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The response of capital goods shipments to demand over the business cycle

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ABSTRACT

We study how producers of capital goods set shipments in response to fluctuations in new orders. We find that shipments respond more to orders when new orders fall below a certain level relative to shipments, usually after orders plunge in recessions. This cyclical change in producers' behavior accounts for a considerable portion of the downturn in equipment investment in the 2001 and 2008–9 recessions. A simple model of production to order suggests that heightened persistence in new orders growth may explain the greater responsiveness of shipments, as may increases in the producers' target delivery lag.

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1. Introduction

Equipment investment is an important part of the US business cycle, accounting for a bit less than half of the cumulative decline in GDP in the 2008–9 recession and about a quarter of the variance of annual real GDP growth since 1985.[2] The primary source data used to estimate equipment investment in the quarterly national income and product accounts are the US Census Bureau's monthly data on manufacturers' shipments of non-defense capital goods. Since capital goods are generally produced after an order is received and are shipped with a lag, the Census Bureau also publishes data on both net *new* orders and the backlog of *unfilled* orders. Reflecting their forward-looking nature, these orders data for capital-goods producers are followed closely as an indicator of where shipments, equipment spending, and the business cycle are headed.

The source data on orders and shipments of non-defense capital goods allow us to study how capital-goods producers react to changes over the business cycle in the demand for equipment spending. Most papers in the investment literature study the behavior of firms who purchase capital goods, that is, the demand side. Relatively few papers study the behavior of firms who produce capital goods, the supply side. Because capital goods are subject to delivery lags, business cycle fluctuations in equipment spending are influenced not only by changes in the demand for equipment but also by the

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[2] The contribution of equipment investment to the variance of GDP growth is measured as the covariance of its contribution to GDP growth with GDP growth itself, a method that ensures the variance contributions of the components of GDP sum to one.

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response of capital-goods producers to these changes in demand. We assume that fluctuations in orders for non-defense capital goods largely reflect fluctuations in equipment demand, while fluctuations in shipments reflect the interaction of decisions of agents on the supply side with those of agents on the demand side of the equipment market.[3]

We document some interesting changes in the response of capital-goods-supplying firms to demand over the business cycle. Using different types of variation and different reduced-form econometric specifications, including threshold cointegration and Markov-switching models, we find that shipments of capital-goods producers exhibit stronger responses to fluctuations in orders when the level of new orders is low relative to the level of shipments, typically in and around recessions. Furthermore, we show that the change in the response of shipments to orders accounts for a substantial fraction of the steep decline in shipments (and thus equipment spending) seen in the last two recessions (i.e. the 2001 and 2008–9 recessions).

We interpret these empirical results through the lens of a simple model where capital-goods producers optimize a tradeoff between smoothing production and keeping the delivery lag for new orders close to a target. The delivery lag is measured as the ratio of unfilled orders to shipments, and the target delivery lag could be modeled similarly to Maccini (1973). In the model, producers use backlogs of unfilled orders as a buffer between demand and production in much the same way as finished goods inventory stocks are used to absorb demand shocks. So this model resembles the theoretical machinery that has been developed over the years to study inventories.[4] Since order backlogs are usually associated with production-to-order industries, which encompass most of the capital goods we analyze, while finished goods inventories are more prominent in production-to-stock industries, we assume that firms do not hold finished goods inventories (Abramowitz, 1950; Besley, 1969).[5]

As in Blanchard (1983) and Ramey and Vine (2006), we analyze how changes in the persistence of demand shocks affect the behavior of producers. In particular, this simple model predicts greater responsiveness of shipments to orders when the effects of shocks to new orders persist longer. Using threshold time-series autoregressions and Markov-switching specifications, we find that the new orders growth process exhibits significant time-varying persistence. For limited periods of time (generally a few quarters in or around recessions), the short-run dynamics of the univariate orders growth process are highly persistent, such that the best estimate of new orders growth next period is close to current orders growth.[6] And, in line with the implications of the theory, these periods of heightened orders growth persistence tend to coincide with the periods of increased responsiveness of shipments to orders. Intuitively, when a shock to new orders signals a protracted shortfall in demand for capital goods, producers cut production more aggressively to avoid entering a prolonged period with suboptimally short delivery lags.

While the changing persistence of the orders process provides a plausible explanation for some of the time variation in the responsiveness of shipments to orders that we observe, it probably does not explain all of it. The model shows that the persistence of the orders process should affect only a subset of the coefficients in our empirical specifications, which is not the case in a number of our specifications. We consider other explanations for these changes in the responsiveness of shipments to orders, including cyclical changes in other parameters of our model. Interestingly, the ratio of unfilled orders to shipments tends to shoot above its trend in the late stages of expansions and in recessions, and then fall back in the early stages of the next expansion, suggesting cyclical changes in the target delivery lag.[7] We explore reasons why firms may desire larger buffer stocks of unfilled orders in bad economic times, amplifying downturns.

Our paper contributes to the literature that studies the large fluctuations in investment spending around recessions. We emphasize that the higher responsiveness of capital-goods producers to shocks to equipment demand exacerbates and hastens the decline in equipment spending observed in downturns. Existing theories on the non-linear dynamics of investment spending tend to focus on the demand side for capital goods, including theories on the aggregate implications of nonconvex capital adjustment costs, such as Caballero et al. (1995), and theories on the effect of uncertainty shocks on investment demand, such as Bloom (2009). We think that these theories likely explain some of the increased persistence of shocks to new orders for capital goods during recessions, one of the interesting facts we document here. However, our paper suggests that the effect of these shocks may be significantly amplified as capital-goods producers choose to smooth production less during downturns in order to avoid persistent deviations of the delivery lag from a target that is likely moving up.

Our focus on how the behavior of firms in production-to-order industries helps explain certain features of the business cycle is related to Kahn (2010). Our analysis of how increased persistence to shocks affect the optimal intertemporal decisions of firms is similar to Blanchard (1983), Tevlin and Whelan (2003), and Ramey and Vine (2006).[8] The business cycle asymmetries in the dynamics of orders and shipments that we uncover also fit in the literature on asymmetric business cycles, such as French and Sichel (1993).

[3] The orders data reflect the market-clearing decision of firms to purchase capital goods at a certain price and delivery lag. However, as shown in Carlton (1983), changes in delivery lags are a more important market clearing mechanism than changes in prices in the short run.

[4] Blinder and Maccini (1991) and Ramey and West (1999) provide surveys of existing models on inventory dynamics. The specification of our model is close to West (1988).

[5] Similar to Braun (1981) and West (1988), we could have implemented a model with both inventory and backlog stocks by treating unfilled orders as stocks of negative inventories, but the evidence in Besley (1969), Reagan and Sheehan (1985), and Haltiwanger and Maccini (1989) argues against such a specification. Kahn (2010) analyzes a model without a production smoothing motive where firms produce to order but hold inventories as work in process.

[6] Note that this is not a unit root in growth rates because the extreme persistence is itself temporary, usually lasting only a few quarters. Our specifications are geared towards capturing the short-run dynamics of orders rather than characterizing their long-run properties, a distinction made in Cochrane (1988).

[7] In the early post-war period this ratio tended to rise and peak towards the end of expansions (Popkin, 1965; Zarnowitz, 1962) rather than continuing to rise through the onset of recessions and peaking towards the end of the recessions, as has been more typical in our sample period.

[8] In particular, Ramey and Vine (2006) argue that a decline in the persistence of auto sales after the mid-1980s explains the decline in the variance of US automobile production both in absolute terms and in relation to the variance of sales.