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Inventories and business Cycles: The story of the last three decades

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Abstract

Although there has been nearly unanimous recognition that inventory cycles are one of the primary drivers of business cycles, surprisingly very few empirical studies have been done to investigate how this relationship has evolved over the years, particularly post-1990. In this study I use Bayesian Time-Varying Parameter framework to investigate changes in reduced-form relationship between business cycles and inventories in the U.S. from 1992 Q1 to 2019 Q2. My estimates show that although the volatility of inventory-to-sales ratios has increased in relation to output, the role played by inventories in generating business cycle fluctuations has diminished significantly over the years. In fact, the time-varying slope coefficient measuring the impact of inventories on output seems to have reached a long-run steady state. I find sufficient empirical evidence in favor of the view that it is not the changes in the U.S. monetary policy alone but the structural transformation of the U.S. economy, together with improved monetary policy making, that has resulted in muted business cycles.

This paper builds on the preliminary findings of the author's dissertation titled "Inventory Cycles and Business Cycles – Has the relationship lost its importance over the years: A Time-Varying Parameter Approach using U.S. Data" supervised by Dr. Naveen Srinivasan (Madras School of Economics). The author would like to thank Dr. Srinivasan; Dr. Benjamin D. Keen, the associate editor and an anonymous referee for their useful comments and suggestions. And of course, the usual caveats apply.
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1. Introduction

Following Blinder's (1990) famous words that business cycles are, to a large degree, inventory cycles, research has been primarily focused on the role played by inventories in the ushering-in and the sustainment of the Great Moderation; the hypothesis being that the introduction of Information Technology (I.T.) and superior inventory management techniques have led to reduced volatility in inventory holdings and this change in inventory behavior has, in turn, led to muted business cycles.

Blinder's (1990) observations summarize the findings of the extensive pre-1990 literature dealing with inventories and business cycle behavior: in the post-war U.S. economy changes in inventory investment accounted for more than 30% of the total changes in quarterly real GDP even though investment in non-farm inventories have averaged about 0.5% of the real GDP during the same time period. In the meantime, most strikingly perhaps, during an average post-war recession the drop in inventory investments constituted more than 85% of the drop in GNP (for an in-depth review see Blinder and Maccini, 1991; Fitzgerald, 1997).

McConnell and Perez-Quiros (2000) was the first study to provide rigorous statistical evidence of a decline in the volatility of real GDP in the mid-1980s. They attribute this to a structural break in the volatility of durable goods output. Since they didn't find any evidence of a similar decline in the volatility of durable goods sales, they argue that the stability in economy since the mid-1980s is due to the decrease in the volatility of inventory investment which, they suggest, stems from the widespread adoption of just-in-time (JIT) management techniques by U.S. manufacturers late-1970s onwards.

Previous attempts to estimate the impact of changes in inventory management techniques on the business cycle (see Morgan, 1991; Bechter and Stanley, 1992; Filardo, 1995) have yielded mixed conclusions. These studies, albeit covering only till the mid-1990s, find the impact of technical innovations in inventory management on business cycle fluctuations to be ambiguous at best.

Kahn, McConnell, and Perez-Quiros (2002) use a structural model, integrating both information technology and inventories, to demonstrate how improved information about future demand leads to lower variability in output without an equivalent decline in the variability of sales. They argue, based on their findings, that changes in inventory cycles due to improvements in information technology have played a direct role in reducing real GDP volatility.

McCarthy and Zakrajšek's (2007) findings suggest that the majority of the change in business cycle dynamics could be attributed to changes in macroeconomic environment: a gradual shift towards a more transparent monetary policy. While microeconomic factors like improved inventory management were, by themselves, insufficient to account for the reduced volatility in the GDP growth. They do, however, note that inventories have been production smoothing since the mid-1980s.

Irvine and Schuh (2005) find that nearly 3/4th of the reduction in overall volatility during the Great Moderation can be attributed to the changes in the structural relationship in the economy – particularly to the decline in the contemporaneous co-movement between and within different sectors' inventory and sales investments. However, Iacoviello et al. (2011) find that the bulk of the Great Moderation can be explained primarily by the lower volatility of shocks, mostly to the goods-sector technology and, to a much lower extent, the discount rate. Both these studies do seem to suggest that the changes in the structural relationship between inventory investment and the remainder of the real economy are rather important in explaining the change in aggregate volatility.

Eggers and Ioannides (2006) examine the role played by the changes in the composition of U.S. output towards its long-run stabilization. Their decomposition of the output growth volatility by one-digit industry shows that nearly half of the drop in volatility between the pre- and the post-1982 periods is accounted for by compositional shifts, most notably the decline of the volatile manufacturing sector and the rise of relatively stable services and the finance sectors.

Most of these studies, however, tend to ignore the impact of monetary policy on inventories. And this might seem rather strange, specifically because economic theory predicts a negative relationship between inventories and the real interest rate: change in the monetary policy changes the interest rate and this, in turn, should ideally affect inventories, since the interest rate represents the opportunity cost of holding inventories. But 40 years of empirical literature (which were mostly based on the older stock-adjustment model) have generally failed to find significant and systematic evidence of a relationship between inventory investment and the real interest rate, especially when it comes to finished goods inventories in manufacturing (for an overview of these studies see Maccini et al., 2004). Maccini et al. (2004) derive parametric tests for the role of the interest rate in specifications based on the firm's optimization problem; they use monthly data on inventories for the non-durable aggregate of U.S. manufacturing for the period 1959-1999. Their empirical findings mirror earlier evidence, finding little role to no role for the interest rate. They suggest a simple and intuitively rather appealing explanation - based on regime switching in the real interest rate and learning – that if the mean real interest rate is highly persistent, firms may, for all intents and purposes, ignore short-run interest rate fluctuations. They would consider altering their average inventory levels only as a response to long-run movements (regime shifts; e.g., between low real interest rates in the 1970s and high rates in the early 1980s).

This study attempts to econometrically estimate the dynamic relationship between inventories and business cycles over 3 decades (1992 Q1 to 2019 Q2) in a Bayesian Time-Varying Parameter (TVP) framework. The TVP model is a more appropriate choice in this case because unlike the traditional estimation methods which assume that the underlying data generating structure is static over the full sample, by allowing the coefficients to change over time this model accounts for the abrupt changes, structural breaks or transition periods, which may have had a significant impact on the relationship between the variables under study.

My estimates show that although the volatility of inventory-to-sales ratios (both composite and the sectorals) has been consistently higher than that of real output – in fact the differences are much more pronounced during recessions – the Time-Varying slope coefficient has reached a long-run steady state and approaching zero, suggesting a significantly reduced role for inventories in generating business cycles. More striking is perhaps the fact that the entire impact of inventories seems to have been driven by those from the manufacturing sector; the retail and wholesale sectors (where majority of the inventories are held) seem to have no (statistically detectable) effect on business cycles. This can only be explained by the declining importance of manufacturing in the U.S. economy and a drastic shift towards service-based industries where virtually no inventories are held.

On the other hand, the impact of the previous period's monetary policy, as measured by the real output-gap persistence parameter (non-zero and very significant), lingers on.

The contribution of this paper can be summarized as follows:

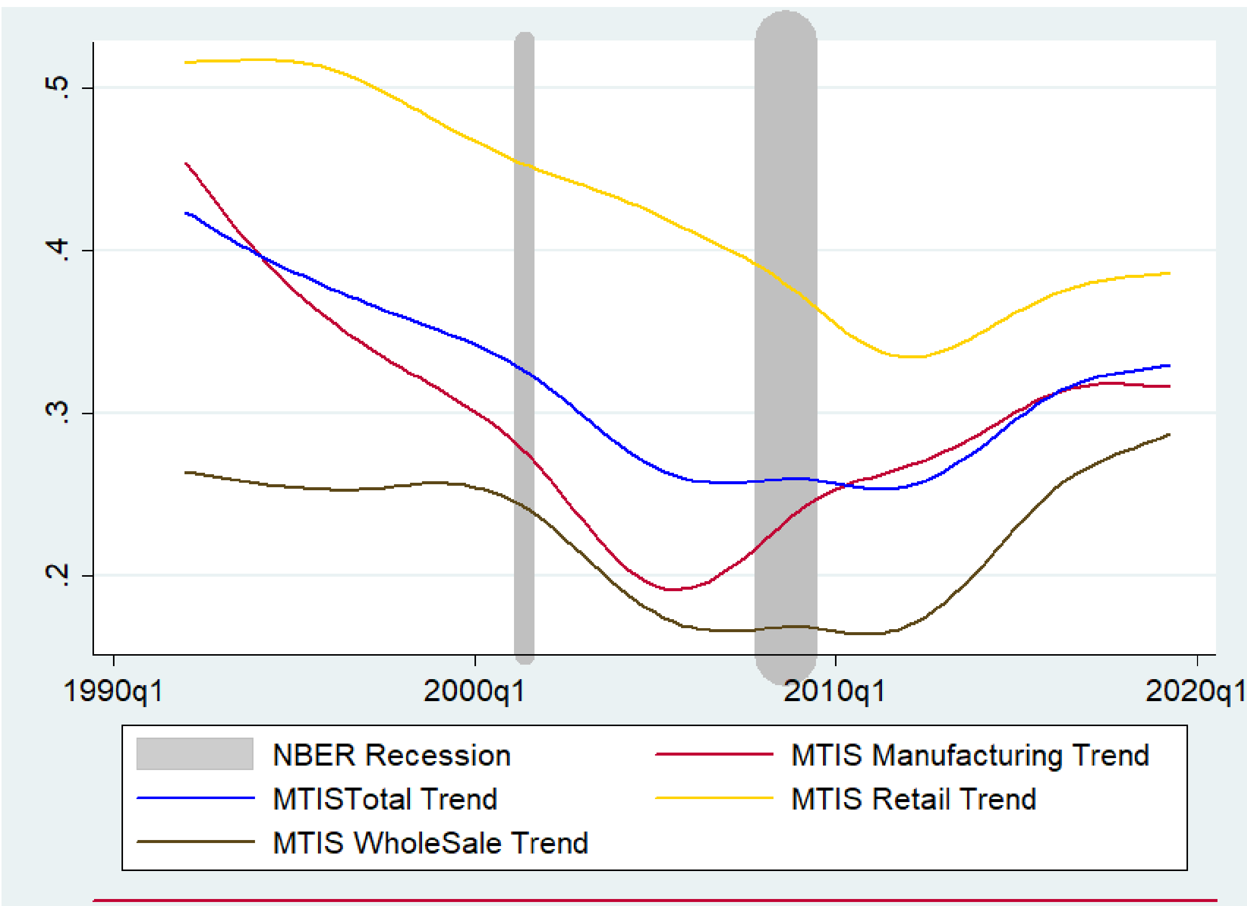
1) This study provides sufficient empirical evidence in support of the view that it is not the changes in the U.S. monetary policy alone but the structural changes in the U.S. economy, together with improved monetary policy making, that has resulted in muted business cycles.
2) It models the evolution of the relationship between inventories and business cycles over three decades in a dynamic, time-varying framework.

The rest of the paper is organized as follows: in section 2, I present the data and the methodology followed by the analysis of the estimation results in section 3 and the concluding remarks in section 4.

2. Data and methodology

For this study, the real GDP (chained 2002 dollars) and the real non-farm inventory-to-sales ratios, which are a part of the National Income and Product Accounts (henceforth referred to as NIPA), have been sourced from the U.S. Bureau of Economic Analysis (henceforth referred to as BEA) while the manufacturing and trade inventory-to-sales ratios (henceforth referred to as MTIS) data comes from the U.S. Census Bureau's Survey of Manufacturing and Trade Inventories and Sales.

Figure 1: Trend component – Manufacturing and Trade Inventory to Sales Ratios (Composite, Manufacturing, Retail and Wholesale) 1992 Q1 - 2019 Q2



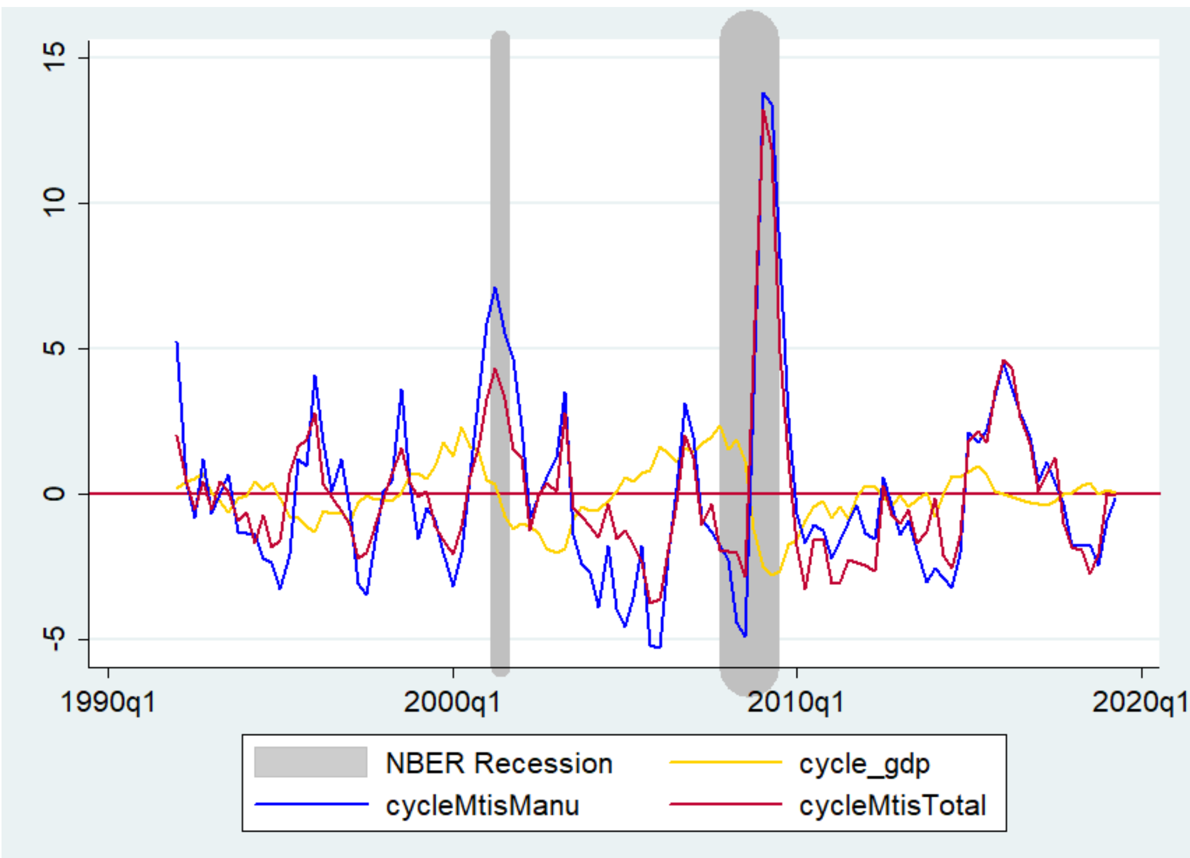
Source: Author's calculation using data from the U.S. Census Bureau.

Since the MTIS data is considered to be a better measure of inventory-to-sales ratios than the NIPA data, I use the MTIS data as the primary inventory measure while the

NIPA data serves as a robustness check. This is because the MTIS inventory data come from the surveys of the same firms that provide the corresponding sales data, while the NIPA inventory and sales data do not have one-to-one correspondence. Thus although, about 90% of the NIPA inventories correspond to the MTIS inventories, the NIPA final sales data is vastly different from that of the MTIS (Filardo, 1995).

It is evident from figure 1 that post-Gulf War, the MTIS inventory-to-sales ratios (both composite and the sectorals; manufacturing, wholesale and retail) have consistently trended downwards till around 2010-11 (right after the end of the Great Recession) when the trend reversed; the only exception being the manufacturing inventory-to-sales ratios which started trending upwards 2005 onwards, quite some time before the recession set in.

Figure 2: Deviations from trend – Real GDP and Manufacturing and Trade Inventory to Sales Ratios (Composite and Manufacturing) 1992 Q1 - 2019 Q2



Notes: Source - Author's calculation using data from the U.S. Census Bureau and BEA.

Quarterly data logged and de-trended using Hodrick-Prescott Filter (λ = 1600). Here, *cycle_gdp* is the cyclical component of Real GDP, *cycleMtisManu* is the cyclical component of MTIS Manufacturing inventory-to-sales ratios and *cycleMtisTotal* is the cyclical component of the MTIS composite inventory-to-sales ratios.

Apart from the counter-cyclical nature of the inventory-to-sales ratios, it is quite apparent from figure 2 that the volatility of the inventory-to-sales ratios (composite and the sectorals) is much higher than that of real output; in fact, the differences become even more pronounced during the recessions.

I estimate the following Time-Varying Parameter model:

$$\tilde{\mathbf{y}}_{\mathbf{t}} = \boldsymbol{\alpha} + \boldsymbol{\beta}_{\mathbf{t}}(\tilde{\mathbf{y}}_{\mathbf{t-1}}) + \boldsymbol{\gamma}_{\mathbf{t}}(\mathbf{isr\_cyclical}) + \mu_{\mathbf{t}} \quad (1)$$

$$\boldsymbol{\beta}_{\mathbf{t}} = \boldsymbol{\beta}_{\mathbf{t-1}} + \boldsymbol{\pi}_{\mathbf{t}} \quad (2)$$

$$\boldsymbol{\gamma}_{\mathbf{t}} = \boldsymbol{\gamma}_{\mathbf{t-1}} + \boldsymbol{\omega}_{\mathbf{t}} \quad (3)$$

Where, $\tilde{\mathbf{y}}_{\mathbf{t}}$ is the real output gap, **isr_cyclical** is the cyclical component of the real inventory-to-sales ratios, $\boldsymbol{\beta}_t$ is the time-varying real output-gap persistence parameter, and $\boldsymbol{\gamma}_t$ (our parameter of interest) is the time-varying slope coefficient measuring the impact of inventory cycles on business cycles.

The intercept of the TVP model ($\boldsymbol{\alpha}$) absorbs the influences of the time-invariant unobservables on the independent variable(s) thus enabling the remaining components of the model to obtain the most accurate estimates possible (Harvey, 1990).

The error terms $\boldsymbol{\mu}_t$, $\boldsymbol{\pi}_t$ and $\boldsymbol{\omega}_t$ are the serially uncorrelated disturbances (hyper-parameters) with zero mean and constant variances and are assumed to be uncorrelated with each other at all time periods.

To ensure that the hyper-parameters have positive variances, log likelihood is constructed using parameterization:

$$\boldsymbol{\Psi}_1 = \ln(\sigma_\mu^2) \xrightarrow{yields} \sigma_\mu^2 = \exp(\boldsymbol{\Psi}_1)$$

Similar argument follows for the remaining $\boldsymbol{\Psi}_i$ s.

My empirical strategy is to estimate the path of $\boldsymbol{\gamma}_t$.

In this model, I treat the output-gap as the observable variable and the two dynamic coefficients ($\boldsymbol{\beta}_t$ and $\boldsymbol{\gamma}_t$) as the time-varying state variables.

The measurement equation (1) collectively with the transition equations (2) and (3) represent a state-space form in which the time-varying parameters ($\boldsymbol{\beta}_t$ and $\boldsymbol{\gamma}_t$) and the hyper-parameters are estimated using Most Likelihood Estimation (M.L.E) methods. The M.L. estimation technique follows an iterative procedure where the iterations aim to maximize the likelihood value with respect to the time-varying parameters and the hyper-parameters. Post-estimation I obtained the optimal estimates of the state variables by Kalman Filter (K.F.) recursions.

In equation (1) for the inventory measure, I alternately use the cyclical component of the composite MTIS and the sectoral MTIS (manufacturing, wholesale and retail) and estimate the entire state-space sequence for each of these measures; I use the NIPA measure as robustness check. This allows to me separately estimate the impact of the composite and the sectoral inventory cycles on the business cycle.

To address endogeneity concerns, following Ramey and West (1999), in this model the final sales are assumed to be exogenous to the representative firm's short-run cost minimization problem (even though sales might not necessarily be exogenous to the firm's long-run profit maximization problem). As such any adjustments to the production levels incur a convex cost, i.e., there exists a non-zero cost of deviating from an exogenously determined target inventory-to-sales ratio and therefore, in the face of fluctuating sales, firms use inventories to smooth production.

3. Estimation results

Table 1 presents the estimation results for the state-space form represented by equations (1), (2) and (3). Column 1 reports the estimated value (final state) of $\boldsymbol{\gamma_t}$, our parameter of interest for each of the corresponding MTIS measures, while column 2 reports the p-value (with the significance levels in parenthesis).

Table 1: Estimates of γ_t

Inventory-to-Sales Ratios	γ_t (Final State)	Probability (Significance)
	(1)	(2)
MTIS Composite	-0.066435	0.07 (*)
MTIS Manufacturing	-0.073811	0.00(***)
MTIS Retail	-0.012594	0.9116
MTIS Wholesale	-0.044675	0.1163
NIPA Non-Farm Total IS Ratio (Robustness Check)	-0.062111	0.0067(***)

Note: ***, ** and * mean significant at 1%, 5% and 10% levels, respectively.

Table 2: Estimates of β_t

Inventory-to-Sales Ratios	β_t (Final State)	Probability (Significance)
	(1)	(2)
MTIS Composite	0.770	0.00 (***)
MTIS Manufacturing	0.743	0.00 (***)
MTIS Retail	0.877	0.00 (***)
MTIS Wholesale	0.799	0.00 (***)
NIPA Non-Farm Total IS Ratio (Robustness Check)	0.920	0.00 (***)

Note: ***, ** and * mean significant at 1%, 5% and 10% levels, respectively.

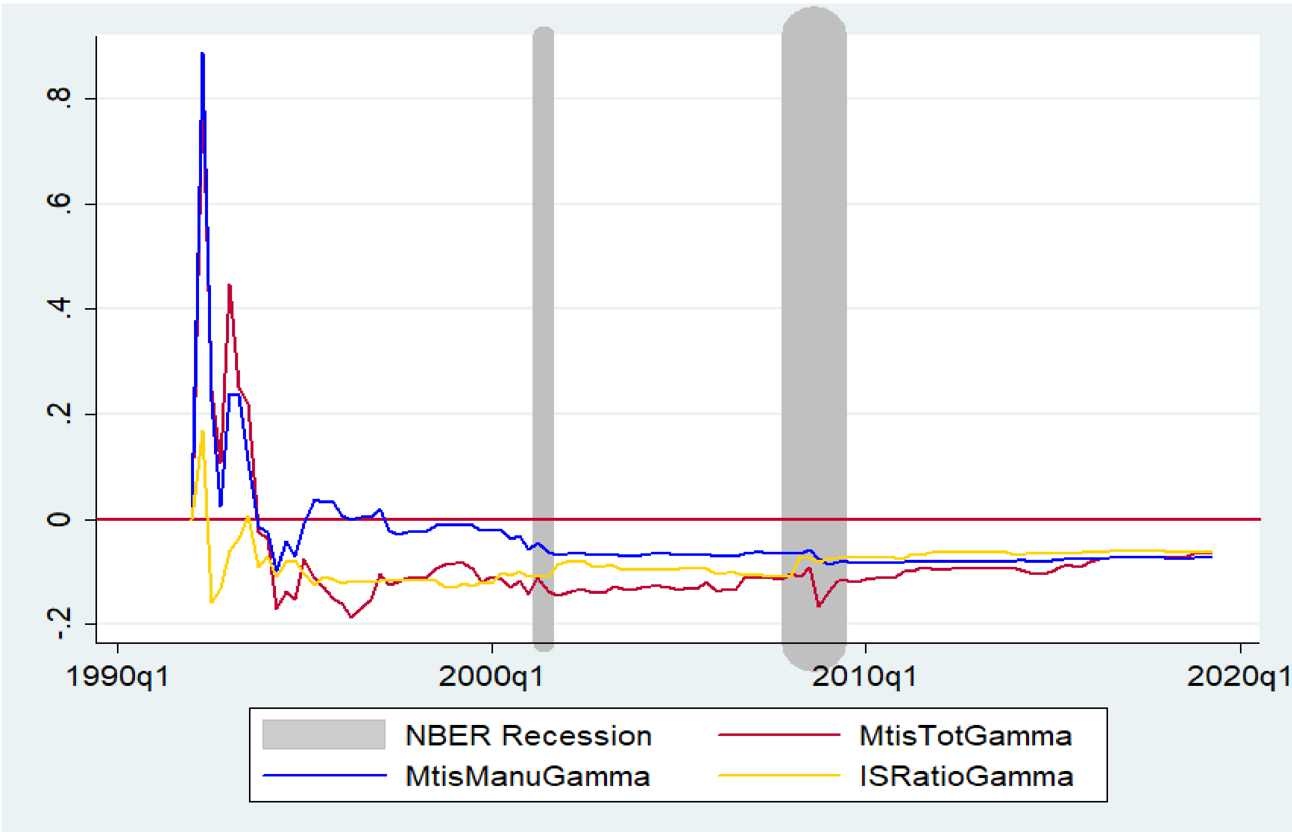
Table 2 presents the final state estimates of the real output-gap persistence parameter β_t for all the inventory measures.

The parameter estimates (see Table 1) are consistent with theory and are relatively precise. The estimated model replicates the volatility and the counter-cyclicality of inventory-to-sales ratios. As we move into the sectorals, it is quite evident that the entire (or at least the bulk of) inventory dynamics responsible for triggering business cycle fluctuations come from the manufacturing sector (significant at 1% level). The wholesale and the retail sectors (where surprisingly the majority of the inventories are held) seem to have no statistically significant impact.

The NIPA data which is considered to be an inferior measure of inventory-to-sales ratios as compared to the MTIS data (see Filardo, 1995), is used as robustness check. The estimate obtained in this case is quite similar to that obtained using the composite MTIS data.

Figure 3 illustrates how γ_t, the time-varying slope coefficient measuring the impact of inventories on real GDP, has evolved over the years from 1992 Q1 to 2019 Q2. Barring a significant spike post-Gulf War, the volatility of γ_t has been steadily trending downwards. Even during recessions (both 2001 and the Great Recession) when the volatility of inventory-to sales ratios (both composite and the sectorals) has been significantly higher than that of real output (see Figure 2), γ_t shows no significant jumps. In fact, post-Great Recession the time-varying slope coefficient seems to have reached a long-run steady state with the final state value hovering around zero.

Figure 3: Time path of γ_t (MTIS Composite and Manufacturing Inventory-to-Sales Ratios and NIPA Non-Farm Total Inventory-to-Sales Ratios) 1992 Q1 - 2019 Q2

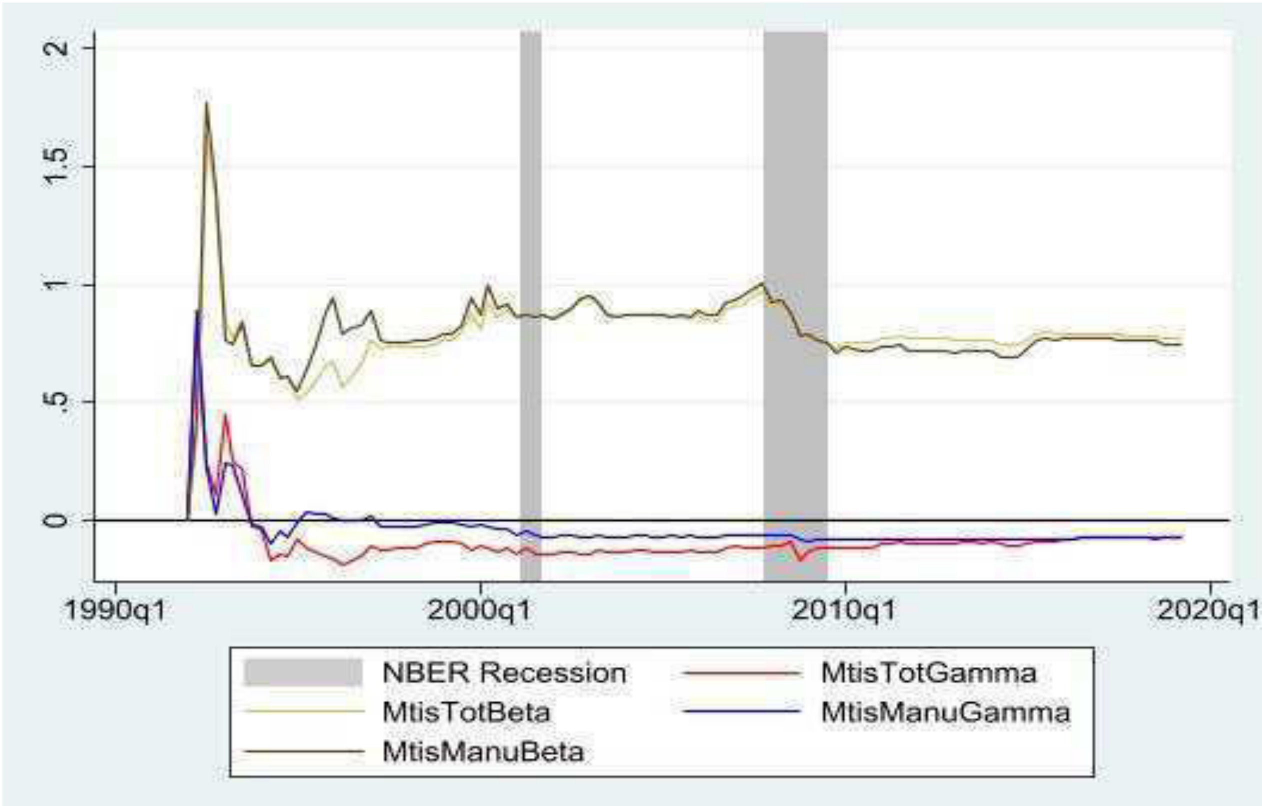


Notes: Source - Author's calculation using data from the U.S. Census Bureau and BEA.

Here, *MtisTotGamma* – γ_t for MTIS Composite inventory-to-sales ratios, *MtisManuGamma* - γ_t for MTIS Manufacturing inventory-to-sales ratios and *ISRatioGamma* - γ_t for NIPA Non-Farm Total inventory-to-sales ratios.

The output-gap persistence parameter seems to have a uniform impact on the dependent variable for all the inventory measures: non-zero (in fact, quite close to 1 in some cases) and very significant (see Table 2). Figure 4 elaborates on the nature of β_t; it offers a comparative insight into the evolution of the time-varying regression coefficients over the three decades. The estimates of β_t suggest that monetary policy continues to be a rather significant factor in the evolution of business cycles and as such, is unlikely to be solely responsible for the decline in the volatility of real output. Effects over time seem to be levelling off though (quite similar to γ_t, at least trend wise) but it is still significantly greater than zero.

Figure 4: Time paths of γ_t and β_t (MTIS Composite and Manufacturing Inventory-to-Sales Ratios): A comparative view - 1992 Q1 - 2019 Q2



Notes: Source - Author's calculation using data from the U.S. Census Bureau and BEA.

Here, *MtisTotGamma* – γ_t for MTIS Composite inventory-to-sales ratios, *MtisManuGamma* - γ_t for MTIS Manufacturing inventory-to-sales ratios, *MtisTotBeta* – β_t for MTIS Composite inventory-to-sales ratios and *MtisManuBeta* - β_t for MTIS Manufacturing inventory-to-sales ratios.

While my findings do seem to be in line with the conclusions of Blanchard and Simon (2001), Stock and Watson (2003), and Summers (2005) that better monetary policy may account for some of the moderation in the volatility of output, the role played by it is rather limited at best. Monetary policy, on its own, is unable to explain the evolution and the trend of the time-varying parameter coefficient. Rather it is the structural transformation of the U.S. economy, aided by better policy making, that has led to the stabilization of the overall U.S. output growth. My conclusions are in agreement with Eggers and Ioannides (2006) who find that nearly half of the decline in U.S. output growth variance between the pre-and the post-1982 period can be explained by the shifts in output composition, particularly the decline of manufacturing and the rise of services and the financial sectors. They observe that in the period between 1947 and

1982, the manufacturing sector was by far the largest of the one-digit sectors, accounting for more than 25% of U.S. output, significantly more than twice the output of both the services and the financial sectors. However, between 1982 and 2001, both the finance and the services sectors surpassed manufacturing, growing to around 18% of the U.S. economy each, while manufacturing declined in relative size to just under 18% of the U.S. output. In 1990, the manufacturing industry employed more workers than any other sectors in 36 U.S. states. By the end of 2014 the picture has completely turned around: Manufacturing is the dominant industry in only seven states while service industries account for a full two-thirds of the U.S. GDP. Because manufacturing is a particularly volatile sector while the services is relatively much more stable (it is also worth noting that virtually no inventories are held in the services sector), any structural changes in the U.S. economy that tend to increase the relative size of stable sectors compared to the volatile ones, would substantially stabilize the overall US output growth. The fact that the wholesale and the retail sectors, where majority of the inventories are held, seem to play no role in these whole dynamics only strengthens the argument.

4. Conclusions

In this study I attempt to analyze the changes in reduced-form relationship between business cycles and inventories in the U.S. from 1992 Q1 to 2019 Q2. My estimates suggest that although the volatility of inventory cycles (long considered to be the primary driver of business cycles) has been greater than the volatility of business cycles over the entire sample period, with the differences being significantly more pronounced during recessions, inventories (or specifically inventories in the manufacturing sector) seem to have lost their importance vis-à-vis the business cycles. Even recessions, unlike in the past, seem to have negligible impact on the relationship. This can be possibly attributed to the changing nature of the U.S. economy where the service-based industries (where virtually no inventories are held) have taken over manufacturing as the primary driver of the economy. While this dynamic model does not rule out the role of better monetary policy, albeit rather marginal, it is the restructuring of the U.S. economy, most notably the decline of manufacturing and the rise of services and the financial sectors, that appears to be the driving force behind the long-run stabilization of the U.S. output.

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