household to save. In turn, it increases the demand for investment goods, appreciates the value of the price of capital, and raises firms' value. Thus, firms are positively exposed to investment TFP-volatility ($\beta_{j,\text{I-TFP-VOL}} > 0, \quad j \in \{c, i, m\}$).

The signs of exposures to first-moment TFP innovations are also rationalized through their impact on the relative price of investment. The relative price of investment drops with higher investment TFP, as a positive investment TFP innovation increases the supply of investment goods, and drops their price. Alternatively, a positive investment TFP innovation implies that it is cheaper to produce and replace assets-in-place and so their marginal value falls. A decline in the price of capital implies a negative impact on firms' valuations, and a negative exposure to investment TFP ($\beta_{j,\text{I-TFP}} < 0, \quad j \in \{c, i, m\}$). A positive consumption

TFP innovation increases the productivity of consumption firms, causing an increase in the demand for new capital goods, and increases their price. As a result, the marginal value of firms' installed capital appreciates, suggesting a positive exposure to consumption TFP ($\beta_{j,\text{C-TFP}} > 0, \quad j \in \{c, i, m\}$). Panel B shows that neither monopolistic competition, nor a volatility feedback, are necessary to rationalize the signs of the empirical betas.

6.4.2 Market-Prices of Risk Implications

Panel A of Table 18 shows that the benchmark model is capable of explaining the signs of the empirical market prices of risk: positive market-price for consumption TFP, investment TFP, and investment TFP-volatility, and a negative market-price for consumption TFP-volatility. The magnitudes of the market prices are of roughly similar magnitude as their empirical counterparts reported in Table 4.

The real SDF in the economy is given by:

$$M_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t}\right)^{-1/\psi} \left(\frac{1-\xi N_{t+1}^{\eta}}{1-\xi N_t^{\eta}}\right)^{1-1/\psi} \left(\frac{U_{t+1}}{\left(E_t U_{t+1}^{1-\gamma}\right)^{\frac{1}{1-\gamma}}}\right)^{1/\psi-\gamma}. \tag{6.9}$$

Expression (6.9) shows that under early resolution of uncertainty ($\gamma > \frac{1}{\psi}$, $\psi > 1$), the SDF, $M_{t-1,t}$, falls under three scenarios: (i) Consumption C_t rises; (ii) The continuation utility (which includes today's consumption as well) U_t rises; (iii) Labor N_t rises. Quantitatively, channels (i) and (ii) dominate fluctuations in channel (iii). Consequently, I analyze below the impact of sectoral shocks on the SDF through their immediate impact on consumption, and their impact on the continuation utility.

Upon a positive consumption TFP innovation, consumption increases by definition. The continuation utility also rises due to the positive impact on today's consumption. Both channels operate to drop the SDF, and thus, yield a positive market price for consumption TFP innovations in the benchmark model, consistently with the data.

When investment TFP rises, in absence of labor frictions, labor flows to the investment sector, as it is becomes more productive. As a result, the immediate impact on consumption is negative. If preferences excluded the impact of the continuation utility (i.e., power utility), this would imply a negative market price for investment TFP innovations. However, since labor and capital are shifted to the investment sector, the economy builds-up more capital goods. This is translated into a large consumption overshoot in the future, and to an increase in the continuation utility. In addition, a positive investment TFP innovation triggers more working hours.[48] The rise in the continuation utility (along with the rise in total working hours) is sufficiently strong to compensate for the immediate decline in consumption. Consequently, investment TFP innovations drop the SDF, and are priced positively in the benchmark model. This is in-line with the results of the empirical analysis. Panel B of Table 18 shows the market-prices of risk in the simplified model, in which firms are perfectly competitive, and that excludes the volatility feedback. The signs of the market-prices of consumption TFP and investment TFP are still positive.

The market-price of risk of consumption TFP-volatility is negative, both in the benchmark model (Panel A), and in a perfect-competition model (Panel B). A negative market-price is consistent with the data. When consumption TFP-volatility rises, in the case of monopolistic competition and nominal rigidities, consumption drops both contemporaneously and predictively (see explanation in Sections 5.3 and 6.3). In addition, future consumption profile becomes more volatile. Under early resolution of uncertainty, the agent dislikes a rise in consumption's volatility, and the continuation utility drops. Both effects generate an increase in the SDF, and yield a negative market price for consumption TFP-volatility.[49]

By contrast, investment TFP-volatility has two opposite impacts on the SDF: (a) Higher investment TFP-volatility drops immediate consumption, and generates a more volatile consumption profile in the future (investment TFP-volatility shocks are *capital-embodied* shocks, that affect the volatility of capital allocations in the consumption sector). This lowers the continuation utility; (b) Higher investment TFP-volatility increases future consumption, due to capital build-up in the present (see Panel D of Figure 4). Higher future consumption can operate to raise the continuation utility. Under a reasonable calibration for aggregate macroeconomic moments, and in the absence of a volatility feedback, I find that channel (a) dominates. As a result, the market-price of risk of investment TFP-volatility in Panel B is counterfactually negative.

Once the empirically-borne volatility feedback is added to the model ($\tau > 0$), Panel A of Table 18 shows that in the benchmark model the market-price of investment TFP-volatility turns positive. This is in-line with the empirical findings, and implies that investment TFP-volatility is welfare improving. Intuitively, a positive feedback from investment TFP-volatility to future consumption TFP, strengthens quantitatively channel (b) above. When channel (b) dominates, investment TFP-volatility is positively priced.

[48]Under King et al. (1988) preferences, total hours moves in an opposite direction to consumption-sector's hours. Since investment TFP increases labor in the investment sector, total hours worked also rises.

[49]Without sticky prices, consumption TFP-volatility raises consumption today and in the near future. Under CRRA preferences this implies a counterfactual positive market-price of risk. Under Epstein and Zin (1989) preferences, the market-price is negative through the impact of higher uncertainty on the continuation utility. Yet, it is not as negative as in the benchmark case (with sticky prices).

Economically, in the benchmark model investment TFP-volatility has a prolonged multi-period effect on the economy, through capital build-up. The capital build-up consequently leads to an overshoot in future consumption, and to improved welfare in the economy. This capital build-up happens because of two reasons. The first is that when investment TFP-volatility rises, it induces precautionary savings. The second reason for capital build-up is the volatility feedback. In a reduced form manner, this feedback could be interpreted as slightly delayed culmination of successful growth options (see discussion in Section 3.6).

6.5 Monte-Carlo Experiment: Using the Model to Rule-Out Mechanical Empirical Results

A general concern regarding the empirical results presented in Section 3 can be that the results are mechanically driven by the methodology in which the volatilities are constructed, as discussed in Section 3.2. Specifically, if the conditional mean of the TFP growth rates is not fully removed from the time-series, then the constructed realized variances are contaminated by the impact of first-moment shocks.

To try to alleviate such a concern, I solve the model presented in section 4, yet with two modifications: (1) No volatility feedback from investment TFP-volatility to future consumption TFP growth; (2) No stochastic-volatility: the conditional volatilities of sectoral TFP growth rates are constant, set at their unconditional values.

I simulate the economy, and construct from the simulated data first- and second- moment sectoral TFP shocks, in an exact fashion to the empirical construction. I then repeat the various data projections, as outlined in sections 3.3 - 3.4. I perform the projections using a a small sample of 272 quarters (same length as data observations), and in a population sample (half-million observations). The results for the volatilities' loadings are reported in Table 19. Under the Null conjecture of this model, one should not find a positive (negative) feedback from investment (consumption) TFP-volatility to future growth.

The Table shows that in finite-samples, the sectoral volatility loadings are indeed insignificant for the macroeconomic projections. In the population sample, the Table shows that in almost all cases, the slope coefficients on consumption TFP-volatility are positive, while the slope coefficients on investment TFP-volatility are negative. This is the *opposite* of what I find in the data. Moreover, for the market portfolio, the betas for both consumption TFP-volatility and investment TFP-volatility are negative, while in the data, investment TFP-volatility exposure is positive.

7 Conclusion

In this paper I empirically document a novel empirical puzzle: consumption-sector's technological volatility and investment-sector's technological volatility oppositely impact economic growth, aggregate asset-prices, and the cross-section of returns. I further develop a general-equilibrium two-sector model, that explains the opposite roles of the sectoral volatilities, and also studies the implications of sectoral first-moment technological innovations.

On the macroeconomic front, the paper sheds new light on the on-going debate regarding the impact of volatility shocks on investment. I find that consumption TFP-volatility inhibits investment, consumption, output and wages. Investment TFP-volatility, on the other hand, stimulates investment and output. It also raises welfare inside the model. Thus, economic policies that are designed to curb uncertainty, may not yield a desired result if the volatility stems from the investment sector. The positive impact of investment TFP-volatility on investment is explained via precautionary-saving channel in equilibrium. The contractionary impact of consumption TFP-volatility on investment hinges on the preferences of the agent. Under *early* resolution of uncertainty, the agent hedges against consumption sector's volatility by shifting her consumption profile to the present, and investing less. In fact, higher consumption TFP-volatility is equivalent to a demand shock (or a time-preference shock), that makes the agent more impatient, thus discouraging investment.

On the asset-pricing front, I find that a production SDF that excludes the sectoral volatilities is misspecified. The misspecification is important, as first-moment sectoral innovations are not able to fully explain certain return spreads (e.g. momentum), while TFP-volatility shocks improve the factor-model's fit to the data. The sectoral volatility risks have market-prices of risk of opposite signs. Moreover, sectoral volatilities have an opposite impact on stock prices. Investment TFP-volatility increases equity valuations, empirically and in the model, as it increases the demand for capital-goods, appreciating the marginal value of installed capital. Consumption TFP-volatility lowers equity valuations, for the opposite reason. From a corporate finance perspective, I document that investment-sector's TFP-volatility lowers the default spread, while consumption TFP-volatility raises it. This differential impact can affect firms' incentive to take leverage oppositely.

In all, the theoretical and empirical evidence show the importance of separate movements in sectoral TFP-volatilities for economic growth and asset prices, beyond first-moment innovations. Future research can explicitly model debt in a two-sector model, to explore the sectoral volatility implications for leverage taking and defaults in equilibrium. Another research direction, which I currently explore, is to endogenize the heterogeneity of risk exposures to investment TFP-volatility in the cross-section, in relation to the momentum spread.

A Appendix A: Consumption TFP as a Preference Shock

In this appendix I show that the maximization programs (5.1) and (5.8) are equivalent. For notational ease, I denote the budget constraint of program (5.1), with the exclusion of consumption production (that is, equations (5.3)-(5.7)), as $\{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it})$.

Define $\hat{C}_t = \frac{C_t}{z_{ct-1}}$ and $\hat{V}_t = \frac{V_t}{z_{ct-1}}$. It is straightforward to show using first-order condition equivalence, that the solution to the program (5.1) solves the partially *detrended* value-function given by:

$$\begin{aligned}
\hat{V}_t(k_{ct}, k_{it}, z_{it}, \frac{z_{ct}}{z_{ct-1}}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} & \Bigg\{ (1-\beta)\hat{C}_t^{1-1/\psi} \\
& + \beta \left(\frac{z_{ct}}{z_{ct-1}}\right)^{1-\frac{1}{\psi}} \left(E_t \hat{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1}, \frac{z_{ct+1}}{z_{ct}})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}} \qquad \text{(A.1)} \\
& \text{s.t.} \\
& \hat{C}_t = \frac{z_{ct}}{z_{ct-1}} k_{ct}^{\alpha} n_{ct}^{1-\alpha} \\
& \{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it}) \\
& \frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t}\varepsilon_{zc,t+1},
\end{aligned}$$

and where $\mathbb{B}(k_{it}, k_{ct}, z_{it})$ is the same budget constraint as of program (5.1).

The detrended value function $\hat{V}$ of program (A.1) is homogeneous of degree one in $\frac{z_{ct}}{z_{ct-1}}$. To see this, plug the expression for $\hat{C}_t$ in the objective function to obtain:

$$\begin{aligned}
\hat{V}_t(k_{ct}, k_{it}, z_{it}, \frac{z_{ct}}{z_{ct-1}}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} & \Bigg\{ (1-\beta)\left(\frac{z_{ct}}{z_{ct-1}} k_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} \\
& + \beta \left(\frac{z_{ct}}{z_{ct-1}}\right)^{1-\frac{1}{\psi}} \left(E_t \hat{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1}, \frac{z_{ct+1}}{z_{ct}})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}} \\
& \text{s.t.} \\
& \{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it}) \\
& \frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t}\varepsilon_{zc,t+1}.
\end{aligned}$$

Notice, that $\frac{z_{ct}}{z_{ct-1}}^{1-1/\psi}$ multiplies both terms inside the maximand $\{\cdot\}^{\frac{1}{1-1/\psi}}$ expression. Thus, one can re-write the program as follows:

$$\hat{V}_t(k_{ct}, k_{it}, z_{it}, \frac{z_{ct}}{z_{ct-1}}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} \left(\frac{z_{ct}}{z_{ct-1}}\right) \Bigg\{ (1-\beta) \left(k_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} + \beta \left(E_t \hat{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1}, \frac{z_{ct+1}}{z_{ct}})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}} \tag{A.2}$$

$$\text{s.t.}$$

$$\{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it})$$

$$\frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t} \varepsilon_{zc,t+1}$$

For any scalar $\lambda > 0$, specification (A.2) permits the following identity:

$$\hat{V}_t(k_{ct}, k_{it}, z_{it}, \lambda\frac{z_{ct}}{z_{ct-1}}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} \lambda \left(\frac{z_{ct}}{z_{ct-1}}\right) \Bigg\{ (1-\beta) \left(k_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} + \beta \left(E_t \hat{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1}, \frac{z_{ct+1}}{z_{ct}})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}}$$

$$\text{s.t.}$$

$$\{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it})$$

$$\frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t} \varepsilon_{zc,t+1}$$

$$= \lambda \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} \left(\frac{z_{ct}}{z_{ct-1}}\right) \Bigg\{ (1-\beta) \left(\hat{k}_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} + \beta \left(E_t \hat{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1}, \frac{z_{ct+1}}{z_{ct}})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}}$$

$$\text{s.t.}$$

$$\{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it})$$

$$\frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t} \varepsilon_{zc,t+1}$$

$$= \lambda \hat{V}_t(k_{ct}, k_{it}, z_{it}, \frac{z_{ct}}{z_{ct-1}}). \tag{A.3}$$

The second equality of equation (A.3) stems from the fact that λ is only a multiplicative constant that rescales the objective function, but does not affect the budget constraints, or the continuation value's state variables (as the growth in z_{ct} is independent over time). The third equality establishes homogeneity of degree one in consumption TFP growth. As a corollary, it is possible to write:

$$\hat{V}_t(k_{ct}, k_{it}, z_{it}, \frac{z_{ct}}{z_{ct-1}}) = \left(\frac{z_{ct}}{z_{ct-1}}\right) \tilde{V}_t(k_{ct}, k_{it}, z_{it}). \tag{A.4}$$

Lastly, the ex-ante expectation of $\frac{z_{ct+1}}{z_{ct}}$ behaves like a preference shock in the problem (A.2). To see this, divide both hands of (A.2) by $\frac{z_{ct}}{z_{ct-1}}$, and use the corollary (A.4), to obtain:

$$\begin{aligned} \tilde{V}_t(k_{ct}, k_{it}, z_{it}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} & \Bigg\{ (1-\beta)\left(k_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} \\ & + \beta \left(E_t \left(\frac{z_{ct+1}}{z_{ct}}\right)^{1-\gamma} \tilde{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}} \\ & \{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it}) \\ & \frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t}\varepsilon_{zc,t+1} \end{aligned} \tag{A.5}$$

As $\tilde{V}_{t+1}$ is independent of $\frac{z_{ct+1}}{z_{ct}}$, we can separate the expectation in the objective function of (A.5) to obtain:

$$\begin{aligned} \tilde{V}_t(k_{ct}, k_{it}, z_{it}) = \max_{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}} & \Bigg\{ (1-\beta)\left(k_{ct}^{\alpha} n_{ct}^{1-\alpha}\right)^{1-1/\psi} \\ & + \beta \underbrace{\left(E_t \left(\frac{z_{ct+1}}{z_{ct}}\right)^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}}}_{\tilde{\beta}_t} \left(E_t \tilde{V}_{t+1}(k_{ct+1}, k_{it+1}, z_{it+1})^{1-\gamma} \right)^{\frac{1-1/\psi}{1-\gamma}} \Bigg\}^{\frac{1}{1-1/\psi}} \\ & \{I_{i,t}, I_{c,t}, n_{c,t}, n_{i,t}\} \in \mathbb{B}(k_{it}, k_{ct}, z_{it}) \\ & \frac{z_{ct+1}}{z_{ct}} = \mu_{zc} + \sigma_{zc,t}\varepsilon_{zc,t+1}. \end{aligned}$$

This program is identical to that specified in (5.8). Thus, the solution of program (5.8), is identical to the solution of (A.1), which is equal to the solution of (5.1). When z_{ct} is a random walk, the expression $\tilde{\beta}_t$ behaves like a preference shock, that depends only on the conditional volatility $\sigma_{zc,t}$.

B Appendix B: Characterization of Model's Solution

B.1 Equilibrium Conditions

This section describes the equilibrium first-order conditions of the model described in section 4. The first-order condition of firm $n \in [0,1]$ in sector $j \in \{c, i\}$:

$$0 = q_{j,t} - P_{it}\Phi'_k(i_{j,t}(n)) \tag{B.1}$$

$$0 = W_t n_{j,t}(n) - (1-\alpha_j)\theta_{j,t} Z_{j,t} k_{j,t}(n)^{\alpha_j} n_{j,t}(n)^{1-\alpha_j} \tag{B.2}$$

$$0 = -q_{j,t} + E_t\Big[M^{\$}_{t+1}\left\{-P_{i,t+1}\Phi_k(i_{j,t+1}) + q_{j,t+1}(1-\delta+i_{j,t+1}(n))\right.$$
$$\left.+\theta_{j,t+1}Z_{j,t+1}\alpha_j k_{j,t+1}(n)^{\alpha_j-1} n_{j,t+1}(n)^{1-\alpha_j}\right\}\Big] \tag{B.3}$$

$$0 = (1-\mu_j)\left[\frac{p_{j,t}(n)}{P_{j,t}}\right]^{-\mu_j} + \theta_{j,t}\mu_j\left[\frac{p_{j,t}(n)}{P_{j,t}}\right]^{-\mu_j-1}\frac{1}{P_{j,t}} - \phi_P\left[\frac{p_{j,t}(n)}{\Pi_j p_{j,t-1}(n)} - 1\right]\frac{1}{\Pi_j}$$
$$+\phi_P E_t\left[M^{\$}_{t+1}\left(\frac{Y_{j,t+1}}{Y_{j,t}}\right)\left\{\left[\frac{p_{j,t+1}(n)}{\Pi_j p_{j,t}(n)} - 1\right]\frac{p_{j,t+1}(n)}{\Pi_j p_{j,t}(n)} - \frac{1}{2}\left[\frac{p_{j,t+1}(n)}{\Pi_j p_{j,t}(n)} - 1\right]^2\right\}\right] \tag{B.4}$$

$$0 = k_{j,t+1}(n) - (1-\delta+i_{j,t}(n))k_{j,t}(n) \tag{B.5}$$

$$0 = y_{j,t}(n) - Z_{j,t}k_{j,t}(n)^{\alpha_j} n_{j,t}(n)^{1-\alpha_j} \tag{B.6}$$

where $q_{j,t}$ be the price of a marginal unit of installed capital in sector j (the Lagrange multiplier of constraint (4.7)), and $\theta_{j,t}$ is the marginal cost of producing an additional unit of intermediate good in sector $j \in \{c, i\}$ (the Lagrange multiplier of constraint (4.11)).
The first-order condition of the household:

$$0 = \frac{W_t}{P_{c,t}} - \frac{C_t}{1-\xi N_t^{\eta}}\xi\eta N_t^{\eta-1} \tag{B.7}$$

The nominal SDF, nominal interest rate, as well as the household utility, are given in equations (4.19), (4.20) and (4.17), respectively. The last equilibrium conditions include four market clearing conditions (labor, investment-goods, consumption-goods, and bond market) specified in equations (4.21), (4.22), (4.23), and (4.24), respectively. We are looking for a symmetric equilibrium in which $P_{j,t}(n) = P_{j,t}$, $n_{j,t}(n) = n_{j,t}$, and $k_{j,t}(n) = k_{j,t}$, for all $n \in [0,1]$ and $j \in \{c, i\}$. Thus, the above equations can be rewritten in terms of only aggregate quantities. There are 20 endogenous variables $\{C_t, N_t, Y_{c,t}, Y_{i,t}, N_{c,t}, N_{i,t}, K_{c,t}, K_{i,t}, i_{c,t}, i_{i,t}, q_{c,t}, q_{i,t}, \theta_{c,t}, \theta_{i,t}, P_{i,t}, P_{c,t}, W_t, R^{\$}_t, U_t, M^{\$}_t\}$. In turn, there are 20 equations: 13 equations for household's and firms' first-order conditions (in both sectors), 4 market clearing conditions, and 3 definitions of SDF, utility and Taylor-rule). Other quantities, such as the real SDF, and firm-valuations, are derived from the endogenous decision variables (see e.g. equation (4.10)).

B.2 Detrended Problem

Covariance-stationary first-order conditions can be achieved by rescaling the non-stationary variables of the problem as follows:

- Divide $k_{c,t}$, $k_{i,t}$, $Y_{i,t}$ by $Z_{i,t-1}^{\frac{1}{1-\alpha_i}}$.
- Divide C_t, $Y_{c,t}$, U_t by $Z_{c,t-1}Z_{i,t-1}^{\frac{\alpha_c}{1-\alpha_i}}$.
- Divide W_t by $P_{c,t}Z_{c,t-1}Z_{i,t-1}^{\frac{\alpha_c}{1-\alpha_i}}$.
- Divide $\theta_{c,t}$ by $P_{c,t}$.
- Divide $\theta_{i,t}$, $q_{i,t}$, $q_{c,t}$, $P_{i,t}$ by $P_{c,t}Z_{c,t-1}Z_{i,t-1}^{\frac{\alpha_c-1}{1-\alpha_i}}$.

After plugging the rescaled variables in the first-order equations, the equilibrium conditions can be written using stationary variables (in particular, using the rescaled variables, and using the *growth* rates of $Z_{c,t}, Z_{i,t}$ and of $P_{c,t}$).

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Tables and Figures

Table 1: **Sectoral Shocks and Aggregate Cash-Flow (Macroeconomic) Growth**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	$Adj-R^2$
Consumption growth:					
0Q Ahead	0.27 [2.96]	0.08 [0.96]	-0.01 [-1.14]	0.02 [1.45]	0.085
1Q Ahead	0.27 [3.29]	0.05 [0.62]	-0.04 [-3.78]	0.06 [4.68]	0.067
4Q Ahead	0.28 [3.35]	-0.14 [-2.10]	-0.02 [-2.72]	0.03 [2.49]	0.089
12Q Ahead	0.21 [2.79]	-0.14 [-2.72]	-0.02 [-2.23]	0.02 [2.06]	0.086
20Q Ahead	0.17 [1.77]	-0.11 [-1.64]	-0.01 [-1.71]	0.02 [1.67]	0.086
GDP growth:					
0Q Ahead	0.72 [7.66]	0.31 [2.67]	-0.01 [-0.48]	0.02 [1.09]	0.485
1Q Ahead	0.50 [4.05]	0.16 [1.49]	-0.09 [-4.09]	0.12 [4.45]	0.148
4Q Ahead	0.48 [2.88]	-0.21 [-1.62]	-0.04 [-2.21]	0.04 [2.06]	0.109
12Q Ahead	0.27 [2.32]	-0.18 [-2.17]	-0.02 [-1.99]	0.02 [1.74]	0.071
20Q Ahead	0.18 [1.53]	-0.14 [-1.62]	-0.01 [-1.36]	0.01 [1.22]	0.057
Sales growth:					
0Q Ahead	-0.45 [-0.46]	1.88 [2.57]	-0.13 [-1.47]	0.11 [1.36]	0.004
1Q Ahead	0.27 [0.40]	0.66 [1.08]	-0.14 [-1.63]	0.15 [1.37]	0.014
4Q Ahead	1.21 [2.76]	-0.21 [-0.59]	-0.14 [-3.29]	0.17 [3.32]	0.110
12Q Ahead	0.95 [2.37]	-0.37 [-1.43]	-0.09 [-2.23]	0.10 [2.28]	0.116
20Q Ahead	0.80 [1.97]	-0.44 [-1.66]	-0.06 [-1.67]	0.07 [1.64]	0.115
Net earnings growth:					
0Q Ahead	3.58 [1.45]	1.98 [1.22]	-0.42 [-1.72]	0.59 [1.90]	0.061
1Q Ahead	4.02 [1.67]	1.06 [0.85]	-0.58 [-1.93]	0.69 [2.28]	0.062
4Q Ahead	3.19 [1.56]	-0.62 [-0.40]	-0.26 [-1.59]	0.32 [1.66]	0.028
12Q Ahead	1.77 [1.24]	-1.00 [-0.84]	-0.10 [-0.93]	0.12 [0.89]	0.004
20Q Ahead	0.70 [1.11]	-0.45 [-0.73]	-0.03 [-0.66]	0.04 [0.91]	0.000

The Table shows the evidence from the projection of contemporaneous and future aggregate cash-flow growth rates on the current sectoral shocks: consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. The predictive projection ($h > 1$) is: $\frac{1}{h}\sum_{j=1}^{h}\Delta y_{t+j} = \beta_0 + \beta_h'[\Delta\text{C-TFP}_t, \Delta\text{I-TFP}_t, \Delta\text{C-TFP-VOL}_t, \Delta\text{I-TFP-VOL}_t] + error$. The contemporaneous projection ($h = 0$) is the same, but the dependent variable is Δy_t. The Table reports the slope coefficients β_h, $t-$statistics, and the adjusted R^2s for the contemporaneous projection ($h = 0$), and the predictive horizons of $h = 1, 4, 12$ and 20 quarters, for the corresponding aggregate growth series Δy. Standard errors are Newey-West adjusted. The data on consumption and GDP are quarterly from 1947Q1-2014Q4. Data on sales and earnings are from 1964Q1-2014Q4.

Table 2: **Sectoral Shocks and Aggregate Inputs Growth**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	$Adj-R^2$
Panel A: Aggregate growth of investment measures					
Capital investment growth:					
0Q Ahead	1.23 [4.03]	1.03 [3.70]	-0.12 [-3.17]	0.19 [3.91]	0.362
1Q Ahead	1.10 [3.53]	0.66 [2.50]	-0.15 [-3.21]	0.21 [4.09]	0.223
4Q Ahead	1.09 [2.41]	-0.28 [-0.85]	-0.09 [-1.93]	0.11 [1.93]	0.109
12Q Ahead	0.63 [1.61]	-0.41 [-1.37]	-0.05 [-1.45]	0.05 [1.33]	0.052
20Q Ahead	0.41 [1.46]	-0.36 [-1.48]	-0.03 [-1.25]	0.03 [1.10]	0.055
Capital expenditures growth:					
0Q Ahead	0.10 [0.03]	4.66 [1.88]	-1.49 [-2.37]	1.30 [1.64]	0.087
1Q Ahead	-3.93 [-1.24]	5.05 [1.96]	-1.15 [-2.00]	1.09 [1.52]	0.077
4Q Ahead	0.73 [0.56]	0.78 [0.77]	-0.20 [-1.88]	0.24 [1.84]	0.078
12Q Ahead	0.75 [1.29]	0.17 [0.25]	-0.10 [-2.59]	0.13 [2.80]	0.050
20Q Ahead	0.08 [0.15]	0.20 [0.35]	-0.03 [-0.54]	0.03 [0.63]	-0.012
Relative investment-price growth:					
0Q Ahead	0.78 [4.50]	-0.93 [-5.04]	-0.01 [-1.01]	0.01 [0.71]	0.152
1Q Ahead	0.61 [4.09]	-0.63 [-3.76]	-0.04 [-1.45]	0.04 [1.39]	0.059
4Q Ahead	0.36 [1.97]	-0.43 [-3.24]	-0.02 [-1.00]	0.01 [0.74]	0.111
12Q Ahead	0.34 [1.92]	-0.36 [-2.61]	-0.02 [-1.23]	0.02 [1.02]	0.105
20Q Ahead	0.38 [2.19]	-0.35 [-2.40]	-0.03 [-1.96]	0.03 [1.93]	0.149
Panel B: Aggregate growth of labor measures					
Hours growth:					
0Q Ahead	0.33 [2.57]	0.22 [2.05]	-0.02 [-1.67]	0.04 [1.15]	0.066
1Q Ahead	0.20 [1.64]	0.08 [0.68]	-0.03 [-1.39]	0.02 [1.93]	0.049
4Q Ahead	0.12 [1.06]	-0.16 [-1.75]	-0.00 [-0.31]	-0.00 [-0.19]	0.037
12Q Ahead	0.02 [0.45]	-0.07 [-1.67]	0.00 [0.51]	-0.00 [-1.14]	0.045
20Q Ahead	0.03 [0.54]	-0.09 [-1.50]	0.00 [0.52]	-0.01 [-0.99]	0.031
Wage growth:					
0Q Ahead	0.51 [4.46]	-0.21 [-1.92]	-0.00 [-0.17]	0.01 [0.70]	0.057
1Q Ahead	0.35 [2.90]	-0.10 [-0.91]	-0.05 [-2.62]	0.06 [2.69]	0.020
4Q Ahead	0.31 [3.37]	-0.23 [-2.71]	-0.03 [-2.65]	0.03 [2.69]	0.060
12Q Ahead	0.26 [2.67]	-0.21 [-2.64]	-0.02 [-2.00]	0.02 [1.92]	0.074
20Q Ahead	0.24 [1.93]	-0.16 [-1.58]	-0.02 [-1.92]	0.02 [2.03]	0.078

The Table shows the evidence from the projection of contemporaneous and future aggregate investment growth rate measures (Panel A), and labor growth rate measures (Panel B) on the current sectoral shocks: consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. The predictive projection ($h > 1$) is: $\frac{1}{h}\sum_{j=1}^{h}\Delta y_{t+j} = \beta_0 + \beta_h'[\Delta\text{C-TFP}_t, \Delta\text{I-TFP}_t, \Delta\text{C-TFP-VOL}_t, \Delta\text{I-TFP-VOL}_t] + error$. The contemporaneous projection ($h = 0$) is the same, but the dependent variable is Δy_t. The Table reports the slope coefficients β_h, $t-$statistics, and the adjusted R^2s for the contemporaneous projection ($h = 0$), and the predictive horizons of $h = 1, 4, 12$ and 20 quarters, for the corresponding aggregate growth series Δy. Standard errors are Newey-West adjusted. The data are quarterly from 1947Q1-2014Q4.

Table 3: **Sectoral Shocks and Detrended Macroeconomic Variables**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	$Adj-R^2$
Detrended consumption:					
0Q Ahead	0.21 [0.33]	1.33 [2.05]	-0.08 [-1.19]	0.14 [1.62]	0.060
1Q Ahead	0.51 [0.70]	1.39 [2.15]	-0.16 [-2.22]	0.22 [1.47]	0.098
4Q Ahead	1.09 [1.26]	0.59 [0.94]	-0.17 [-1.97]	0.21 [1.98]	0.093
12Q Ahead	1.08 [1.13]	-0.25 [-0.37]	-0.11 [-1.39]	0.13 [1.34]	0.034
20Q Ahead	0.53 [0.62]	-0.42 [-0.63]	-0.04 [-0.67]	0.04 [0.56]	-0.001
Detrended GDP:					
0Q Ahead	0.79 [1.38]	1.41 [2.20]	-0.14 [-2.55]	0.22 [3.27]	0.160
1Q Ahead	1.14 [2.03]	1.38 [2.51]	-0.23 [-3.52]	0.32 [4.06]	0.214
4Q Ahead	1.56 [2.30]	0.54 [1.10]	-0.20 [-2.81]	0.26 [2.94]	0.177
12Q Ahead	0.98 [1.41]	-0.27 [-0.53]	-0.09 [-1.52]	0.10 [1.44]	0.038
20Q Ahead	0.22 [0.43]	-0.25 [-0.63]	-0.01 [-0.28]	0.00 [0.11]	-0.009
Detrended capital investment:					
0Q Ahead	0.33 [0.13]	4.12 [1.80]	-0.29 [-1.35]	0.48 [1.89]	0.063
1Q Ahead	1.92 [0.77]	4.03 [1.84]	-0.53 [-2.26]	0.76 [2.70]	0.111
4Q Ahead	4.21 [1.54]	1.65 [0.82]	-0.62 [-2.35]	0.80 [2.55]	0.113
12Q Ahead	4.37 [1.64]	-1.89 [-0.95]	-0.41 [-1.88]	0.47 [1.84]	0.051
20Q Ahead	2.04 [1.37]	-2.17 [-1.54]	-0.10 [-1.03]	0.08 [0.78]	0.036
Detrended relative-price of investment:					
0Q Ahead	1.25 [2.00]	-1.11 [-2.36]	-0.09 [-1.50]	0.08 [1.28]	0.112
1Q Ahead	1.11 [1.69]	-1.15 [-2.12]	-0.05 [-0.92]	0.04 [0.75]	0.102
4Q Ahead	0.98 [1.54]	-1.05 [-1.89]	-0.04 [-0.79]	0.03 [0.64]	0.087
12Q Ahead	0.59 [1.08]	-0.79 [-1.51]	-0.00 [-0.04]	0.01 [0.24]	0.057
20Q Ahead	-0.37 [-1.19]	0.10 [0.31]	0.05 [2.09]	-0.06 [-2.14]	0.023
Detrended hours:					
0Q Ahead	0.24 [1.11]	0.41 [1.99]	-0.04 [-2.01]	0.07 [2.90]	0.132
1Q Ahead	0.27 [1.33]	0.43 [2.50]	-0.05 [-2.39]	0.07 [2.64]	0.182
4Q Ahead	0.31 [1.67]	0.30 [1.96]	-0.05 [-2.60]	0.06 [2.81]	0.174
12Q Ahead	0.24 [1.15]	0.11 [0.74]	-0.03 [-1.21]	0.03 [1.20]	0.082
20Q Ahead	0.04 [0.22]	0.03 [0.21]	0.00 [0.01]	-0.00 [-0.06]	-0.003

The Table shows the results from the projection of contemporaneous and future business-cycle component of selected macroeconomic variables, averaged over h periods, on the current sectoral shocks: consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. The predictive projection ($h > 1$) is: $\frac{1}{h}\sum_{j=1}^{h} y_{t+j}^{\text{cycle}} = \beta_0 + \beta_h'[\Delta\text{C-TFP}_t, \Delta\text{I-TFP}_t, \Delta\text{C-TFP-VOL}_t, \Delta\text{I-TFP-VOL}_t] + error$. The contemporaneous projection ($h = 0$) is the same, but the dependent variable is $\Delta y_t^{\text{cycle}}$. The cyclical component y^{cycle} of a variable y is obtained from one-sided HP-filtering the trending level-series of y with a smoothing parameter of 1600. The Table reports the slope coefficients β_h, $t-$statistics, and the adjusted R^2s for the contemporaneous projection ($h = 0$), and the predictive horizons of $h = 1, 4, 12$ and 20 quarters, for the corresponding business-cycle variable y^{cycle}. Standard errors are Newey-West adjusted. The data are quarterly from 1947Q1-2014Q4.

Table 4: **Sectoral Shocks and the Cross-section of Returns**

Panel A: Market-prices of risk (Λ)

	$\lambda_{\text{C-TFP}}$	$\lambda_{\text{I-TFP}}$	$\lambda_{\text{C-TFP-VOL}}$	$\lambda_{\text{I-TFP-VOL}}$
λ	2.39	1.36	-0.43	0.70
	[2.30]	[1.37]	[-3.49]	[4.75]

Panel B: Exposures to risks (β)

	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$
Market	2.80	-0.94	-0.06	0.08
bm1	3.04	-0.78	-0.01	0.03
bm2	2.48	-1.06	-0.04	0.04
bm3	2.35	-1.23	-0.04	0.05
bm4	2.43	-0.85	-0.13	0.16
bm5	2.60	-1.17	-0.04	0.03
bm6	2.88	-0.90	-0.13	0.16
bm7	2.42	-0.75	-0.07	0.09
bm8	3.27	-0.58	-0.19	0.25
bm9	2.76	-0.53	-0.07	0.10
bm10	3.13	0.08	-0.07	0.09
mom1	5.41	-2.44	-0.06	0.04
mom2	4.07	-1.58	0.01	-0.01
mom3	3.19	-1.39	-0.12	0.12
mom4	2.73	-0.77	-0.03	0.05
mom5	2.78	-0.97	-0.11	0.16
mom6	2.51	-0.95	-0.09	0.11
mom7	2.25	-0.94	-0.14	0.18
mom8	2.43	-0.83	-0.07	0.09
mom9	2.71	-0.76	-0.07	0.11
mom10	3.15	-0.64	-0.04	0.16
size1	3.58	-0.31	0.08	-0.07
size2	3.37	-0.83	0.08	-0.08
size3	3.05	-0.70	0.07	-0.06
size4	3.39	-1.06	0.01	0.00
size5	3.06	-1.01	0.05	-0.06
size6	2.96	-1.10	0.01	0.00
size7	2.87	-0.97	-0.04	0.04
size8	2.52	-0.85	-0.01	0.02
size9	2.42	-0.75	-0.08	0.09
size10	2.78	-0.90	-0.08	0.11

The Table shows the estimates of the market-prices of risks (Panel A) and the exposures (Panel B) to consumption TFP, C-TFP, investment TFP, I-TFP, consumption TFP-volatility, C-TFP-VOL, and investment TFP-volatility, I-TFP-VOL, risks for the cross-section of equity returns. The cross-section includes the market, ten portfolios sorted on book-to-market (bm), ten portfolios sorted on momentum (mom), and ten portfolios sorted on size (size). The reported market prices of risks are divided by 10. T-statistics are in brackets, and are based on Newey-West standard errors from GMM estimation. For brevity, the significance of exposures is omitted. The data are quarterly from 1947Q1-2014Q4.

Table 5: **Sectoral (Industry) Exposures to Sectoral Shocks**

Sector	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$
All	2.80 [9.72]	-0.94 [-3.62]	-0.06 [-1.69]	0.08 [1.86]
Services	2.17 [4.24]	-0.98 [-2.18]	-0.13 [-2.95]	0.17 [3.34]
Nondurables	2.33 [5.58]	-1.18 [-3.56]	-0.05 [-0.75]	0.05 [1.67]
Durables	4.56 [6.42]	-1.50 [-3.05]	-0.25 [-2.49]	0.28 [2.13]
Investment	4.07 [8.85]	-1.01 [-2.13]	-0.02 [-0.32]	0.04 [1.35]

The Table shows the exposures of sectoral (industry) portfolios, to consumption TFP, C-TFP, investment TFP, I-TFP, consumption TFP-volatility, C-TFP-VOL, and investment TFP-volatility, I-TFP-VOL risks. Each portfolio is comprised of value-weighted returns from CRSP. Sorting firms into industry portfolios is made each June, based on Gomes et al. (2009) SIC classifications for sectors. *T*-statistics are in brackets, and are Newey-West adjusted. The data are quarterly from 1947Q1-2014Q4.

Table 6: **Summary of Pricing Statistics from a Four-Factor Model**

Panel A: Adjusted R^2 of Fama-Macbeth second-stage projection

Adj-R^2	0.73

Panel B: Cross-sectional spreads

Spread	Data	Model	$Spread_{\text{C-TFP}}$	$Spread_{\text{I-TFP}}$	$Spread_{\text{C-TFP-VOL}}$	$Spread_{\text{I-TFP-VOL}}$
MOM	-2.65	-0.83	1.15	-0.95	1.39	-2.43
BM	-1.00	-0.69	-0.08	-0.32	1.31	-1.60
SIZE	0.46	0.27	0.50	0.22	5.25	-5.70
Q	0.98	1.28	0.12	0.35	-0.70	1.52
OP	-0.79	-1.03	0.27	-0.20	-0.20	-0.90
RVAR	1.55	0.88	-2.84	1.18	-8.18	10.72

Panel C: Market risk premium decomposition

	Data	Model	$Prem_{\text{C-TFP}}$	$Prem_{\text{I-TFP}}$	$Prem_{\text{C-TFP-VOL}}$	$Prem_{\text{I-TFP-VOL}}$
Market Premium	1.64	1.63	1.88	-0.67	-1.91	2.34

The Table shows summary asset-pricing results of a four-factor model: consumption TFP, C-TFP, investment TFP, I-TFP, consumption TFP-volatility, C-TFP-VOL, and investment TFP-volatility, I-TFP-VOL, risk factors. Panel A reports the adjusted R^2 of the second-stage regression (mean-excess returns projected on risk-exposures) from a Fama-Macbeth procedure, using a cross-section of ten book-to-market sorted portfolios, ten momentum sorted portfolios, ten size sorted portfolios, and the market portfolio. Panel B reports data and model counterpart quarterly spreads of quantile sorted portfolios, along the momentum dimension (MOM), book-to-market dimension (BM), size dimension (SIZE), Tobin's Q dimension (Q), operating profitability dimension (OP), and residual (idiosyncratic) variance of return (RVAR) dimension. The operating profitability is measured via operating profits divided by book equity value. Residual variance refers to the variance of the residuals from the Fama-French three-factor model using 60 days of lagged returns. Each spread is computed by subtracting the return of portfolios 5 (the portfolio of stocks with the highest characteristic), from the return of portfolio 1 (the portfolio of stocks with the lowest characteristic). Panel C reports the market risk-premium in the data versus the model. Panels B and C also show the decomposition of the model-implied spreads (*Spread*), and model-implied risk premia (*Prem*), into the compensations for the four risk factors. The data for OP and RVAR sorted portfolios are from 1964Q1-2014Q4. All other data are quarterly from 1947Q1-2014Q4.

Table 7: **Summary of Pricing Statistics from a Two-Factor Model**

Panel A: Adjusted R^2 of Fama-Macbeth second-stage projection				
Adj-R^2	0.52			

Panel B: Cross-sectional spreads				
Spread	Data	Model	$Spread_{\text{C-TFP}}$	$Spread_{\text{I-TFP}}$
MOM	-2.65	0.50	1.87	-1.37
BM	-1.00	-0.55	0.05	-0.59
SIZE	0.46	1.29	1.36	-0.07
Q	0.98	0.41	0.07	0.34
OP	-0.79	0.51	0.43	0.08
RVOL	1.55	-3.12	-5.26	2.14

Panel C: Market risk premium decomposition				
	Data	Model	$Prem_{\text{C-TFP}}$	$Prem_{\text{I-TFP}}$
Market Premium	1.64	1.39	2.47	-1.08

The Table shows summary asset-pricing results of a two-factor model: consumption TFP, C-TFP, and investment TFP, I-TFP. Panel A reports the adjusted R^2 of the second-stage regression (mean-excess returns projected on risk-exposures) from a Fama-Macbeth procedure, using a cross-section of ten book-to-market sorted portfolios, ten momentum sorted portfolios, ten size sorted portfolios, and the market portfolio. Panel B reports data and model counterpart quarterly spreads of quantile sorted portfolios, along the momentum dimension (MOM), book-to-market dimension (BM), size dimension (SIZE), Tobin's Q dimension (Q), operating profitability dimension (OP), and residual (idiosyncratic) variance of return (RVAR) dimension. The operating profitability is measured via operating profits divided by book equity value. Residual variance refers to the variance of the residuals from the Fama-French three-factor model using 60 days of lagged returns. Each spread is computed by subtracting the return of portfolios 5 (the portfolio of stocks with the highest characteristic), from the return of portfolio 1 (the portfolio of stocks with the lowest characteristic). Panel C reports the market risk-premium in the data versus the model. Panels B and C also show the decomposition of the model-implied spreads (*Spread*), and model-implied risk premia (*Prem*), into the compensations for the four risk factors. The data for OP and RVAR sorted portfolios are from 1964Q1-2014Q4. All other data are quarterly from 1947Q1-2014Q4.

Table 8: **Sectoral Volatilities and Debt Measures**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	$Adj-R^2$
Panel A: Sectoral volatilities and the default Spread					
0Q Ahead	-3.32 [-1.52]	-1.57 [-0.69]	0.57 [1.89]	-0.60 [-1.71]	0.065
1Q Ahead	-3.81 [-2.15]	-1.06 [-0.62]	0.48 [1.97]	-0.58 [-1.97]	0.017
4Q Ahead	-3.96 [-1.96]	2.58 [1.61]	0.26 [1.23]	-0.28 [-1.12]	0.035
12Q Ahead	-2.71 [-2.00]	2.74 [2.23]	0.13 [1.11]	-0.12 [-0.90]	0.055
20Q Ahead	-0.26 [-0.62]	0.92 [2.20]	-0.02 [-0.57]	0.05 [1.10]	0.048
Panel B: Sectoral volatilities and real debt growth					
0Q Ahead	4.70 [1.39]	-2.70 [-1.19]	-1.13 [-2.26]	1.28 [2.00]	0.011
1Q Ahead	7.61 [2.22]	-4.32 [-1.68]	-0.36 [-0.55]	0.55 [0.71]	0.015
4Q Ahead	3.82 [2.02]	-2.27 [-1.53]	-0.24 [-1.62]	0.28 [1.63]	0.048
12Q Ahead	1.87 [1.58]	-1.63 [-1.50]	-0.10 [-0.97]	0.11 [0.94]	0.020
20Q Ahead	1.54 [1.26]	-1.12 [-1.19]	-0.10 [-1.01]	0.11 [1.01]	0.017

The Table shows the results of projecting contemporaneous and future default-spread growth rates (Panel A) and real-debt growth rates (Panel B) on the current sectoral shocks: consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. The predictive projection ($h>1$) is: $\frac{1}{h}\sum_{j=1}^{h}\Delta y_{t+j}=\beta_0+\beta_h'[\Delta\text{C-TFP}_t,\Delta\text{I-TFP}_t,\Delta\text{C-TFP-VOL}_t,\Delta\text{I-TFP-VOL}_t]+error$. The contemporaneous projection ($h=0$) is the same, but the dependent variable is Δy_t. The default-spread is computed as the difference between the yield of BAA and AAA rated corporate bonds. Total debt for publicly traded firms is computed as debt in current liabilities (*dlcq*) plus long term debt (*dlttq*). The Table reports the slope coefficients β_h, $t-$statistics, and the adjusted R^2s for the contemporaneous projection ($h=0$), and for the predictive horizons of 1 up to 20 quarters. Standard errors are Newey-West adjusted. Data on the default spread are quarterly from 1947Q1-2014Q4. Data on real debt growth span from 1966Q1-2014Q4.

Table 9: **Sectoral Volatility Feedback to Future Technological Growth**

$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	$Adj-R^2$
1Q Ahead C-TFP:				
0.46 [3.69]	-0.23 [-1.77]	-0.78 [-1.06]	0.82 [2.20]	0.047
1Q Ahead I-TFP:				
-0.10 [-0.67]	0.38 [3.32]	-0.32 [-0.67]	0.42 [0.88]	0.056

The Table shows the volatility feedback evidence from projections of one-quarter ahead sectoral TFP growth rates, on the current sectoral shocks: consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL: $\Delta j-TFP_{t+1}=\beta_0+\beta_h'[\Delta\text{C-TFP}_t,\Delta\text{I-TFP}_t,\Delta\text{C-TFP-VOL}_t,\Delta\text{I-TFP-VOL}_t]+error,\quad j\in\{C,I\}$. The Table reports the slope coefficients β_h, $t-$statistics, and the adjusted R^2s. Standard errors are Newey-West adjusted. The data are quarterly from 1947Q1-2014Q4.

Table 10: **Summary Results Based on Total Ex-Ante Volatilities as Factors**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	R^2
Panel A: Macroeconomic growth rate predictability					
Consumption growth	0.32 [0.66]	-0.24 [-0.51]	-21.89 [-1.29]	19.95 [3.22]	0.256
GDP growth	1.00 [1.58]	-0.91 [-1.45]	-49.75 [-2.11]	30.88 [3.43]	0.214
Capital investment growth	3.09 [3.42]	-2.80 [-3.16]	-136.13 [-3.76]	75.92 [4.37]	0.181
Capex growth	4.56 [1.35]	-3.85 [-1.06]	-256.49 [-1.31]	158.59 [0.92]	0.096
Relative price growth	-0.28 [-0.55]	0.30 [0.61]	-12.95 [-0.77]	30.88 [3.56]	0.357
Wage growth	-0.11 [-0.24]	0.15 [0.34]	-7.45 [-0.43]	16.21 [1.64]	0.183
Hours growth	0.27 [1.51]	-0.28 [-1.56]	-12.83 [-1.93]	6.97 [2.14]	0.061
Panel B: Macroeconomic business-cycle predictability					
Detrended consumption	3.58 [1.47]	-2.76 [-1.16]	-218.44 [-2.10]	159.15 [2.02]	0.148
Detrended GDP	5.00 [2.75]	-4.21 [-2.28]	-264.34 [-3.40]	171.11 [2.95]	0.225
Detrended capital investment	24.40 [4.01]	-21.82 [-3.72]	-969.05 [-4.20]	457.18 [3.66]	0.129
Detrended capex	14.10 [0.94]	-9.58 [-0.58]	-933.08 [-1.14]	761.00 [1.13]	0.119
Detrended relative price	-1.88 [-1.77]	1.71 [1.66]	57.65 [1.22]	-13.31 [-0.58]	0.032
Detrended wage	1.39 [1.43]	-1.46 [-1.45]	-57.48 [-1.56]	20.54 [1.08]	0.005
Detrended hours	0.32 [0.59]	-0.24 [-0.42]	-26.29 [-1.38]	24.00 [2.55]	0.115
Panel C: Asset-pricing implications					
Market prices of risk	13.72 [4.72]	-12.50 [-4.23]	-720.05 [-6.65]	435.18 [6.70]	
Market betas	4.60 [3.53]	-2.90 [-2.61]	-88.92 [-1.93]	38.20 [2.51]	

The Table presents the summary of the macroeconomic and asset-pricing implications of sectoral factors, using the (total) ex-ante sectoral TFP volatilities as risk-factors, as opposed to their shocks (first differences) as in the benchmark case. Panel A documents the slope coefficients, $t-$statistics and the R^2 in the projections of 12-quarters ahead macroeconomic growth rates on consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility, C-TFP-VOL, and investment TFP-volatility, I-TFP-VOL. Panel B shows the evidence from projecting 12-quarters ahead average business-cycle component of macroeconomic variables on the sectoral innovations and ex-ante volatilities. Panel C shows the estimates of the market-prices of risks and the market return exposures to the four risk factors, constructed and reported as in Table 4. The data are quarterly from 1947Q1-2014Q4.

Table 11: **Summary Results Based on Sale-Dispersion as Sectoral Volatility Factors**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-DISP}}$	$\beta_{\text{I-DISP}}$	R^2
Panel A: Macroeconomic growth rate predictability					
Consumption growth	0.09 [1.49]	-0.04 [-0.74]	-0.04 [-1.21]	0.01 [1.63]	0.014
GDP growth	0.16 [1.89]	-0.09 [-1.10]	-0.06 [-1.43]	0.01 [1.75]	0.031
Capital investment growth	0.72 [2.05]	-0.44 [-1.43]	-0.08 [-0.76]	0.03 [1.70]	0.063
Capex growth	0.37 [0.96]	0.13 [0.29]	-0.31 [-2.25]	0.14 [2.44]	0.015
Relative price growth	0.33 [2.57]	-0.53 [-3.41]	0.10 [1.17]	0.01 [0.10]	0.122
Wage growth	0.03 [0.34]	-0.02 [-0.29]	0.01 [0.39]	0.01 [1.68]	-0.019
Hours growth	0.03 [0.97]	-0.08 [-2.27]	-0.02 [-1.99]	-0.01 [-0.35]	0.096
Panel B: Macroeconomic business-cycle predictability					
Detrended consumption	0.43 [0.89]	0.08 [0.20]	-0.24 [-1.40]	0.02 [1.33]	0.030
Detrended GDP	0.61 [1.48]	-0.10 [-0.28]	-0.33 [-1.76]	0.02 [1.38]	0.044
Detrended capital investment	3.67 [2.24]	-1.44 [-1.04]	-0.74 [-1.26]	0.17 [1.80]	0.072
Detrended capex	6.51 [2.11]	-0.62 [-0.18]	-0.65 [-0.64]	0.58 [1.85]	0.074
Detrended relative price	0.94 [2.24]	-0.95 [-2.40]	-0.16 [-1.47]	0.06 [1.31]	0.126
Detrended wage	0.03 [0.14]	-0.12 [-0.60]	-0.13 [-1.76]	0.01 [1.37]	0.007
Detrended hours	0.13 [1.01]	-0.06 [-0.52]	-0.06 [-1.28]	0.00 [1.07]	0.005
Panel C: Asset-pricing implications					
Market prices of Risk	0.84 [1.04]	0.38 [0.45]	-0.20 [-10.81]	0.12 [6.70]	
Market betas	3.85 [1.79]	-0.89 [-0.79]	-0.02 [-1.12]	0.06 [1.60]	

The Table presents the summary of the macroeconomic and asset-pricing implications of sectoral factors, using an alternative measure of sectoral volatilities: sales growth dispersion in the consumption sector as a substitute for consumption TFP-volatility, and sales growth dispersion in the investment sector as a substitute for investment TFP-volatility. Panel A documents the slope coefficients, $t-$statistics and the R^2 in the projections of 12-quarters ahead macroeconomic growth rates on consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption sales dispersion, C-DISP, and investment sales dispersion, I-DISP. Panel B shows the evidence from projecting 12-quarters ahead average business-cycle component of macroeconomic variables on the sectoral innovations and sale dispersions. The slope coefficients on I-TFP-VOL and C-TFP-VOL are multiplied by 10. Panel C shows the estimates of the market-prices of risks and the market return exposures to the four risk factors, constructed and reported as in Table 4. The data are quarterly from 1964Q1-2014Q4.

Table 12: **Summary Results Based on Different Predictors of Future Volatility**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	R^2
Panel A: Macroeconomic growth rate predictability					
Consumption growth	0.18 [2.70]	-0.13 [-2.55]	-0.01 [-2.17]	0.01 [1.78]	0.070
GDP growth	0.23 [2.21]	-0.17 [-2.05]	-0.01 [-2.42]	0.01 [1.85]	0.060
Capital investment growth	0.52 [1.51]	-0.38 [-1.28]	-0.02 [-1.60]	0.01 [1.17]	0.043
Capex growth	0.33 [0.60]	0.25 [0.37]	-0.01 [-0.30]	0.00 [0.11]	0.029
Relative price growth	0.35 [2.29]	-0.37 [-2.75]	-0.01 [-2.29]	0.01 [2.44]	0.111
Wage growth	0.23 [2.65]	-0.20 [-2.59]	-0.01 [-1.87]	0.01 [1.80]	0.067
Hours growth	0.03 [0.63]	-0.07 [-1.64]	-0.00 [-1.92]	0.00 [0.69]	0.043
Panel B: Macroeconomic business-cycle predictability					
Detrended consumption	0.71 [0.85]	-0.14 [-0.22]	-0.02 [-0.72]	0.01 [1.64]	0.022
Detrended GDP	0.72 [1.17]	-0.19 [-0.38]	-0.02 [-0.89]	0.02 [0.75]	0.028
Detrended capital investment	3.33 [1.41]	-1.62 [-0.82]	-0.10 [-1.29]	0.09 [1.15]	0.035
Detrended capex	3.50 [1.93]	-0.77 [-0.31]	-0.09 [-0.77]	0.12 [1.37]	0.045
Detrended relative price	0.65 [1.28]	-0.80 [-1.54]	-0.01 [-0.75]	0.01 [1.62]	0.055
Detrended wage	0.00 [0.00]	-0.11 [-0.39]	-0.01 [-0.63]	-0.01 [-0.21]	-0.004
Detrended hours	0.01 [0.08]	0.05 [0.32]	-0.00 [-0.04]	-0.00 [-0.49]	0.002
Panel C: Asset-pricing implications					
Market prices of risk	7.21 [0.70]	6.59 [8.20]	-0.26 [-4.07]	0.21 [3.38]	
Market betas	0.00 [1.10]	0.05 [0.19]	-0.31 [-4.26]	0.08 [2.84]	

The Table presents the summary of the macroeconomic and asset-pricing implications of sectoral shocks, using alternative construction of ex-ante TFP volatilities, in which the set of predictive variables Γ_t includes the benchmark predictors, as well as the risk-free rate and the market price-dividend ratio. Panel A documents the slope coefficients, $t-$statistics and the R^2 in the projections of 12-quarters ahead macroeconomic growth rates on consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. Panel B shows the evidence from projecting 12-quarters ahead average business-cycle component of macroeconomic variables on the sectoral innovations and volatility shocks. Panel C shows the estimates of the market-prices of risks and the market return exposures to the four risk factors, constructed and reported as in Table 4. The data are quarterly from 1947Q1-2014Q4.

Table 13: **Summary Results Based on Different Window in Construction of Realized Variances**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-VOL}}$	$\beta_{\text{I-TFP-VOL}}$	R^2
Panel A: Macroeconomic growth rate predictability					
Consumption growth	0.21 [2.86]	-0.14 [-2.60]	-0.03 [-2.07]	0.03 [1.96]	0.082
GDP Growth	0.27 [2.44]	-0.16 [-1.96]	-0.04 [-2.03]	0.05 [1.89]	0.070
Capital investment growth	0.64 [1.66]	-0.43 [-1.34]	-0.09 [-1.49]	0.10 [1.40]	0.054
Capex growth	0.71 [1.24]	0.21 [0.32]	-0.24 [-2.45]	0.30 [2.38]	0.054
Relative price growth	0.33 [1.87]	-0.36 [-2.42]	-0.02 [-0.85]	0.02 [0.70]	0.096
Wage growth	0.25 [2.60]	-0.19 [-2.32]	-0.03 [-1.86]	0.03 [1.81]	0.063
Hours growth	0.04 [0.84]	-0.06 [-1.56]	-0.00 [-0.33]	0.00 [0.05]	0.023
Panel B: Macroeconomic business-cycle predictability					
Detrended consumption	0.89 [0.93]	-0.14 [-0.20]	-0.15 [-1.91]	0.18 [1.89]	0.025
Detrended GDP	0.84 [1.13]	-0.15 [-0.27]	-0.14 [-1.04]	0.17 [1.01]	0.029
Detrended capital investment	4.44 [1.51]	-2.09 [-0.91]	-0.65 [-1.35]	0.75 [1.30]	0.043
Detrended capex	5.79 [1.88]	0.14 [0.04]	-1.53 [-2.13]	1.95 [2.11]	0.111
Detrended relative price	0.08 [0.20]	-0.32 [-0.74]	0.04 [0.77]	-0.06 [-0.84]	0.016
Detrended wage	0.15 [0.38]	-0.11 [-0.32]	-0.01 [-0.09]	0.00 [0.01]	-0.011
Detrended hours	0.22 [1.07]	0.14 [0.84]	-0.03 [-0.71]	0.04 [0.70]	0.085
Panel C: Asset-pricing implications					
Market prices of risk	4.81 [3.25]	-1.41 [-1.03]	-1.58 [-5.05]	2.12 [5.43]	
Market betas	2.75 [11.12]	-1.11 [-3.24]	-0.04 [-1.51]	0.04 [1.85]	

The Table presents the summary of the macroeconomic and asset-pricing implications of sectoral shocks, using alternative construction of ex-ante volatilities, in which the sectoral TFP realized variances are computed over a window of 12 quarters, as opposed to 8 quarter in the benchmark case. Panel A documents the slope coefficients, $t-$statistics and the R^2 in the projections of 12-quarters ahead macroeconomic growth rates on consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. Panel B shows the evidence from projecting 12-quarters ahead average business-cycle component of macroeconomic variables on the sectoral innovations and volatility shocks. Panel C shows the estimates of the market-prices of risks and the market return exposures to the four risk factors, constructed and reported as in Table 4. The data are quarterly from 1947Q1-2014Q4.

Table 14: **Summary Results Based on Realized Volatilities as Factors**

Offset	$\beta_{\text{C-TFP}}$	$\beta_{\text{I-TFP}}$	$\beta_{\text{C-TFP-RV}}$	$\beta_{\text{I-TFP-RV}}$	R^2
Panel A: Macroeconomic growth rate predictability					
Consumption growth	0.12 [2.21]	0.02 [0.87]	-2.80 [-1.89]	1.61 [2.29]	0.117
GDP growth	0.13 [1.43]	0.03 [0.96]	-1.98 [-1.48]	2.64 [2.64]	0.142
Capital investment growth	0.36 [1.39]	0.07 [0.72]	-0.18 [-0.01]	2.84 [0.77]	0.051
Capex growth	-0.32 [-0.72]	0.37 [1.26]	-27.84 [-0.58]	34.75 [4.14]	0.193
Relative price growth	0.06 [0.57]	-0.07 [-1.78]	23.66 [3.80]	0.41 [0.48]	0.366
Wage growth	0.08 [1.24]	-0.00 [-0.11]	-6.99 [-1.24]	1.56 [1.34]	0.196
Hours growth	0.00 [0.08]	-0.02 [-2.07]	-1.65 [-0.76]	1.13 [2.59]	0.095
Panel B: Macroeconomic business-cycle predictability					
Detrended consumption	0.52 [0.90]	0.47 [2.04]	-79.06 [-1.74]	22.89 [2.21]	0.130
Detrended GDP	0.50 [1.06]	0.41 [2.24]	-51.19 [-1.23]	16.31 [1.65]	0.100
Detrended capital investment	2.77 [1.58]	1.04 [1.58]	-66.28 [-0.55]	18.36 [0.69]	0.037
Detrended capex	1.42 [0.65]	2.43 [1.39]	-101.58 [-0.38]	104.61 [2.24]	0.126
Detrended relative price	-0.02 [-0.08]	-0.20 [-1.41]	34.64 [1.22]	-4.94 [-0.96]	0.062
Detrended wage	0.21 [0.59]	0.03 [0.23]	-29.77 [-1.28]	5.81 [1.57]	0.031
Detrended hours	0.03 [0.27]	0.08 [1.48]	-4.65 [-0.46]	1.50 [0.54]	0.005
Panel C: Asset-pricing implications					
Market prices of risk	-0.11 [-0.20]	1.29 [2.34]	-37.44 [-4.12]	304.14 [5.19]	
Market betas	2.25 [5.48]	-0.76 [-2.89]	-12.13 [-1.62]	15.33 [4.28]	

The Table presents the summary of the macroeconomic and asset-pricing implications of sectoral factors, using the realized variances of sectoral TFP growth rates as the volatility risk-factors. Panel A documents the slope coefficients, $t-$statistics and the R^2 in the projections of 12-quarters ahead macroeconomic growth rates on consumption TFP innovation, ΔC-TFP, investment TFP innovation, ΔI-TFP, consumption TFP realized variance, C-TFP-RV, and investment TFP realized variance, I-TFP-RV. Panel B shows the evidence from projecting 12-quarters ahead average business-cycle component of macroeconomic variables on the sectoral innovations and realized variances. Panel C shows the estimates of the market-prices of risks and the market return exposures to the four risk factors, constructed and reported as in Table 4. The data are quarterly from 1947Q1-2014Q4.

Table 15: **Calibration of the Benchmark Model**

Symbol	Value	Parameter
γ	25	Relative risk aversion
ψ	1.7	Intertemporal Elasticity of Substitution
β	0.997	Time discount factor
ξ	3	Disutility from labor
η	1.4	Sensitivity of disutility to working hours
$\alpha_c = \alpha_i$	0.33	Share of capital in output
δ	0.015	depreciation rate
μ_{zc}	1.0024	Drift of consumption sector TFP
μ_{zi}	1.0050	Drift of investment sector TFP
$\sigma_{zc,0}$	0.01	Unconditional volatility of consumption TFP shock
$\sigma_{zi,0}$	0.02	Unconditional volatility of investment TFP shock
ρ_σ	0.95	Persistence of volatilities
μ_c	4	Markup of 25% in the consumption sector
μ_i	4	Markup of 25% in the investment sector
ϕ_P	250	Nominal price rigidity (Rotemberg)
π_{ss}	0.005	Steady state inflation
ρ_π	1.5	Weight on inflation gap in Taylor rule
ρ_y	0.5	Weight on output gap in Taylor rule
τ	1.5	Feedback from investment TFP-volatility to future consumption TFP

The Table presents parameter choice of the model parameters in the Benchmark case.

Table 16: **Model-Implied Macroeconomic Moments against Data Counterparts**

	Model (Annualized)			Data (1947-2014)		
	Mean	Std.dev.	Ac(1)	Mean	Std.dev.	Ac(1)
ΔC	1.92 [0.99,2.84]	2.17 [1.70,2.67]	0.54 [0.33,0.70]	1.92	1.52	0.49
ΔY	1.93 [0.98,2.81]	3.01 [2.49,3.52]	0.43 [0.23,0.59]	1.98	2.53	0.18
ΔI	1.88 [0.89,2.99]	6.64 [5.54,7.90]	0.30 [0.10,0.48]	1.67	6.75	0.18
ΔP_I	-0.95 [-2.08,0.24]	3.48 [2.89,4.08]	0.30 [0.07,0.47]	-0.97	3.62	0.45

The Table presents model-implied mean, standard deviation, and auto-correlation for key macroeconomic growth rates, against their empirical counterparts. The macroeconomic growth rates reported include (log-real growth rates of) consumption growth ΔC, output growth ΔY, investment-expenditures growth ΔI, and relative-price of investment growth ΔP_I. The model-implied macroeconomic moments are computed from simulated data. I simulate the model at a quarterly frequency and then time-aggregate the data to annual observations. I report median moments along with the 5% and 95% percentiles, across 10,000 simulations, each with a length of 272 quarters, similarly to the length of the data time-series. The data moments are computed using annual data from 1947-2014.

Table 17: **Model-Implied Pricing Moments against Data Counterparts**

	Model (Annualized)			Data (1947-2014)		
	Mean	Std.dev.	Ac(1)	Mean	Std.dev.	Ac(1)
R_m^e	6.64 [6.16,7.20]	8.01 [7.06,9.03]	-0.00 [-0.19,0.14]	6.20	17.63	-0.03
R_f	1.37 [0.75,2.02]	2.27 [2.02,2.59]	0.79 [0.69,0.87]	0.89	2.24	0.73

The Table presents model-implied mean, standard deviation, and auto-correlation for the real market excess return, R_m^e, and the real risk-free rate, R_f, against their empirical counterparts. In the model, the market excess return is levered-up using a factor of 5/3. The model-implied macroeconomic moments are computed from simulated data. I simulate the model at a quarterly frequency and then time-aggregate the data to annual observations. I report median moments along with the 5% and 95% percentiles, across 10,000 simulations, each with a length of 272 quarters, similarly to the length of the data time-series. The data moments are computed using annual data from 1947-2014.

Table 18: **Model-Implied Market-Prices of Risk and Risk Exposures**

	C-TFP	I-TFP	C-TFP-VOL	I-TFP-VOL
Panel A: Benchmark				
Market prices of risk	2.452	0.974	-0.194	0.611
Market betas	0.595	-0.016	-0.030	0.064
C-Sector betas	0.597	-0.061	-0.029	0.061
I-Sector betas	0.587	-0.001	-0.031	0.074
Panel B: No monopolistic competition and no volatility feedback ($\tau = 0$)				
Market prices of risk	2.499	0.969	-0.140	-0.127
Market betas	1.000	-0.638	-0.012	0.097
C-Sector betas	1.000	-0.697	-0.010	0.088
I-Sector betas	1.000	-0.516	-0.016	0.117

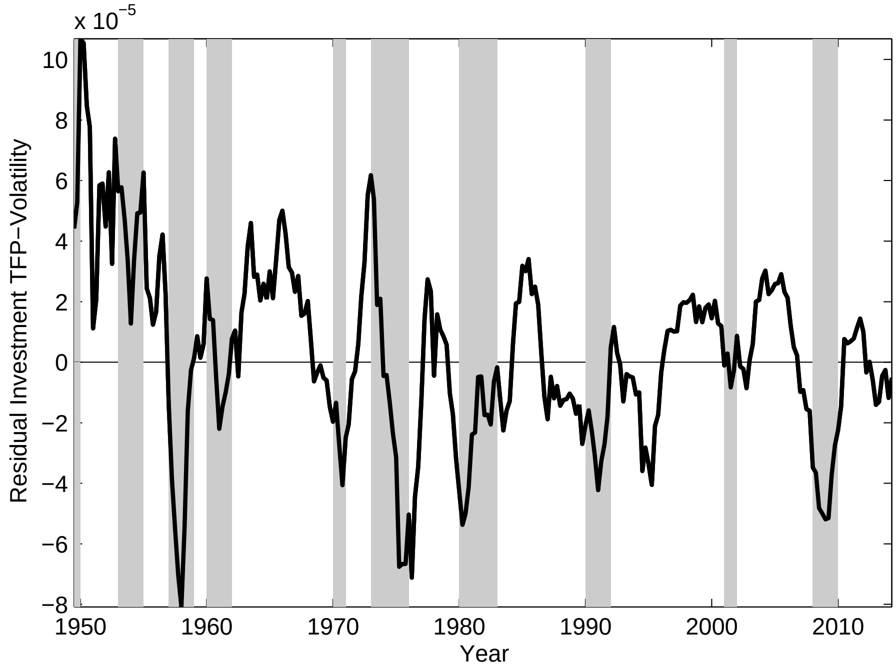
The Table presents model-implied market-prices of risk (λ) and risk exposures (β) to consumption TFP innovation risk (C-TFP shock $\varepsilon_{c,t}$), investment TFP innovation risk (I-TFP shock $\varepsilon_{i,t}$), consumption TFP-volatility risk (C-TFP-VOL shock $\varepsilon_{\sigma,c,t}$) and investment TFP-volatility risk (I-TFP-VOL shock $\varepsilon_{\sigma,i,t}$). The exposures (betas) to the risk factors are reported for consumption firms (V_c), investment firms (V_i), and the market ($V_m = V_c + V_i$). Panel A reports model implied market-prices and betas for the benchmark model. Panel B shows the results for a model with no volatility feedback ($\tau = 0$) and no monopolistic competition. The reported market prices of risks are divided by 10. The construction of market-prices of risk and betas is described in section 6.4.

Table 19: **Simulation Analysis of Sectoral Volatilities in a Model of Constant Volatility**

	C-TFP-VOL				I-TFP-VOL				R^2			
Offset	Pop	Med	5%	95%	Pop	Med	5%	95%	Pop	Med	5%	95%
No Stochastic Volatility and $\tau = 0$:												
Consumption growth:												
0Q	0.64	0.42	[0.17,	0.83]	-0.55	-0.36	[-0.82,	0.01]	0.12	0.17	[0.02,	0.39]
1Q	0.57	0.38	[0.12,	0.76]	-0.47	-0.30	[-0.74,	0.07]	0.19	0.19	[0.04,	0.37]
12Q	0.42	0.15	[-0.05,	0.61]	-0.31	-0.10	[-0.52,	0.17]	0.12	0.06	[-0.08,	0.28]
Output growth:												
0Q	0.42	0.30	[0.16,	0.53]	-0.36	-0.25	[-0.50,	-0.03]	0.33	0.48	[0.21,	0.71]
1Q	0.35	0.27	[0.06,	0.50]	-0.28	-0.21	[-0.49,	0.06]	0.25	0.22	[0.09,	0.37]
12Q	0.20	0.09	[-0.01,	0.30]	-0.15	-0.06	[-0.25,	0.07]	0.15	0.11	[-0.04,	0.33]
Investment growth:												
0Q	0.07	0.12	[-1.31,	1.58]	-0.17	-0.09	[-0.54,	0.23]	0.20	0.36	[0.08,	0.72]
1Q	0.05	0.06	[-1.77,	1.98]	-0.19	-0.08	[-0.64,	0.37]	0.03	-0.02	[-0.08,	0.10]
12Q	-0.03	-0.02	[-1.47,	1.45]	-0.21	-0.07	[-0.60,	0.22]	0.05	-0.01	[-0.10,	0.18]
Market betas:												
	-0.02	-0.00	[-0.21,	0.19]	-0.03	-0.02	[-0.08,	0.03]	0.98	0.99	[0.98,	0.99]

The Table shows the Monte-Carlo evidence of various projections, in a model without stochastic volatility and no volatility feedback ($\tau = 0$). For an economic variable of interest y, the table reports the model-implied loadings on the sectoral volatilities shocks, in the projection of contemporaneous and future growth rates of y, on the current sectoral shocks: consumption and investment TFP innovations, consumption TFP-volatility shock, ΔC-TFP-VOL, and investment TFP-volatility shock, ΔI-TFP-VOL. The predictive projection ($h > 1$) is: $\frac{1}{h}\sum_{j=1}^{h}\Delta y_{t+j} = \beta_0 + \beta_h'[\Delta\text{C-TFP}_t, \Delta\text{I-TFP}_t, \Delta\text{C-TFP-VOL}_t, \Delta\text{I-TFP-VOL}_t] + error$. The variables of interest y include consumption, output, and investment growth rates. The predictive horizons are $h = 0, 1, 12$ quarters. Market betas are based on projection of contemporaneous market returns on the contemporaneous sectoral shocks.The Table reports the population and small-sample estimates (corresponding to $5\%, 50\%$ and 95% percentile of the distribution in simulations) of the slope coefficients and R^2s. Consumption, investment, output and market-returns are simulated at quarterly frequency under a model that is identical to the benchmark model, but in which the volatility of shocks are fixed at their mean value. Sectoral shocks are then computed from the simulated time-series of TFP growth rates, in an identical fashion to the empirical benchmark construction, as described in Section 3.2. Small-sample evidence is based on 10,000 simulations of 272 observations of quarterly data; the population estimates are based on a long simulation of 500,000 quarters of data.

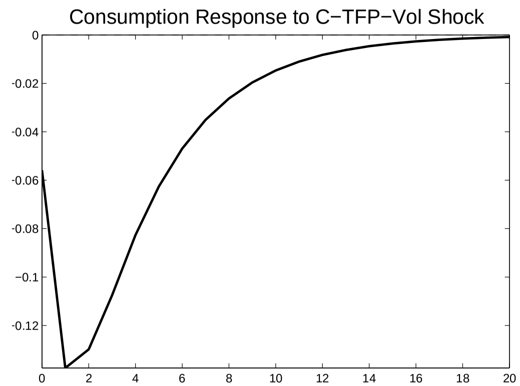
Figure 1: **Residual Investment TFP-Volatility**



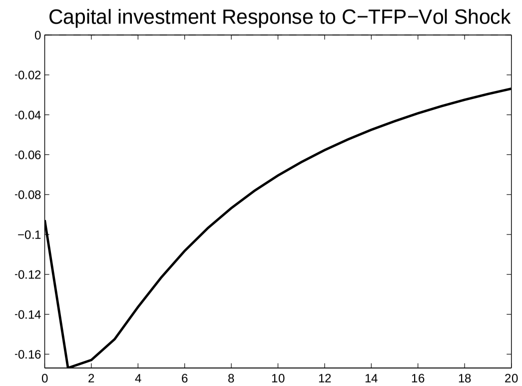
The figure shows the time series plot of the residual investment TFP-volatility which is orthogonal to consumption TFP-volatility. The sectoral TFP-volatilities are constructed from the predictive regressions of future sectoral TFP realized variances. The residual investment TFP-volatility is computed from the projection of investment TFP-volatility onto consumption TFP-volatility. The shaded areas represent NBER recessions.

Figure 2: **Data Impulse Response of Detrended Consumption, Output and Investment to Sectoral Volatilities**

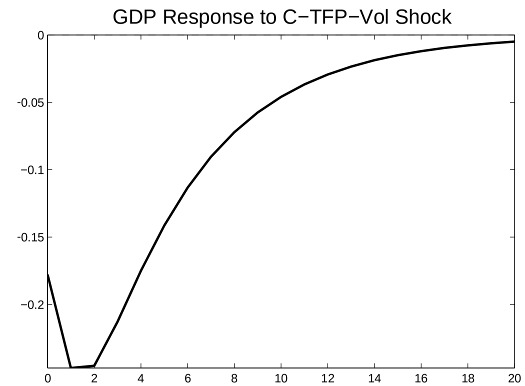
(a) Consumption response to consumption TFP-volatility shock



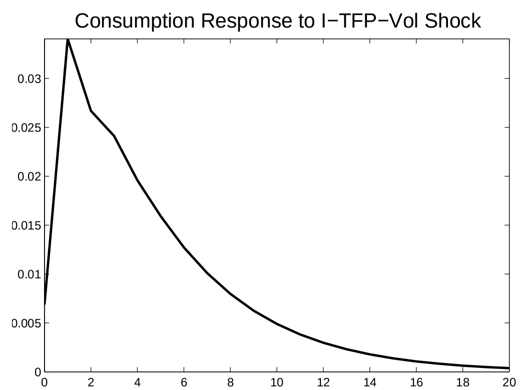
(b) Capital investment response to consumption TFP-volatility shock



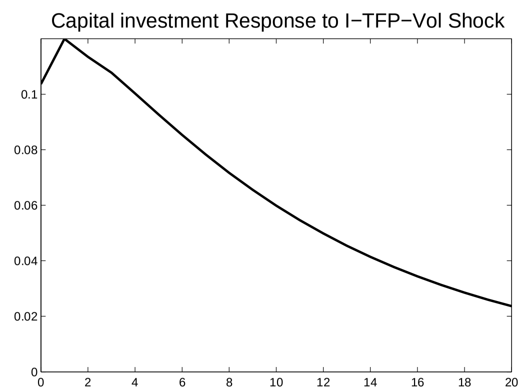
(c) Output response to consumption TFP-volatility shock



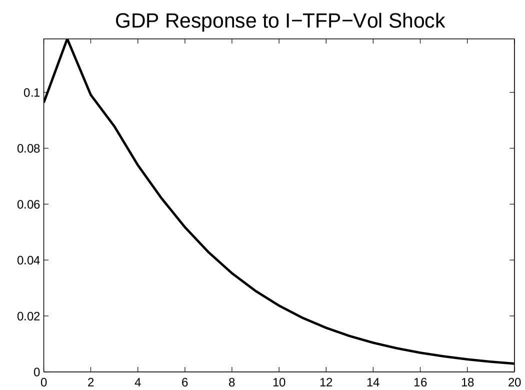
(d) Consumption response to investment TFP-volatility shock



(e) Capital investment response to investment TFP-volatility shock

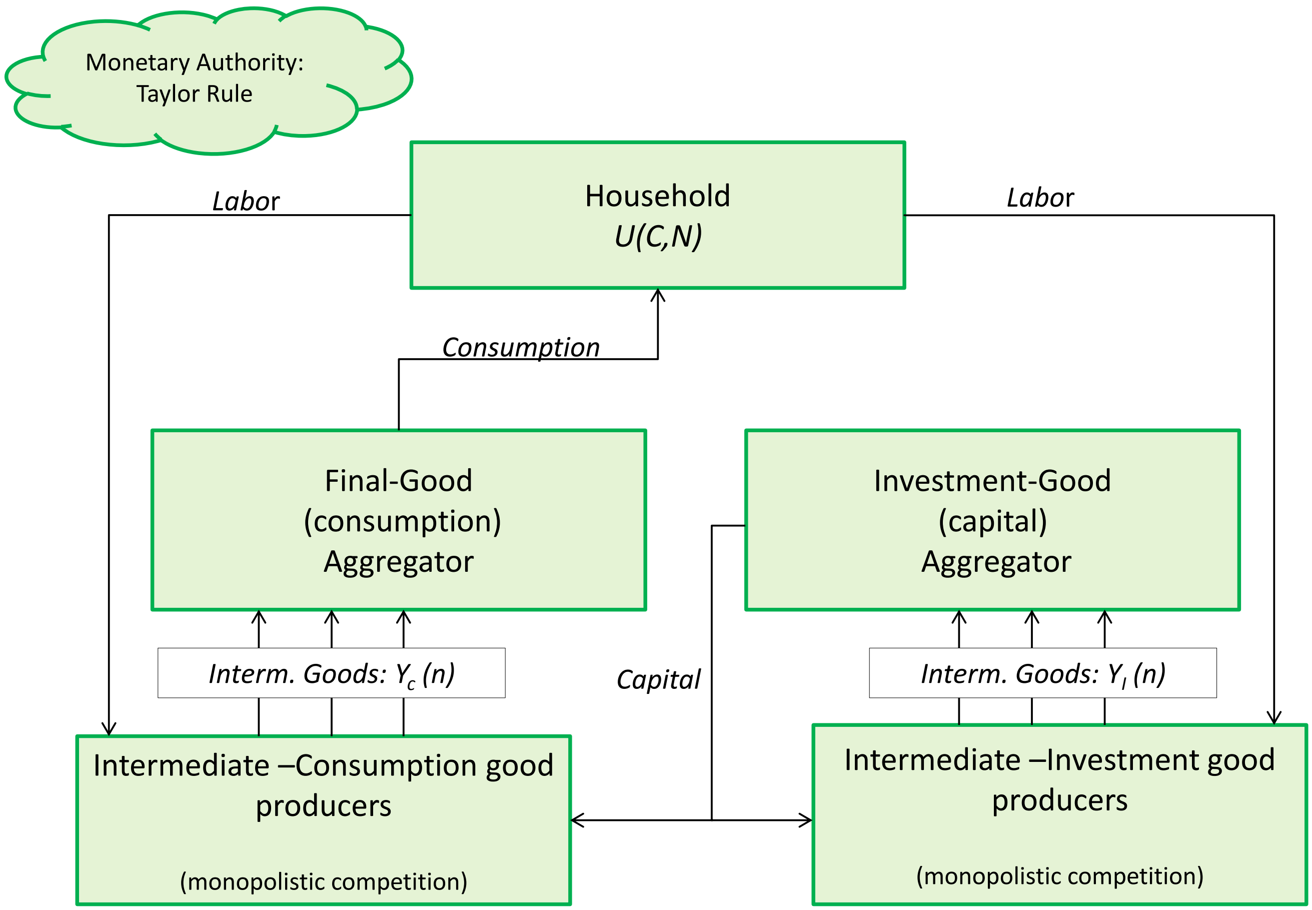


(f) Output response to investment TFP-volatility shock



The Figure shows impulse responses of the cyclical component of consumption, GDP, and capital investment to one-standard deviation shocks of consumption TFP-volatility (C-TFP-VOL) and investment TFP-volatility (I-TFP-VOL). The impulse responses are computed from a VAR(1) which includes sectoral volatilities, sector first-moment innovations, and the economic variable of interest. The cyclical component of each macroeconomic variable is obtained using a one-sided HP-filter. Each cyclical component is standardized. The horizontal axis represents quarters. The vertical axis represents response in standard deviation units of the cyclical component. The data are quarterly from 1947Q1-2014Q4.

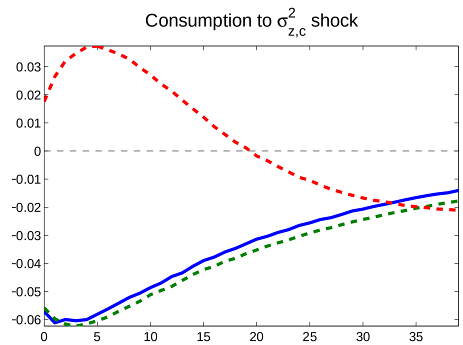
Figure 3: **Model Scheme**



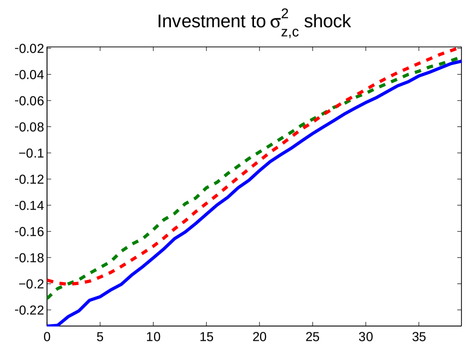
The figure outlines the structure of the benchmark two-sector economy.

Figure 4: **Model Impulse Response of Detrended Consumption, Output and Investment to Sectoral Volatilities**

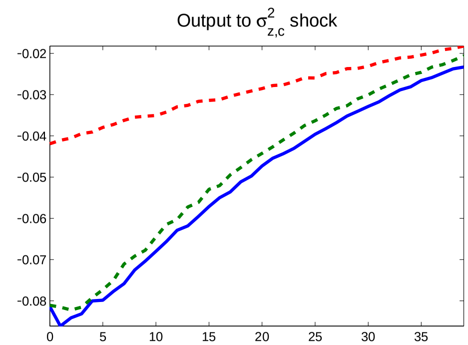
(a) Consumption response to consumption TFP-volatility shock



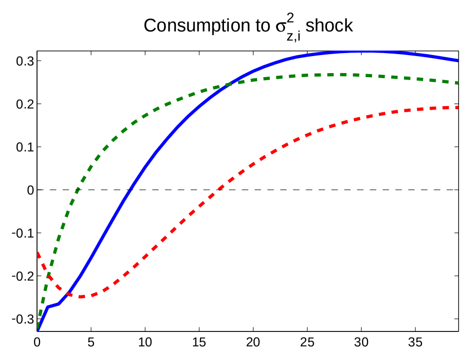
(b) Investment response to consumption TFP-volatility shock



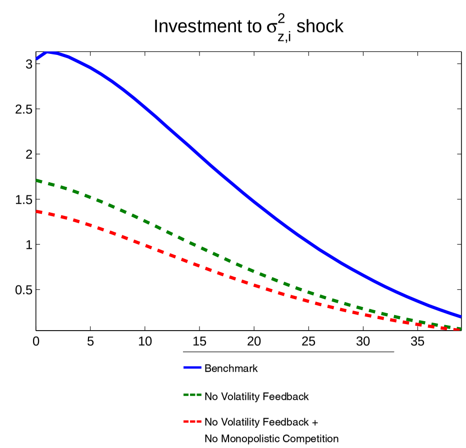
(c) Output response to consumption TFP-volatility shock



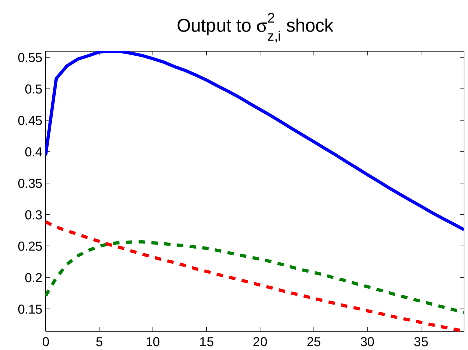
(d) Consumption response to investment TFP-volatility shock



(e) Investment response to investment TFP-volatility shock

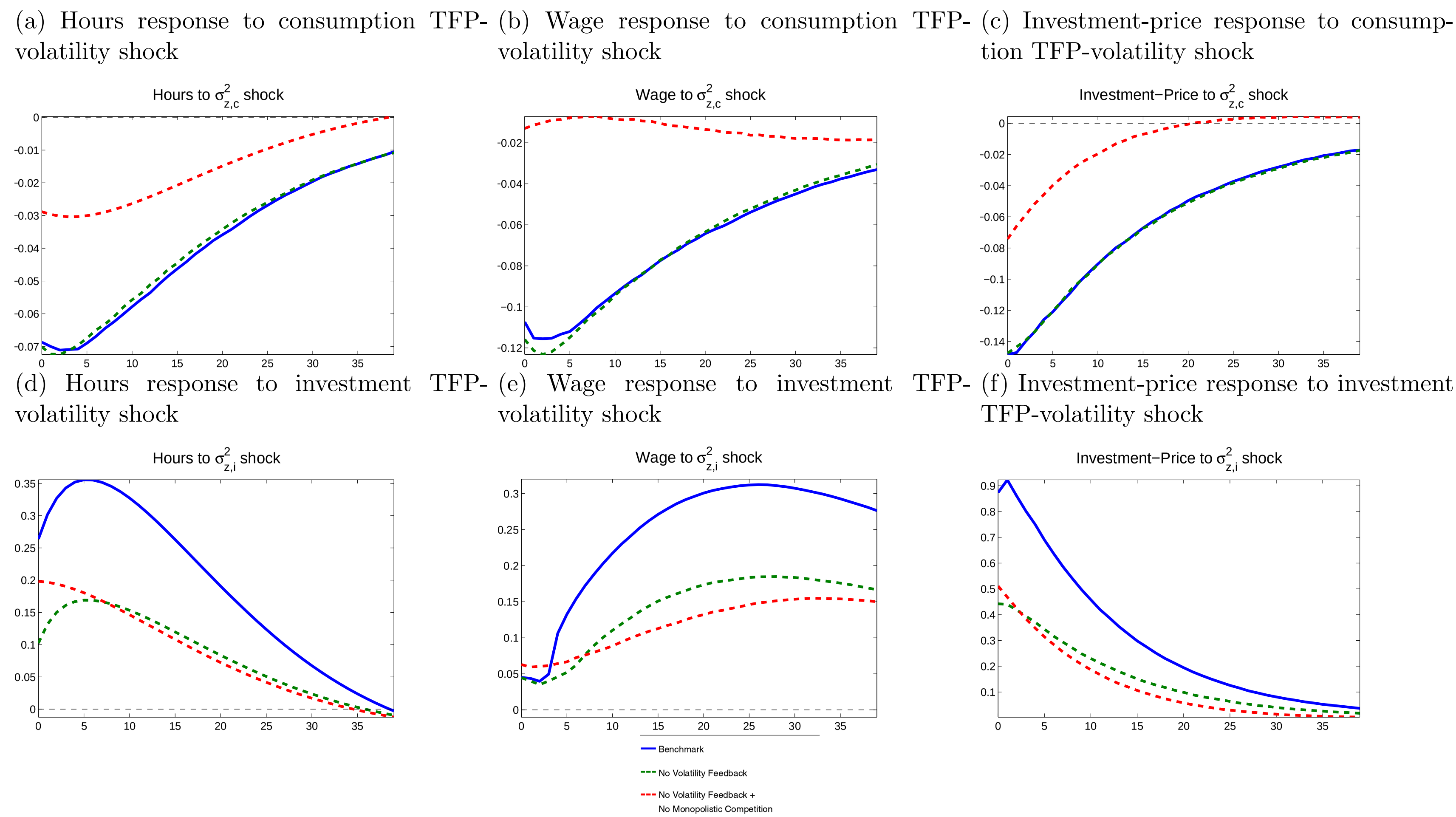


(f) Output response to investment TFP-volatility shock



The Figure shows impulse responses of model-detrended real consumption, investment expenditures, and output to one-standard deviation shocks of consumption TFP-volatility (σ^2_{zc}) and investment TFP-volatility (σ^2_{zi}). The impulse responses are computed using simulated model-data. The solid blue-line shows impulse-responses from the benchmark model. The dashed green line shows impulse responses from a model with an identical calibration to the benchmark model, but without a feedback from investment TFP-volatility to future consumption TFP growth ($\tau = 0$). The dashed red line shows impulse responses from a model without volatility feedback ($\tau = 0$), and without monopolistic competition or nominal rigidities ($\mu_j \to \infty \quad j \in \{c, i\}, \quad \phi_P = 0$). The horizontal axis represents quarters. The vertical axis represents percent deviations from the steady-state.

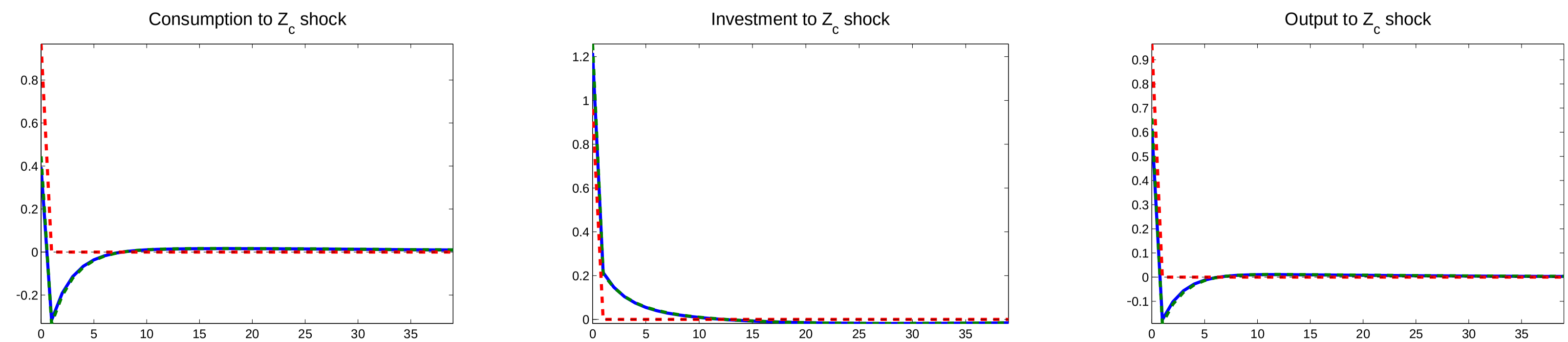
Figure 5: **Model Impulse Response of Hours, Detrended Wages and Investment-Price to Sectoral Volatilities**



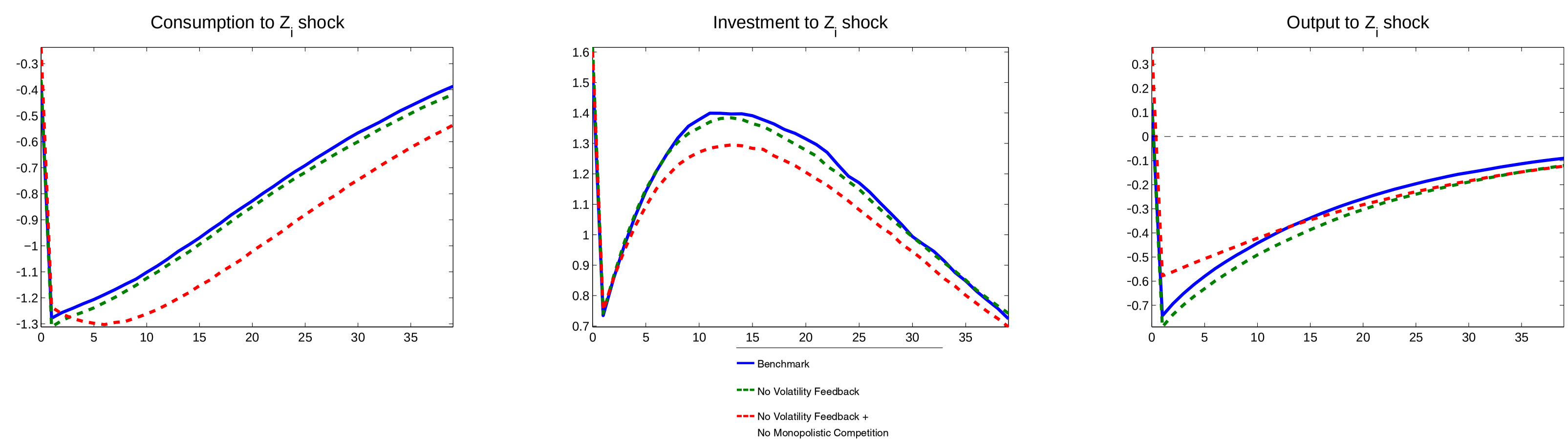
The Figure shows impulse responses of model-implied hours, detrended real wages, and real relative price of investment to one-standard deviation shocks of consumption TFP-volatility (σ^2_{zc}) and investment TFP-volatility (σ^2_{zi}). The impulse responses are computed using simulated model-data. The solid blue-line shows impulse-responses from the benchmark model. The dashed green line shows impulse responses from a model with an identical calibration to the benchmark model, but without a feedback from investment TFP-volatility to future consumption TFP growth ($\tau = 0$). The dashed red line shows impulse responses from a model without volatility feedback ($\tau = 0$), and without monopolistic competition or nominal rigidities ($\mu_j \to \infty \quad j \in \{c, i\}, \quad \phi_P = 0$). The vertical axis represents percent deviations from the steady-state.

Figure 6: **Model Impulse Response of Detrended Consumption, Output and Investment to Sectoral Innovations**

(a) Consumption response to consumption TFP innovation (b) Investment response to consumption TFP innovation (c) Output response to consumption TFP innovation



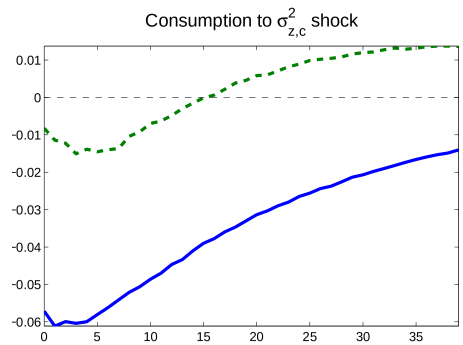
(d) Consumption response to investment TFP innovation (e) Investment response to investment TFP innovation (f) Output response to investment TFP innovation



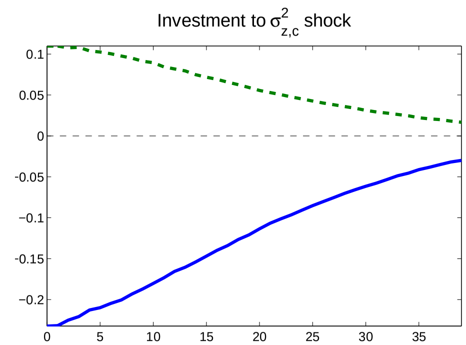
The Figure shows impulse responses of model-detrended consumption, investment expenditures, and output to one-standard deviation shocks of consumption TFP growth ($Z_{c,t}/Z_{c,t-1}$) and investment TFP growth ($Z_{i,t}/Z_{i,t-1}$). The impulse responses are computed using simulated model-data. The solid blue-line shows impulse-responses from the benchmark model. The dashed green line shows impulse responses from a model with an identical calibration to the benchmark model, but without a feedback from investment TFP-volatility to future consumption TFP growth ($\tau = 0$). The dashed red line shows impulse responses from a model without volatility feedback ($\tau = 0$), and without monopolistic competition or nominal rigidities ($\mu_j \to \infty \quad j \in \{c, i\}, \quad \phi_P = 0$). The vertical axis represents percent deviations from the steady-state.

Figure 7: **Model Impulse Responses to Sectoral Volatilities: The Role of IES**

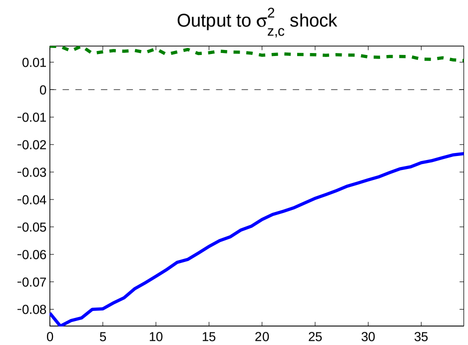
(a) Consumption response to consumption TFP-volatility shock



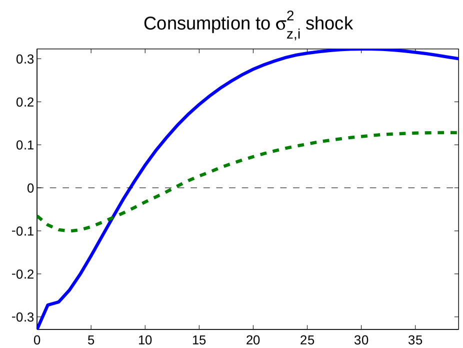
(b) Investment response to consumption TFP-volatility shock



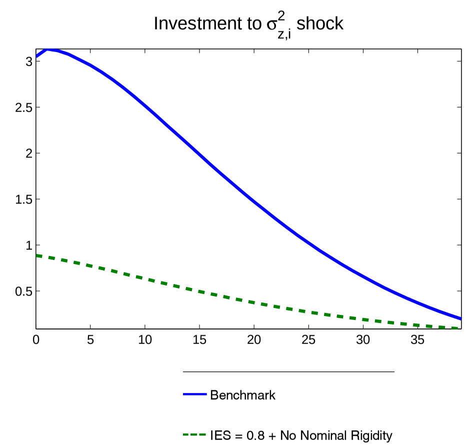
(c) Output response to consumption TFP-volatility shock



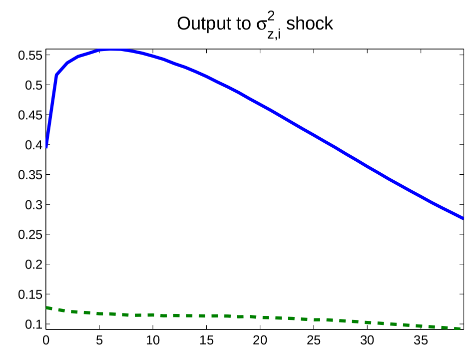
(d) Consumption response to investment TFP-volatility shock



(e) Investment response to investment TFP-volatility shock



(f) Output response to investment TFP-volatility shock



The Figure shows impulse responses of model-detrended consumption, investment expenditures, and output to one-standard deviation shocks of consumption TFP-volatility (σ^2_{zc}) and investment TFP-volatility (σ^2_{zi}). The impulse responses are computed using simulated model-data. The solid blue-line shows impulse-responses from the benchmark model. The dashed green line shows impulse responses from a model with an identical calibration to the benchmark model, but without a feedback from investment TFP-volatility to future consumption TFP growth ($\tau = 0$), no nominal rigidities ($\phi_P = 0$), and the IES (ψ) is set to 0.8. The horizontal axis represents quarters. The vertical axis represents percent deviations from the steady-state.