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Time-to-produce, inventory, and asset prices[☆]

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ABSTRACT

Time-to-build, time-to-produce, and inventory have important implications for asset prices and quantity dynamics in a general equilibrium model with recursive preferences. Time-to-build captures the delay in transforming new investments into productive capital, and time-to-produce captures the delay in transforming productive capital into output. Both delays increase risks in that time-to-build generates procyclical payouts, whereas the time-to-produce amplifies this procyclicality. Inventory smooths consumption and helps capture interest rate volatility even when the elasticity of intertemporal substitution is small. The model is consistent with a high equity premium, a high stock return volatility, and lead-lag relations between asset prices and macroeconomic quantities.

1. Introduction

Recent production-based general equilibrium models have made significant progress towards understanding both asset prices and quantity dynamics. However, several challenges remain. First, payouts are counterfactually countercyclical and contribute little to the equity premium (Kaltenbrunner and Lochstoer, 2010). Second, when the elasticity of intertemporal substitution (EIS, hereafter) is small, the risk-free rate is excessively volatile and the term premium is abnormally large (Boldrin, Christiano, and Fisher, 2001; Jermann, 1998; Kaltenbrunner and Lochstoer, 2010). Third, the asset pricing role of inventories is largely overlooked, given its impact on the cost of capital (Belo and Lin, 2012; Jones and Tuzel, 2013). Fourth, the time-series interaction between asset prices and macroeconomic quantities has received little attention. For example, asset prices tend to lead quantities (Backus, Routledge, and Zin, 2007, 2010; Liu, Whited, and Zhang, 2009), a challenge to a standard real business cycle (RBC, hereafter) model in which everything moves simultaneously. This paper attempts to address these issues via production delay risks.

In their seminal time-to-build (TTB, hereafter) work, Kydland and Prescott (1982) consider a technology imperfection in building productive capital and define TTB as the delay in transforming new investment into productive

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capital. This paper extends Kydland and Prescott (1982) by incorporating another technology imperfection, namely, the delay in transforming productive capital into final goods, which I refer to as time-to-produce (TTP, hereafter). TTB and TTP are two natural yet different technology imperfections in the real world. First, the TTB constraint focuses on frictions during the formation of productive capital, while the TTP constraint focuses on frictions during the use of productive capital. Thus, current capital stock depends on investment projects initiated several periods ago under the TTB constraint, and current output depends on capital stock in place several periods ago under the TTP constraint. Second, the productivity of current capital stock is unobservable under the TTP constraint since the output of current capital is not realized until several periods later, while it is measurable under the TTB constraint.

These two production delays accumulate uncertainty and increase risks in the economy. Their impacts can be seen on the macroeconomic side. First, TTB slows the response of capital investment to productivity shocks, making it more difficult for agents to use capital investment to smooth consumption. In particular, when most investment expenditures occur in the later periods, TTB makes consumption extremely volatile because investment becomes less procyclical. But the good news is that TTB helps generate procyclical payouts. Inventories are necessary to smooth consumption under TTB. However, inventory holdings are too small under TTB, so consumption remains too volatile, compared with the case without TTB. Second, since the productivity of current capital stock is unobservable under TTP, capital investments cannot effectively smooth out the consumption and output volatilities caused by TTP. Thus, firms need to use inventory technology to smooth consumption under TTP. Only the TTP constraint ensures substantial inventory holdings observed in the data. Moreover, TTP amplifies the procyclical payouts, because capital investment becomes much riskier and less procyclical under the TTP constraint. Turning to the asset prices, the procyclical payouts lead to a high stock return volatility and a sizable equity premium. Additionally, as inventories are less risky and more responsive to the productivity shocks than the capital investment, inventories help generate a low volatility risk-free rate and a reasonable term premium even when EIS is small.

Given the number of state variables in this economy, I solve this model by a projection method with non-product monomial rules instead of a full tensor grid. The static and dynamic Euler equation errors show that the projection method is highly accurate and much more accurate than the first-order, second-order, and third-order perturbation methods. For example, the static and dynamic consumption errors from the projection method are at least an order of 2 smaller than those from the perturbation methods. Most dynamic consumption errors from the perturbation methods are as large as 6–10%, which cautions the application of perturbation methods in asset pricing models. Quantitatively, the main model reasonably matches both macroeconomic quantities and asset prices with the data. For example, the model generates a mean stock return of 5.28% and a volatility of 10.11% per year, compared with those of 5.53% and 12.03% for the unlevered returns in the data, respectively. The model also features a low risk-free rate volatility of 2.42% and a moderate term premium of 1.95%, together with an equity premium of 3.85% per year. The model exhibits the return predictability observed in the data as well (see Cochrane, 2008).

In this economy, current capital stock alone is not a sufficient statistic since inventories, TTB, and TTP expand the state space. Thus, stock returns and investment returns are usually different. Calibrations show that investment returns account for 79% of stock returns while contributing 93% to the volatilities. Expanded state space implies that asset prices contain more information than a single macroeconomic quantity. This explains the lead-lag patterns between asset prices and macroeconomic quantities documented by Backus, Routledge, and Zin (2007, 2010), the negative contemporaneous correlation between stock returns and investment growth (Liu, Whited, and Zhang, 2009), and the lagged investment effect in the investment regression (Eberly, Rebelo, and Vincent, 2012).

This paper builds on the large literature of production-based asset pricing models (e.g., Jermann, 1998; Boldrin, Christiano, and Fisher, 2001; Gomes, Kogan, and Zhang, 2003; Zhang, 2005; Kaltenbrunner and Lochstoer, 2010; Croce, 2014). These models introduce risks into the economy through investment frictions (e.g., convex capital adjustment costs, investment irreversibility, and capital immobility) or stochastic productivity shocks. In contrast, this paper emphasizes production delays. Only a few papers study the asset pricing implications of TTB. For example, Boldrin, Christiano, and Fisher (2001) investigate TTB under habit formation. This paper adds to the literature by studying TTP in a recursive preferences setting.

My paper also contributes to the business cycle literature. This paper motivates inventory from a consumption smoothing perspective and explores its asset pricing implications in a general equilibrium setting. This specification allows to explore the connection between inventories and the risk-free rate. In contrast, Belo and Lin (2012) and Jones and Tuzel (2013) examine the relation between inventory investment and stock returns in a partial equilibrium setting. Moreover, this paper constructs a general equilibrium model with production delays to endogenize the lead-lag patterns between asset prices and macroeconomic quantities. In contrast, Backus, Routledge, and Zin (2010) build a long-run risk model, assuming a positive correlation between consumption growth and stochastic volatility to capture such patterns.

The paper proceeds as follows. I first construct a production-based general equilibrium model and describe the numerical solution in Section 2. Section 3 outlines the data and parameters used in the calibrations. It also verifies the numerical accuracy of the projection method used. Section 4 presents the main numerical results. Finally, Section 5 concludes.

2. A general equilibrium model

Consider an all-equity representative firm that produces one real good and operates in a discrete and infinite time horizon. This assumption is abstract from the complications of real-world production, which features