"Business Cycle Implications of Capacity Constraints under Demand Shocks"
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Referee Report

Summary

This paper provides a parsimonious mechanism targeting four business cycle patterns:

1. Business cycle asymmetry - larger recessions than booms.

2. Increases in micro dispersion and macro volatility - sometimes considered to be "uncertainty" proxies - during recessions.

3. Procyclicality of the raw Solow residual, and acyclicality of the utilization-adjusted Solow residual.

4. Countercyclicality in fiscal multipliers.

In particular, the authors augment a benchmark quantitative New Keynesian DSGE model driven by household preference shocks with variable capacity utilization at the firm level. Firms choose their capital stock in advance and face convex utilization costs limiting their ability to increase production in the short run in the face of idiosyncratic demand shocks. The result is that the number of firms facing capacity constraints is procyclical. The model is qualitatively consistent with each of the targeted business cycle patterns. In particular:

1. The model generates business cycle asymmetry because the capacity constraint limits upward adjustment of production by firms but does not constrain declines in production.

2. The model generates countercyclical movement in uncertainty proxies - micro dispersion and macro volatility - because during downturns more firms are away from their capacity constraints. With room for firms to adjust production in either direction in response to firm-level shocks, micro-level outcomes become more dispersed. Through the same mechanism, the aggregate economy becomes more responsive to shocks and hence volatile.

3. Because the capacity utilization choices of firms are on average procyclical, the model generates procyclical movements in the raw Solow residual ignoring utilization. Because the fundamental shocks in the economy are to household preferences rather than aggregate productivity, the model generates acyclical movements in the Solow residual after accounting for utilization rates.

4. Because the number of firms with binding upward capacity constraints is procyclical, firms on average are more responsive to fiscal stimulus during recessions. This generates countercyclicality in the fiscal multiplier.

Quantitatively, the authors calibrate their model to US data and find that the capacity utilization choices of firms can explain a moderate fraction of each of the business cycle patterns they target. They explain around one quarter of business cycle asymmetry, around one fifth of the countercyclicality of micro-level TFP dispersion, around one quarter of the countercyclicality in the conditional

heteroskedasticity of GDP, around one half of the volatility of the raw Solow residual, and counter-cyclical movements in the fiscal multiplier from around 0.95 to 1.07 from booms to recessions.

I enjoyed reading this manuscript. It is well written and shows an admirable amount of attention to detail in documentation and notes throughout. The economic mechanism at work - variable capital utilization at the micro level - is uncontroversial and parsimonious, yet this small tweak to an otherwise standard model admirably explains a range of business cycle facts. On the other hand, this paper's simple firm-level mechanism has strong implications for the cyclicality of the fiscal multiplier, so taking their results seriously requires that the micro implications of the model receive extra scrutiny both empirically and theoretically. My major comments below contrast the authors' analysis with some empirical facts from the literature on firm dynamics, highlighting some tensions and suggesting some extensions which might alleviate these concerns. I follow with a list of minor issues - mostly typographical - and conclude with a list of citations to papers which I mention outside of the paper's bibliography.

Major Comments

Other mechanisms for generating countercyclical movements in uncertainty proxies already exist - and are consistent with some first-order firm-level facts - but this paper does not offer disaggregated support for its mechanism.

Micro-level measures of dispersion and macro volatility have been found to vary countercyclically by a remarkably large range of previous papers in the uncertainty literature. This manuscript's explanation - procyclical variation in the fraction of firms whose capacity is constrained upwards - matches these cyclical patterns. However, other mechanisms can match these patterns as well. See, for example, any of the large number of uncertainty papers based on micro and macro stochastic volatility, or the recent work by Kozeniauskas, et al. (2016) based on micro-level learning. The alternative approaches have the virtue of also generating higher variance in the forecast errors of individual firms about their own output or investment (see Bachmann, et al. 2013 or Bachmann, et al. 2016), a fact which seems at first glance to be inconsistent with the variable capital utilization mechanism of the current manuscript. Unfortunately, the exact micro mechanism may matter a great deal here, because some of the papers matching the evidence on forecast errors imply procyclical fiscal multipliers rather than countercyclical multipliers (see Bloom, et al. 2012 or Vavra 2014).

In this context, additional disaggregated evidence or at least more direct evidence for the main mechanism in this model - procyclicality in capacity constraints - would go far towards validating the paper's conclusions.

Small steps towards "canonical" models of firm dynamics and heterogeneity - persistent micro-level heterogeneity and/or lumpy input adjustment - would lead to forces pushing away from countercyclical fiscal multipliers.

The paper's main mechanism is based on idiosyncratic firm heterogeneity through demand shocks, paired with capacity constraints. However, in order to maintain a structure which aggregates perfectly, the authors chose to omit two of the most central features of canonical firm dynamics models: 1) persistent heterogeneity (their firms receive iid demand shocks) and 2) lumpy

capital adjustment costs (their firms are subject only to time-to-build constraints). Persistent heterogeneity is required to match the extraordinary persistence and volatility in micro-level profitability measures in firm-level datasets even after removing time effects. And lumpy capital adjustment is typically required to endogenously generate investment spikes seen in establishment-level data.

The omission of persistent heterogeneity through the assumption of iid demand shocks may matter quantitatively here because persistent micro demand shocks would change the policy functions in Figure 2 on p9. Instead of a single production schedule for firms, there would be heterogeneous production schedules. Because micro-level volatility is substantially higher than macro-level volatility (see Castro, et al. 2015), the movements across production schedules as firms receive persistent demand shocks may swamp or smooth out the kinks or capacity constraints when aggregating. I speculate that the result would likely be less business cycle asymmetry and less countercyclicality of the fiscal multiplier.

The omission of lumpy capital adjustment at the firm level matters here for multiple reasons. First, flexible capital makes the model unable to match the classic facts about investment spikes at the establishment level (see the overview in Khan and Thomas 2008, for example). Second, the resulting homogeneity in capital makes the model unable to match recent evidence on the procyclicality of investment dispersion (see Bachmann and Bayer 2014). Third, by omitting lumpy adjustment, the model is likely unable to generate state-dependence in investment sensitivity to the business cycle. As shown by papers like Winberry (2016a), state-dependence is a natural implication of many models with lumpy capital adjustment, and the implication is typically procyclical fiscal multipliers rather than the countercyclical multipliers found in the current manuscript.

The model is intentionally stylized at the micro level. But a few feasible extensions would add much more quantitative realism to the paper's results.

As I noted in the previous comment, I am worried about the ability of the model - which is based on a firm-level mechanism - to maintain consistency with some basic firm dynamics facts. Although I understand that the authors desire to simplify their analysis to maintain aggregation, some of these simplifications may matter either quantitatively for aggregate dynamics or qualitatively for the cyclicality of the fiscal multiplier. However, several extensions of this paper's analysis would go far to add quantitative realism to the paper's analysis.

1. *Extension with persistent micro shocks*
   The authors can conduct an additional exercise in which they maintain the assumption of flexible capital but add persistent heterogeneity in demand shocks for firms. The authors can allow the demand shocks to have two components: a persistent component following a two-point Markov chain and a transitory component functioning just like the current manuscript's iid shock. With this structure, aggregation would be more complicated but would still be tractable (replace K with K_{low} and K_{high}, for example, where low and high refer to persistent demand states in the Markov chain). In other words, it could still be done in Dynare.

2. *Extension with capital adjustment costs*
   As a step towards incorporating full blown micro-level lumpy input adjustment frictions, the authors could conduct an additional exercise in which they maintain the assumption of iid demand shocks but add quadratic capital adjustment costs. This would not generate lumpiness, of course, but it would add some useful persistence at the aggregate level and be feasible to aggregate due to symmetry and the investment timing assumption. In other words, it could still be done in Dynare.

3. *Extension with lumpy capital adjustment costs and persistent shocks*
   To fully address my concerns about the ability of the model to match basic firm dynamics facts, the authors would need to add both persistent micro shocks and lumpy capital adjustment. Clearly, this would be intractable if the authors went the Krusell-Smith route of Khan and Thomas (2008). However, by taking the projection plus perturbation route of Winberry (2016b), which builds substantially on the approach of Reiter (2009), this exercise would be feasible within Dynare. The result would likely be dampened asymmetries and reduced countercyclicality of the fiscal multiplier, as I noted above, but this exercise go far towards improving the credibility of this manuscript's quantitative results.

Minor Comments

- **Table 1 & Table 3:** Please add formal tests for the significance of the difference in means across recession and boom states. Doing so would require taking into account serial correlation at the aggregate level, but since we're concerned only with a difference in means here it's quite feasible.
- **p8:** I believe there is a typo here, and it should read directly under the maximization problem that " there is a chance of R that the capacity constraint binds."
- **Fig 2:** This is an informative figure. However, given the nature of the underlying economic mapping here, it would seem to make more sense to flip the axes on this figure.
- **p10-p11:** The text discussion on these pages suggests that the assumption that firm prices are set before demand shock realization is necessary for the generation of New Keynesian aggregate dynamics from demand shocks. But the addition of price rigidities via the Rotemberg price adjustment cost function in the model already generates these New Keynesian dynamics. I would be more comfortable if the assumption on pricing before demand shocks was recognized for what it is: a tractability assumption. Alternatively, you could refer the reader to studies like Zbaracki, et al. (2004) on price adjustment schedules within a large manufacturing firm, which would seem to provide disaggregated support for this assumption.
- **p13:** In the paragraph with the title "Supply function and cutoff $\bar{b}$" there is a typo. The phrase "level demand" should read "level of demand."
- **p13:** As noted in the text discussion on this page, the firm's maximization problem for y on this page ignores the uncertainty in the demand shocks b. I'm not convinced that this assumption matters a huge amount quantitatively, since there's not an incredibly large amount of nonlinearity in the cost function. However, it's a clear violation of rational expectations, so it deserves more mention even if speculative.
- **p16, p18:** Neither on p16 in the discussion of equation (14) nor on p18 in the discussion of Fig 3's IRF did I fully understand the mechanism behind the movements in the relative price of final and intermediate goods. Is this driven quantitatively by standard New Keynesian markup mechanisms, or is it something mechanical having to do with fluctuations in the fraction of firms which are constrained, $F(b_{it})$? More discussion would be welcome.
- **p20:** The mention of the fiscal multiplier in the first sentence in section 5.2.2 should be delayed to the discussion of fiscal multipliers in section 5.2.5.
- **p20:** The mention of the first row of Table 1 should be changed to mention the same information in Table 3.
- **p20:** Table 3 should be expanded to include results about the asymmetry or lack thereof in employment growth and levels series. The model will fail to produce asymmetry, as noted in the text. But the text's explanation is perfectly satisfactory: this is a model with flexible labor. So there's

no harm in providing the reader with a clearer picture of what your model does and does not do.
- **p26:** The authors use 2nd-order approximations in Dynare to solve the model. Since the paper already relies on the packaged solver, I don't see any disadvantage in also trying a 3rd-order approximation.

Citations

The following papers outside of the current manuscript's bibliography are mentioned in my report:

- Bachmann, Rüdiger and Christian Bayer (2014). "Investment Dispersion and the Business Cycle," *American Economic Review* 104(4), 1392-1416.

- Bachmann, Rüdiger, Steffen Elstner, and Atanas Hristov (2016). "Surprise, Surprise - Measuring Firm-Level Investment Innovations," working paper.

- Bachmann, Rüdiger, Steffen Elstner, and Eric R. Sims (2013). "Uncertainty and Economic Activity: Evidence from Business Survey Data," *American Economic Journal: Macroeconomics* 5(2), 217-49.

- Castro, Rui, Gian Luca Clementi, and Yoonsoo Lee (2015). "Cross Sectoral Variation in the Volatility of Plant Level Idiosyncratic Shocks," *Journal of Industrial Economics*, 63(1), 1-29.

- Khan, Aubhik and Julia Thomas (2008). "Idiosyncratic Shocks and the Role of Nonconvexities in Plant and Aggregate Investment Dynamics," *Econometrica* 76, 395-436.

- Kozeniauskas, Nicholas, Anna Orlik, and Laura Veldkamp (2016), "The Common Origin of Uncertainty Shocks," NBER working paper 22384.

- Reiter, Michael (2009). "Solving Heterogeneous-Agent Models by Projection and Perturbation," *Journal of Economic Dynamics and Control* 33, 649-665.

- Vavra, Joseph (2014). "Inflation Dynamics and Time-Varying Volatility: New Evidence and an Ss Interpretation," *Quarterly Journal of Economics* 129(1).

- Winberry, Thomas (2016a), "Lumpy Investment, Business Cycles, and Stimulus Policy," working paper.

- Winberry, Thomas (2016b), "A Toolbox for Solving and Estimating Heterogeneous Agent Macro Models," working paper.

- Zbaracki, Mark J., Mark Ritson, Daniel Levy, Shantanu Dutta, and Mark Bergen (2004), "Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets," *Review of Economics and Statistics* 86, 514-33.