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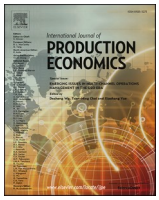

The effect of economic uncertainty on inventory and working capital for manufacturing firms

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ABSTRACT

This paper develops an empirical model to investigate the impact of macro-economic risk on working capital and the various types of inventory. Our analysis helps manufacturing firms anticipate the implications of high macro-economic risk, measured through the economic policy uncertainty (EPU) index, on their operations. Using a sample of 6503 US manufacturing firms during the period 1990–2018, we show that EPU drives high levels of inventory, thus corroborating existing theories about random disruptions raising safety-stock levels. We also show that increased economic uncertainty yields higher trade credits, payables, and working capital, thus requiring firms to tie more capital to their operations. Our results are statistically significant, yet these effects are small at the firm level. The results are robust when applying the monetary policy uncertainty (MPU) index to the subsample of the data from 1990 to 2007, instead of the EPU index to the same data set.

1. Introduction

The financial underpinnings of supply chains are of paramount importance, as firms need to carefully manage their uses of cash, including working capital (WC), alongside their inventory. WC constitutes a significant portion of a firm's investment (Fazzari et al., 2000) and comprises three components: Inventory, payables, and receivables. In this regard, it is defined as the difference between current assets and current liabilities (Wuttke et al., 2013). WC is measured through the cash conversion cycle (CCC), which is the average time it takes an invested dollar to buy inputs, produce and sell outputs, and collect cash. When accounts payable are credited, the input is shipped by the supplier, then it is received, and cash is paid for it. WC management includes finding the adequate cash levels, granting credit, managing inventory, ensuring the conversion of accounts receivable and inventories to cash, paying the accounts payable on time, guaranteeing access to bank credit lines, investing in highly liquid securities, deciding on the best ways to raise cash, and renegotiating long term liabilities (Fazzari et al., 2000; Kieschnick et al., 2013; Frankel et al., 2017). WC management decisions require careful planning to ensure access to cash at a minimal cost at the right time. Analyzing inventory while ignoring the impact of the inter-related financial flows, portrays an incomplete picture, as it ignores trade receivables and payables. For example, bloated inventory levels may cause cash-flow constraints because of a longer CCC (Kesavan and Mani, 2013). Also, while trade credit entices sales and increases inventory turnover, it is not indicative of inventory efficiency since trade receivables are high. As such, WC best captures the interactions of inventory and cash management.[1]

The existing literature on the topic of WC management offers different perspectives on its effectiveness as a tool for improving performance. While one stream of the literature argues that raising investments in WC, particularly through inventory, can drive sales,

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[1] Forbes (2012) reported that the best stock returns over the past five years relate to firms managing their CCC efficiently, with Amazon, Costco, and Walmart being among those firms. While Costco has the highest inventory turnover ratio, Amazon has the shortest cash conversion cycle. Amazon stands out in how quickly it converts material to cash, having a negative cash conversion cycle (−41 days in December 2017), as it manages to hold inventory for 38.1 days plus 20.9 days to collect AR and takes too long to pay its suppliers, 95.8 days on average last year (Morningstar, 2017). Amazon's cash cycle is the shortest in the retail industry, followed by Costco's 2.8 days, and Walmart's 5 days (Morningstar, 2017). Specifically, it is not an inventory turnover that distinguishes Amazon from Walmart and Costco, but rather CCC. Amazon attributes its "cash-generating operating cycle" to proper WC management: "On average, our high inventory velocity means we generally collect from consumers before our payments to suppliers come due." (HBR, 2014). Similarly, Apple has had a negative CCC of – 86.11 in the first quarter of 2018 due to the way it manages its WC cycle (Apple, 2018).

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provide input price hedging, and lower purchasing costs (Blinder and Maccini, 1991; Fazzari and Petersen, 1993; Corsten and Gruen, 2004), another stream shows that WC management frequently does not reflect optimal levels, and, therefore, must change to realize investment gains (Ek and Guerin, 2011). For instance, excessive WC investment may tie up useful resources, thereby resulting in lost opportunities. Also, it can increase the need for credit, which by itself increases solvency risk, thereby reducing company value (Kieschnick et al., 2013). Hence, the importance of understanding the dynamics of WC, especially increasing or decreasing it towards optimal levels tend to improve firms' operating performance and valuation (Aktas et al., 2015).

Economic policy changes can transform the economic environment that firms face. Uncertainty about future government policy, for example, has the potential to influence firm decisions (Kang et al., 2014). It disrupts the flow of goods and services in a supply chain and puts pressure on firms' WC, which may limit their access to bank credit (Bordo et al., 2016). Policy uncertainty is the economic risk associated with undefined future government policies and regulatory frameworks. It affects businesses and individuals spending and investments (Al-Thaqeb and Algharabali, 2019). According to Baker et al. (2016), after the 2008 global financial crisis, uncertainty around government policies peaked due to business and household uncertainty regarding the government's future regulatory framework, spending, taxes, monetary policies, and healthcare. Several measures of economic uncertainty have been proposed (Manela and Moreira, 2017; Scotti, 2016), with the most comprehensive being the Economic Policy Uncertainty (EPU) index, developed by Baker et al. (2016). The EPU index is a measure of macroeconomic uncertaintycaused by fiscal policy matters (especially tax policy and government spending), monetary policy, health care policy, national security, financial regulations, debt and currency crisis, entitlement programs, and trade policy. Baker et al. (2016) aggregated these factors into the EPU index and show that this index corresponds well with events associated with times of high policy uncertainty, with spikes occurring around elections, wars, debt ceiling debates, etc. Baker et al. (2016) also investigated the relationship of policy uncertainty to firm-level stock price volatility, investment rates, output, and employment, and show that market volatility increases during periods of high policy uncertainty, and spending decreases as well. Macroeconomic effects of uncertainty act like volatile aggregate demand shocks, raising unemployment level and resulting in a decline in sales (Leduc and Liu, 2016).

In this paper, we investigate the impact of macroeconomic uncertainty on WC, its components, (accounts payables and receivables), and the various types of inventory (raw material, work-in-process, and finished goods) for US manufacturing firms. Managing inventory and cash flows and the associated risks is a continuous challenge to those firms (Li et al., 2013). In our work, macroeconomic uncertainty is measured using the EPU index developed by Baker et al. (2016). We show that EPU and monetary policy uncertainty (MPU), a subcategory of EPU defined as the increased volatility resulting from uncertainties in monetary policies, increase the levels of WC, its components, inventory levels, and cause harm to the liquidity positions of firms. Although the results are statistically significant, they show that the impact of EPU on WC is small. These significant but not substantial results might still correspond to large absolute dollar-amounts.

Our contribution can be highlighted as follows. To the best of our knowledge, this is the first paper that investigates the effect of macroeconomic risk measured by the EPU on WC, its components, and different types of inventory. We show that all determinants of WC are driven by EPU. Specifically, a higher uncertainty level is costly to the economy since firms need to invest more in their WC. Also, EPU affects inventory at all levels of production, with the highest impact being on finished goods. Furthermore, we confirm that WC studies should methodologically rely on dynamic panel regression of WC because variables depend heavily on their lagged values. This paper provides managers with mechanisms to manage working capital, and insights on how to operate inventory efficiently while maintaining healthy cash flow management, in the face of macroeconomic uncertainty.

This paper is organized as follows: Section 2 reviews the current literature in the field. Section 3 develops the hypotheses for the study. The methodology and model are developed in Section 4. Section 5 describes the data and samples. Section 6 discusses the findings, managerial implications, and robustness tests. The conclusion and limitations are provided in Section 7.

2. Related literature review

The present paper is associated with strands of studies focusing on EPU, WC, and empirical operations literature on factors impacting inventory dynamics in the manufacturing sector.

The model we develop in this paper links macro-economic, operational, and financial variables to the WC and various types of inventory (raw material, work-in-process, and finished goods). Several papers in the operations management literature have focused on identifying the factors that drive changes in inventory levels of supply chain players, including gross margin, capital intensity and sales surprise (Gaur et al., 2005), abnormal inventory growth (Steinker and Hoberg, 2013; Kesavan and Mani, 2013), sales growth and size (Kesavan et al., 2016), demand uncertainty and lead time (Rumyantsev and Netessine, 2007a), competition (Olivares and Cachon, 2009), and product variety (Rajagopalan and Malhotra, 2001). In our model, we use some of those factors, namely, gross margin, sales growth, and lead time. Rumyantsev and Netessine (2007b) showed that higher demand uncertainty, longer lead times, increasing profit margins on the one hand, and decreasing economies of scale on the other, contributed to high inventory levels. None of these models has considered the impact of macro-economic risk on the levels of inventory.

Some studies have looked at the inclusion of the accounts receivable (AR) and accounts payable (AP), components of WC measured through trade credits (Lo et al., 2009; Seifert et al., 2016), especially that these financial components have allowed the supply chain to partly overcome the asymmetric information between capital markets and the ones needing capital (Pfohl and Gomm, 2009). Lee et al. (2018) examined how trade credit enhances supply chain efficiency by allowing the retailer to share some of the demand risks with the supplier. Lorentz et al. (2016) provided evidence of how the business cycle affects trade credit in firms on different tiers of the supply chain. Breza and Liberman (2017) argued that restrictions to the set of feasible financial contracts (e.g., trade credit agreements) affect the relationship between a supplier and a buyer and a firm's organizational form.

This literature on WC recognized that a supply chain should work on improving its financial flows by helping buyers and their suppliers improve their WCs and reduce costs (Wuttke et al., 2013). For instance, WC management can improve performance by shortening days of sales outstanding, hence leading to a better firm financial performance (Stewart, 1995; Churchill and Mullins, 2001; Farris and Hutchison, 2002, 2003). Several studies focus on improving the financial performance of a firm by reducing the WC and the volume, rate, or duration of the financing terms, achieved by finding the best AP, AR, and inventory policies (Richards and Laughlin, 1980; Moss and Stine, 1993; Stewart, 1995; Christopher and Ryals, 1999; Brewer and Speh, 2000; Farris and Hutchison, 2002, 2003; Gelsomino et al., 2016). Several other papers have examined the management of WC. Hill et al. (2010) discussed the impact of demand fluctuations on WC and its components. They argued that demand fluctuations make WC investment planning unpredictable, which results in higher inventory, especially for firms that enjoy access to cheap credit, as they can pass on favorable credit receivable terms to customers to rid themselves of the excess inventory and smooth out demand fluctuations. We build on the work of Hill et al. (2010) to argue that macroeconomic uncertainty influences WC and its components, by impacting demand and financing channels.

Since 1960, the EPU in the United States has been rising due to an

increase in government spending, taxes, regulation, and high levels of political polarization. In turn, this uncertainty has paved the way for severe concerns for the US economy, considering that EPU goes hand in hand with poor macroeconomic performance (Baker et al., 2016), as manifested by decreased output, investment, and employment rates (Julio and Yook, 2012). Many studies on economic uncertainty have recommended that firms slow down on investment and recruitment in a high-risk operating environment, i.e., when EPU is high (e.g., Deloof, 2003). Moreover, EPU puts upward pressure on the cost of financing firms, which makes banks less willing to lend to them (Bordo et al., 2016). At the same time, firms with different characteristics are in a better position to reduce the negative impact of uncertainty, as they rely on internal financing (Wang et al., 2014). In addition to firm-specific characteristics, industry characteristics might affect a firm's behavior as well. According to Patnaik (2016), firms operating in highly competitive industries increase their WC investments in response to heightened uncertainty, as deferring investments is likely to make them less competitive in the long run. The literature shows that incorporating EPU as an additional predictive variable into volatility models has helped significantly improve the stock market volatility forecast (Baker et al., 2016), which could be due to EPU's ability to predict business cycle fluctuations (Rapach and Zhou, 2013).

Hence, understanding how macro-economic uncertainty risk affects WC management is of utmost importance, given the implications that WC disruptions have on the overall performance of a firm. There has been an effort in the literature to analyze the effect of macroeconomic risk on inventory management. For instance, Chen et al. (2005) examined the different inventory types of manufacturing companies and found that factors such as inflation, interest rates, and GDP affect inventory levels. Similarly, Kesavan et al. (2016) analyzed the behaviors of high and low inventory turnover on retailers in response to macro-economic risk and the impact on their financial performance. They found that when the inventory turnover is high, retailers responded, usually quickly, by changing their purchase quantities, whereas when the inventory turnover is low, retailers responded by changing prices. Nevertheless, this literature did not address the effect of macroeconomic uncertainty risk. To the best of our knowledge, none of the studies in the literature has explicitly addressed the effect of macroeconomic uncertainty risk on inventory and WC management.

3. Developing the hypotheses

WC management decisions require careful planning and control of a firm's current assets and liabilities to meet short-term debt obligations while avoiding excessive investment in short-term assets. Thus, one may pose the following question: How does EPU affect the development of firms in a WC management context? This question is crucial given that WC drives the financial and operational health of firms, especially for small and medium-sized ones that depend on efficient WC management to survive. Addressing this question has been more feasible by introducing a news-based search approach, developed by Baker et al. (2016). WC management is a dynamic process of continuous assessment of the trade-offs between expected profitability and investments' risks in current assets and liabilities. The EPU, a risk measure, is expected, therefore, to affect the WC and its components. We begin by formulating the hypotheses, postulating the relationship between EPU and WC and its components: Accounts receivable (AR), accounts payable (AP), and inventory.

Suppliers extend trade credit to buyers (retailers) to increase sales by postponing payments. This practice makes the number of days that it takes retailers to pay their suppliers amounts; i.e., days payable outstanding (DPO), on average, to half of the days sales of inventory (DSI); see Table 1 in Yang and Birge (2018). When suppliers offer manufacturers industry-average trade credit, both parties will benefit, as this offer improves both sales and gross profits for both parties in the supply chain (Lee et al., 2018). The literature has proposed three key theories for why trade credit is valuable (Breza and Liberman, 2017). First, trade credit plays a valuable intermediation role, as the supplier can provide funds to the manufacturer cheaper than the market. Second, trade credit could be a manifestation of asymmetric bargaining power, held by manufacturers, over small suppliers. In this case, manufacturers try to extract more of the suppliers' surplus. Third, trade credit may provide incentives for suppliers and manufacturers through relational contracts. Trade credit also helps in increasing demand during slow periods (Emery, 1987), and smoothing demand, thus reducing the seller's inventory cost. Therefore, instead of responding to demand uncertainty through varying production or via price fluctuations, which is not always feasible, firms revert to trade credit as a more sustainable alternative. Since the EPU is reflective of aggregate demand shocks (Leduc and Liu, 2016), the newsvendor model indicates that an increase in uncertainty is associated with higher inventory if the service level is above the median, which tends to be the case in most applications.

Table 1
Descriptive statistics.

Variable	Quarterly					Annual				
	Mean	Median	Std. Dev.	Min	Max	Mean	Median	Std. Dev.	Min	Max
CCC	115.48	97.50	94.28	−63.53	430.68	114.23	100.41	88.43	−90.23	397.09
DSO	62.35	57.02	32.46	13.15	191.78	62.88	57.45	33.00	12.41	195.1
DPO	62.78	44.81	60.99	10.02	335.75	61.41	44.99	61.11	10.83	396.03
DIH	113.99	86.86	91.19	10.06	454.21	111.06	89.45	84.24	10.23	442.58
Growth	4.72	3.54	25.78	−49.74	98.66	11.23	6.03	33.59	−46.64	160.65
CF	−16.06	9.27	97.97	−546.39	36.03	−14.82	5.89	89.32	−606.55	29.07
Size	5.08	4.99	2.36	0.31	10.07	5.26	5.20	2.43	0.38	10.32
Leverage	24.65	20.06	25.11	0.00	107.77	18.95	13.13	21.22	0.00	91.14
FA	33.94	31.40	20.37	3.46	78.9	31.11	28.19	18.73	2.99	75.83
ROA	0.79	2.59	7.10	−28.36	10.50	−0.45	6.56	26.14	−124.34	28.72
AbI	−0.04	−0.22	0.77	−1.19	2.50	−0.07	−0.22	0.74	−1.21	2.48
EPU	96.1	84.94	41.00	37.27	271.83	97.80	87.49	41.59	50.61	174.90
MPU	89.63	71.32	59.30	16.57	407.94	86.43	71.32	49.08	33.15	108.65
3Mrate	2.94	3.10	2.25	0.00	8.07	2.67	3.10	2.17	0.00	6.63
GDPg	0.64	0.62	2.28	−3.70	6.11	2.54	2.65	1.85	−3.29	9.91
Inf	0.5	0.39	2.25	−13.20	7.65	1.87	2.07	4.31	−16.06	17.36
Invt						3.26	3.27	2.36	0.00	7.98
Invfg						2.30	2.31	2.49	0.00	7.13
Invrm						2.15	2.16	2.18	0.00	6.46
Invwip						1.58	1.62	2.38	0.00	6.48

Therefore, firms tend to buy more, and we expect AR to increase. Drawing upon the asymmetric bargaining power theory of trade credits, if prices fluctuate, buyers will suffer from high information costs, and if production varies, sellers will suffer from high production costs (Long et al., 1993). Moreover, firms offering trade credit with appropriate terms could allow an increase, not only in demand but also in cash sales, to help them meet their liquidity obligations (Lee et al., 2018; Bougheas et al., 2009). Subsequently, manufacturers might need to increase AR to fill a financing gap that the customers might suffer from due to higher uncertainty. When EPU is high, banks face high liquidity risk, and trade credits may increase, acting as a substitute for decreased bank lending (Bordo et al., 2016). Therefore, when bank loans dry up, demand for AR from financially constrained customers increases and leads to higher AR levels for the manufacturing firms.

On the other hand, managing AR during a period of high EPU is critical since it affects a firm's profitability, risk, and value. As a result, we speculate, in this paper, that during periods of high EPU, firms tend to increase AR to boost their sales and mitigate the negative impact of EPU on operations. We argue that a manufacturer facing uncertain demand tends to extend credit to constrained customers to encourage credit purchases and accumulate AR rather than costly inventories, which may or may not be sold later for cash (Bougheas et al., 2009; Hill et al., 2012). Hence, we formulate the first hypothesis:

Hypothesis 1. (H1): EPU increases AR.

The literature shows that the macroeconomic effects of uncertainty take the form of volatile aggregate demand shocks (Leduc and Liu, 2016). Since EPU is reflective of aggregate demand uncertainty, we use the newsvendor model to argue that EPU increases all three types of inventory (raw material, work-in-process, and finished), provided that the service level is above the median, which is most often the case. Based on the newsvendor model, an increase in uncertainty is associated with more inventory, provided the critical ratio is large enough. Thus, we expect manufacturing organizations to maintain higher levels of safety-stocks of finished goods to hedge against economic uncertainty (Snyder et al., 2016). Many studies have proposed increasing safety-stock levels as a way to hedge against random disruptions and demand fluctuations (Akella and Kumar, 1986; Groenevelt et al., 1992; Moinzadeh and Aggarwal, 1997; Parlar, 1997; Cheung and Hausman, 1997; Das and Sarkar, 1999; Mohebbi, 2003; Gharbi et al., 2007; Dhouib et al., 2012). Manufacturing firms operating in an uncertain economic environment also tend to hold raw materials inventory to hedge against uncertainties, e.g., unexpected supply disruptions and/or price increases (Maccini and Pagan, 2012; Nilsen, 2013; Kroes and Manikas, 2014). Therefore, the second hypothesis is:

Hypothesis 2. (H2): EPU increases inventory levels (raw material, work-in-process, and finished inventory).

AP is another significant component of WC. AP management aims to monitor WC efficiently without threatening the credit rating of a firm or its relationships with suppliers. Based on the newsvendor model, an increase in aggregate demand uncertainty leads to firms buying more (and so do their customers), thus, accounts payable increase and, overall, the CCC. This causes firms to rely on suppliers' credit to adjust production without being constrained by the lower levels of cash flows and bank credit offerings. Hence, manufacturers are expected to rely more on AP to smooth out the production process (Martinez-Sola et al., 2014). Moreover, sales uncertainty triggers firms to increase their AP to save costs. The volatility in sales can cause fluctuations in production, which, in turn, causes unpredictable purchasing cycles. Therefore, firms with such erratic cycles tend to improve performance by acquiring the inputs needed for production, separate from the payment cycle (Nelson and Nelson, 2002).[2] Firms with sales volatility are expected to have higher AP levels compared with firms having a stable demand. It is expected, therefore, that firms have higher AP levels in periods of higher uncertainty and demand fluctuations.

Following the incentive theory of trade credit (Emery, 1987; Breza and Liberman, 2017), suppliers have an incentive to increase their sales by offering better credit terms. Suppliers also tend to give more credit to their customers when the bank lending channels dry. It is expected, therefore, to witness high AP levels in periods of high EPU, to stay competitive. The literature identified two opposite effects of an increase in AP on a firm's operating and financial performances. On the one hand, the value intermediation theory of trade credit indicates that firms can benefit from a cheap source of financing (Breza and Liberman, 2017). An increase in AP might also indicate missing trade discounts and jeopardize the relationship with their suppliers (Niskanen and Niskanen, 2006).

Hypothesis 3. (H3): EPU increases payables.

WC competes with fixed investments for the limited pool of finance. Thus, when firms choose to decrease (increase) WC, fixed investments would rise (fall). As Bordo et al. (2016) have shown, the bank lending channel is affected by EPU, and banks tend to give fewer loans. So, the value of financing becomes higher for financially constrained firms, which would respond by reducing their investments in their accumulated assets. Increasing the WC level comes at the expense of investing in fixed assets. First, the reason is to secure the short-term survival of a firm during downturns by liquidating some assets to have more WC on hand. (Braun and Larrain, 2005). Second, firms focus their investments in fixed assets and WC by treating them as a source of funds (Fazzari and Petersen, 1993). In short, during periods of high EPU, firms experience high levels of AR, inventories, and AP. We also expect the aggregate effect of a higher EPU to increase investments in WC. On the one hand, we expect higher EPU to lower sales growth in the economy, given the tendency of households to decrease their consumption and increase their precautionary savings if EPU is associated with labor income uncertainty (Carroll, 1997). Hill et al. (2010), however, found that rising sales growth will result in lower investments in WC, as companies achieve their targeted sales performance objectives. Hence, if firms do not meet their sales growth objectives, as predicted in higher EPU environments, it is, therefore, likely that those firms tend to increase their WC levels. Doing so could negatively impact a firm as it increases the CCC, which reduces the present value of the net cash flow generated by the assets and, therefore, a lower firm value. Hence.

Hypothesis 4. (H4): EPU increases WC levels.

4. The model

4.1. Model specifications

In this paper, we develop a dynamic panel model by applying the Arellano-Bover/Blundell-Bond GMM (Generalized Method of Moments) to determine a firm's WC (Arellano and Bover, 1995; Blundell and Bond, 1998). In general, dynamic panel models have an advantage over fixed and random effect models when endogeneity resulting from reverse causality and/or bias caused by omitted variables is a real concern (e.g., Isaksson and Seifert, 2014). The reverse causality is likely to exist in our model since the literature has identified profitability as a primary

[2] The separation between payment and purchase is fundamental to the performance of firms with sales volatility because it allows them to avoid holding precautionary cash balances and reduces transaction costs associated with cash management (Ferris, 1981).

determinant of WC. However, WC levels affect profitability as well (Aktas et al., 2015) since over investing in WC leads to a loss of returns that could have been gained by reallocating these funds to long term assets (Ponsian et al., 2014). Moreover, it is somewhat unlikely that all relevant firm-specific variables that determine WC and its components are only related to publicly available accounting data. Hence, the first differencing in the GMM estimator helps us overcome the individual unobserved effects (Roodman, 2009).

Unlike the static and random panel data models that require strict exogeneity, dynamic panel data models also include lagged levels of the dependent variable as explanatory variables. Consequently, static models lead to biased estimators, since the lagged dependent are correlated with the idiosyncratic error, violating the strict exogeneity condition (Anderson and Hsiao, 1981). In this context, dynamic panel models allow for partial adjustment of the dependent variable, which is suitable for our study because, usually, WC does not change drastically from one quarter to another. WC adjustment is slow. This behavior is because decision making about the investment in and financing of current assets and their components is time-consuming for companies in an attempt to find the optimal balance between liquidity and profitability and, consequently, between risk and return (Richards and Laughlin, 1980; Koralun-Bereźnicka, 2014). Accordingly, it is appropriate to use a dynamic equation that includes the dependent variable with a lag among the explicative variables. The reason that the two-step GMM estimator, on the one hand, eliminates unobservable individual effects using first-order differencing, while on the other hand, the estimator includes lagged instrumental variables, which control the correlation that exists between the dependent variable difference and the error term (Blundell and Bond, 1998)[3,4]

We consider a maximum of 4 lags in the regressions and select the optimal final lag structure using a general-to-specific approach, as advocated by Hendry (1995). We also standardize all the variables in our model by subtracting the mean of each variable (i.e., centering) and then dividing by the standard deviation of that variable to make the model unitless.[5] The model is as follows:

$$Y_{i,t}=\beta_0+\beta_1 Y_{i,t-1}+\beta_2 EPU_t+\beta_3 CF_{i,t}+\beta_4 Leverage_{i,t}+\beta_5 Growth_{i,t+1}+\beta_6 FA_{i,t}+\beta_7 Size_{i,t}+\beta_8 ROA_{i,t}+\beta_9 AbI_{i,t}+\beta_{10} 3Mrate_t++\beta_{11} GDPg_t+\beta_{12} Inf_t+\delta_t Time_t+\varepsilon_{i,t} \quad (1)$$

In Eq. (1), $Y_{i,t}$ measures the WC or one of its components in this study. We alternate the dependent variable across four models to include CCC, days sales outstanding (*DSO*), days inventory held (*DIH*), and days payable outstanding (*DPO*). Thus, we obtain four different models with four different dependent variables. The days-of-sales-outstanding measures how many days, on average, it takes to receive cash from the buyers from their orders. Let $COGS_{it}$ denote the cost of goods sold for firm *i* in quarter *t*, then the days of sales outstanding for firm *i* is the ratio of the AR to the sales, and is measured as:

$$DSO_{it}=\frac{AR_{it}\times 365}{Sales_{it}\times 4} \quad (2)$$

DIH_{it} captures how many days on average it takes for inventory (INV_{it}) to turn over, for firm *i* in quarter *t,* and is measured as:

$$DIH_{it}=\frac{INV_{it}\times 365}{COGS_{it}\times 4} \quad (3)$$

Product deliveries and payments to suppliers both experience lead times. We use the average number of days of accounts payable outstanding as a proxy measure for lead time, following Rumyantsev and Netessine (2007b). The days of sales outstanding of firm *i* in quarter *t*, DPO_{it}, measures how many days, on average, it takes for the firm to pay its suppliers. We compute DPO_{it} as follows:

$$DPO_{it}=\frac{AP_{it}\times 365}{4\times COGS_{it}} \quad (4)$$

Then, the cash conversion cycle of firm *i* at time *t*, CCC_{it}, is obtained as:

$$CCC_{it}=DSO_{it}+DIH_{it}-DPO_{it} \quad (5)$$

As aforementioned, we expect the EPU index constructed by Baker et al. (2016) to have a positive impact on CCC and its components. Let Y_{it-1} denote the lagged dependent variable for firm *i*. It is worthy of mentioning that dynamic panel models capture the persistence of WC measures by including their lagged values. For the model to converge this lagged variable, it should have a value between 0 and 0.99.

4.2. Control variables

We include in the model firm-specific, industry-specific, and macroeconomic control variables.

Cash flow (CF): WC items, including inventories, AR, and AP, are susceptible to cash flow levels. In general, low cash flow affects WC negatively by decreasing its investment, whereas high cash flow allows firms to build up their WC to very high levels in anticipation of less favorable liquidity conditions and drained liquidity sources (Hovakimian and Hovakimian, 2009). Firms facing cash flow problems tend to decrease or even cut financing to clients to have more cash on hand; i.e., reduce AR (Molina and Preve, 2009). However, Moss and Stine (1993), Richards and Laughlin (1980), and Chiou et al. (2006) found that higher cash flow firms are characterized by better liquidity management (i.e., shortening DSO and DIH and extending DPO), which could lead to better financial performance. However, cash flow could be negatively correlated with AP, meaning that firms with low cash flows depend more on suppliers' credit, which reflects the role of trade credit in the financing of the firm (Deloof and Jegers, 1999). We compute the cash flow variable for firm *i* at time *t* as:

$$CF_{it}=100\times\frac{EBITDA_{it}}{Sales_{it}} \quad (6)$$

, where *EBITDA* stands for earnings before interest, taxes, depreciation, and amortization.[6]

Leverage: The variable *Leverage* is a proxy used to account for a firm's cost of capital. It captures the effect of debt financing on WC as it measures the cost of debt to equity. It is measured as the ratio of short- and long-term debt to total assets, and we compute it as:

[3] The first-differenced GMM estimator of Arellano and Bover (1995) suffers from bias and imprecision when the series are highly persistent or if the variance of the individual specific effect is large relative to the variance of the error (Blundell and Bond, 1998). Hence we use the system two-step GMM proposed by Blundell and Bond (1998) in our estimation.

[4] Our standard unit root tests show that the data is stationary. The Koa Residual Co-Integration test shows a long run association between the chosen variables, which further supports relying on dynamic panel models (Kao and Chiang, 2001). These results are available upon request.

[5] We use the std function in Stata, which standardizes the variables to have mean 0 and standard deviation 1.

[6] In other words, it is Revenues –COGS-all other operating expenses except for depreciation and amortization. We use EBITDA to measure product profit margins. Rumyantsev and Netessine (2007a, 2007b) used gross margin when investigating the factors that affect inventory turns. Even though other operating performance measures (such as gross profit) exist, EBITDA is more appropriate since gross margin only accounts for the cost of production as expenses. EBITDA measures a company's operational profitability and factors the essential expenses to run the business on a day-to-day basis. We normalize EBITDA by sales to mitigate the effect of write-ups of operating assets.

$$Leverage_{it} = 100 \times \frac{Debt\ \ in\ \ current\ \ Liabilities_{it} + long\ \ term\ \ debt_{it}}{Total\ \ Assets_{it}} \quad (7)$$

Leverage has an ambiguous effect on WC and its components. Firstly, under-levered firms can borrow to carry more inventory, while those that are over-levered tend to decrease inventories (Carpenter et al., 1994). Secondly, high leverage reduces the level of AR (Meltzer, 1960). Sopranzetti (1999) showed that firms with high levels of debt tend to choose to sell their AR as a source of funding when they have high-quality credit, instead of using debt for upcoming projects. However, the ability of a firm to borrow at a reasonable cost increases its ability to supply AR (Garcia-Teruel and Martinez-Solano, 2010). Thirdly, the effect of leverage on AP is not always noticeable, as these two financial sources could either be complementary or substitutes. Welch (2011) reported that firms with high leverage incur higher costs for their financial debt. They then tend to demand more financing from their suppliers, thus increasing their AP. However, a firm with low debt and access to short-term bank financing reduces its need for AP.

Sales growth (Growth): Sales growth measures the increase in demand for a firm's products, where changes impact a firm's WC and all its components. We measure the quarterly growth of firm i at time t as:

$$Growth_{it} = 100 \times \frac{(Sale_{it} - Sale_{it-1})}{Sale_{it-1}} \quad (8)$$

Carpenter and Miller (1979) suggested that if sales for a product increase, a company tends to extend credit to its customers, thus increasing its AR. Consequently, increasing sales by supplying trade credit to customers makes it necessary to have more investment in WC (Petersen and Rajan, 1997). Similarly, AP is positively associated with sales growth since high growth firms rely on external financing, especially trade payables, to finance their growth (Cunat, 2006). Although the relationship between growth and AP is prominent for large firms, the literature shows a negative one (Niskanen and Niskanen, 2000). One explanation is that higher sales generate more cash and, subsequently, there will be less need for short-term financing. Moreover, growth in sales could positively or negatively affect inventories. It could increase inventory levels to meet higher demand, or it could experience stock-outs if faster sales deplete inventory before a replenishment occurs.[7] Nevertheless, it would be surprising to see a negative effect of sales growth in WC and its components, if this growth increases the efficiency of WC management for the growing firms (Hogan and Hogan, 2011).

Fixed assets (FA): When firms operate under imperfect capital markets, a trade-off in capital occurs between investment in fixed assets and WC due to financial constraints (Fazzari and Petersen, 1993). Alternatively, a higher percentage of tangible assets allows a firm to be less opaque and more adept at accumulating funds at a lower cost (Baños-Caballero et al., 2010). Consequently, when firms increase their investments in fixed assets, different effects on WC would result. On the other hand, Rumyantsev and Netessine (2007b) and Gaur et al. (2005) found a negative relationship between the capital intensity of firms, which measures a firm's fixed assets, and its inventory level. We use the following fixed asset in our model:

$$FA_{it} = 100 \times \frac{Tangible\ \ Assets_{it}}{Total\ \ Assets_{it}} \quad (9)$$

Firm size (Size): The firm size, $Size_{it}$, is the natural logarithm of total assets. The literature shows a negative relationship between a firm's size and inventory levels (Rumyantsev and Netessine, 2007a). Deloof (2003) argued that larger firms have fewer inventories due to their size and sales growth, which means that as a firm's performance improves, it can build a larger and more stable customer base, hence leading to more consistent demand. Big firms, as already known, often have a larger pool of resources than smaller ones, which allows them to engage in practices that would reduce supply risk, such as managing inventory levels.

The literature also reported a mixed effect of size on AR, since well-established firms can finance their trade credit (Baños-Caballero et al., 2009) but have fewer investment opportunities (Niskanen and Niskanen, 2006). Large firms with a good business reputation also tend to receive favorable trade-credit options (Wu et al., 2019). Consequently, the literature found mixed results concerning the effect of size on WC. For instance, Moss and Stine (1993) and Eljelly (2004) found that larger firms could handle their WC more proficiently than smaller ones, while Kieschnick et al. (2006) found higher levels of WC in larger firms.

Profitability (ROA): Firms with higher profitability have an exceptional ability to obtain funds from external sources. These firms receive more credit from suppliers (Peura et al., 2017) and hold lower finished-goods inventories (Chen et al., 2005, 2007). Most importantly, firms with a high return on assets (ROA) can reduce their WC due to their market power. The literature shows that AR and a firm's profitability are negatively correlated. Deloof (2003) indicated that companies with lower profitability entice their customers by providing them with extended terms of payment. Also, Deloof (2003) counter-argued that firms with higher profits have more cash to lend to customers.

Similarly, the literature reported a negative association between profitability and inventory levels (Chen et al., 2007; Kesavan and Mani, 2013; Rumyantsev and Netessine, 2007a). Companies with less profitability would have high inventory levels as they might face a decrease in sales. This shortage of cash makes it difficult for non-profitable companies to pay their bills on time, thus delaying payments to suppliers and increasing their AP. We measure ROA as:

$$ROA_{it} = \frac{EBIT_{it}}{Total\ \ Assets_{it}} \quad (10)$$

Abnormal inventory (AbI): To control for the industry effect, we follow Chen et al. (2005) and include in our model the normalized deviation from the industry norm, to capture whether the firm has a lean ($AbI_{it} < 0$) or bloated inventory ($AbI_{it} > 0$) where:

$$AbI_{it} = \frac{DIH_{it} - Industry's\ \ DIH_t\ \ based\ \ on\ \ the\ \ three\ \ digit\ \ SIC}{Standard\ \ deviation\ \ of\ \ Industry's\ \ DIH_t} \quad (11)$$

There are many possible ways to control for the industry effect, but the alternative methods, including the elimination of the industry effect from the model, kept the results robust and consistent.

Macroeconomic Variables: We use the conventional macroeconomic variables used in the literature. Namely, we use the three-month risk-free rate ($3Mrate_t$), the quarterly inflation rate (Inf_t), and the quarterly growth of GDP ($GDPg_t$). We use the 3-Month Treasury Constant Maturity Rate [DGS3MO], and the growth of the real GDP series (GDPC1) that were both retrieved from FRED, Federal Reserve Bank of St. Louis. To compute the quarterly inflation rate, we use the quarterly change in the "Producer Price Index: All Commodities" retrieved from the Bureau of Labor Statistics at the U.S. Department of Labor. U.S. Bureau of Labor Statistics, Producer Price Index for All Commodities [PPIACO], retrieved from FRED, Federal Reserve Bank of St. Louis.

5. Data sample

In our investigation, we use a quarterly sample of manufacturing firms from Compustat for the period 1990 to 2018. We focus on manufacturing firms as they regularly practice trade credit, inventory, and WC management (e.g., Moussawi-Haidar et al., 2014; Li et al., 2019). We omit from our sample, firms with reported zero or missing values for sales, inventory, AR, AP, operating income, and cost of goods sold as these erroneous or missing variables prevent us from computing the variables needed for the model. Hence, we end up with a sample of

[7] We used sales growth instead of using the market to book ratio since market prices were missing for many firms in Compustat for a large number of firms, especially small and medium-sized ones.

230,575 firm observations.

Our data sample consists of 6503 manufacturing firms (SIC codes between 2000 and 3999). We receive EPU and MPU data from Baker et al. (2016) economic policy uncertainty website.[8] To mitigate the influence of outliers, we winsorize all firm-specific variables at the 1st and 99th percentiles.[9]

Table 1 represents the descriptive statistics of these firms, based on the variables as commonly mentioned in the inventory and WC literature. CCC and its components (DSO, DIH, and DPO) are measured in days while CF, Leverage, FA, forward-looking sales growth (Growth), ROA, 3Mrate, GDPg, and Inflation are measured using percentages. The range of CCC for firms stretches between −318.27 and 732.48 days with a mean of 115.97 days, which implies that manufacturing firms need around one-third of a year on average to turn cash to cash. Subsequently, it is feasible for many firms to operate with negative WC and CCC levels. Typically, they are large-scale manufacturing firms with extreme market power that allows them to dictate their terms to the suppliers. Some firms have very high DSO, DIH, and DPO, which shows that many firms may not have optimal WC levels. CF and ROA are severely negative for some firms with values as low as −1822% and −56%, respectively. On that account, these firms should be profoundly affected by high EPU and MPU levels. The sample includes firms with a high quarterly sales growth rate as high as 210%, while other firms show growth that runs low to reach a decline of around −68%. These descriptive statistics also show that some firms operate without leverage, whereas others have a debt-to-capital ratio as high as 187.5%[10]. The former is less sensitive to EPU and MPU because they are less affected by bank lending, while the latter tend to be highly sensitive to EPU and MPU levels. Finally, it appears that uncertainty about monetary policy over the sample years is greater than that of EPU with a higher standard deviation for the MPU index.

We use the annual data to investigate the effect of EPU and MPU on the different stages of inventory, as the quarterly Compustat datasets rarely have data about the raw material, work in progress, and finished goods inventories. We also report the annual descriptive statistics, retrieved from the same source, and that the descriptive statistics of this dataset as well, which conforms to the descriptive statistics of the quarterly data.

6. Results and managerial implications

We report in Tables 2–5 the effect of economic uncertainty on WC and its different components of the US manufacturing firms from 1990 to 2007 using the dynamic panel data regressions described in Eq. (1) and the standardized variables in section (4). The Z test of each variable is reported in a separate column. The symbols +, *, and ** denote statistical significance at the 10%, 5%, and 1%, respectively. We also report Hansen's J test and its p-value. In parentheses, we show the number of lags used for each variable as an instrument in our estimation.

6.1. Effect of EPU on WC

The results of Table 2 show a statistically significant effect of EPU on WC and its different components at 1% and 5% significance levels. Model 1 shows that the EPU lengthens the CCC (resulting in higher WC levels in the manufacturing sector) by 0.01 standard deviation for each one standard deviation increase in EPU. Even though these results are significant but not substantial as the effect of EPU on WC is small, they might still correspond to large absolute dollar-amounts. The decrease in customer demand necessitates an intervention from manufacturers to enhance sales and shift the inventory costs to customers. Models 2, 3, and 4 support this notion. The results also show that one of the contributing factors to the rise in WC is the growth of financing activities with both DSO and DPO increasing as a result of higher EPU levels. This finding suggests that manufacturers loosen their receivables and use their payables as a source of financing to boost their sales.

As predicted, DSO increases with EPU, as shown in Model 2 of Table 2, with a coefficient of 0.011 significant at the 1% level. This positive association between AR and EPU is due to many reasons. Firms undergoing financial distress tend to increase trade receivables with an attempt to gain market share and sales, as opposed to the assumption that financial problems cause firms to reduce trade receivables (Peura et al., 2017). This approach has one drawback. It entails high costs for firms in distress as they have limited access to financial credit. More importantly, during periods of high EPU, AR tends to increase as clients are not able to make prompt payments. By allowing more flexible terms, firms will enhance the relationship with distressed customers and improve sales (Chay and Suh, 2009).

During periods of uncertainty, we expect AP to increase because suppliers are obliged to give financially-constrained customers more flexible payment terms to stay competitive in the market. Suppliers may offer favorable trade credit options, hence encouraging manufacturing firms to purchase more and shift the storage costs to their side. Moreover, customers are likely to postpone payments of goods bought on credit because other sources of credit are scarce (Peura et al., 2017). The abovementioned expectations are well-supported, as there is a significant and positive relationship between EPU and AP, as shown in Model 4 of Table 2, with an EPU coefficient of 0.005 significant at the 5% level.

Another main contributor to the increase in WC levels when EPU increases is the accumulation of inventory. Firms face demand uncertainty due to adverse economic conditions associated with EPU. Model 3 shows that higher EPU levels in manufacturing firms increase inventory levels. A positive DIH implies slow sales. Besides, it suggests that without increasing their DSO, the impact of EPU could have been direr on the levels of sales.

Our control variables exhibit, in general, the right signs. These results indicate that all our firm-specific and macroeconomic variables determine WC. Our findings support the notion that cash flow and internally available funds extend the CCC by positively affecting AR (Molina and Preve, 2009). Similarly, our results show that cash flow also leads to higher inventory levels, which backs the view that high cash flow allows firms to build up their WC in anticipation of less favorable liquidity conditions (Hovakimian and Hovakimian, 2009). On the other hand, our results show a negative impact of cash flow on AP, which supports the notion that better-managed firms with a high cash flow tend to decrease their AP (Richards and Laughlin, 1980; Moss and Stine, 1993; Chiou et al., 2006). Table 2 shows that the overall effect of leverage on WC is negative. It also affects AP as higher leverage encourages firms to resort to AP as a complementary source of funding (Welch, 2011). On the other hand, higher leverage impairs the ability of firms to borrow to accumulate more inventory (Carpenter et al., 1994). Also, the results show that sales growth bears a negative impact on WC. An increase in sales was found to make short-term financing less appealing to firms, due to the increased availability of cash generated by those sales (Niskanen and Niskanen, 2000), and also due to high growth firms becoming more efficient in managing their WC (Hogan and Hogan, 2011).

We found that larger firms have more ability to finance their trade credit (Baños-Caballero et al., 2009) and receive more favorable trade-credit options (Wu et al., 2019), with an overall positive effect on WC (Kieschnick et al., 2006). Also, our results indicate a substitution effect between investment in fixed assets and WC due to financial constraints (Fazzari and Petersen, 1993). We also found that ROA is

[8] Downloadable from http://www.policyuncertainty.com/.

[9] Before winsorizing the data, we have investigated the presence of outliers by analyzing observations that are more than four standard deviations away from the mean. Our investigations have revealed the need to winsorize the data to mitigate the influence of outliers on our analysis.

[10] Firms with debt and negative equity end up with a leverage ratio greater than 1.

Table 2
The effect of EPU on WC components from 1990 to 2018.

	Model 1		Model 2		Model 3		Model 4	
	CCC	Z	DSO	Z	DIH	Z	DPO	Z
CCC(-1)	0.610** (-1)	12.24			–	–		
DSO(-1)	–	–	0.587** (-1)	12.16	–	–		
DIH(-1)	–				0.601** (-1)	9.42		
DPO(-1)	–						0.727** (-1)	15.12
EPU	0.010** (-1)	2.71	0.011** (-1)	3.59	0.008* (-1)	2.34	0.005* (-1)	2.33
CF	0.470** (-2)	3.73	0.181** (-2)	2.30	0.244** (-2)	2.83	−0.167** (-1)	−4.84
Leverage	−0.269** (-1)	−6.62	−0.410* (-1)	−2.00	−0.187** (-1)	−4.85	0.062* (-1)	2.44
Growth	−0.068** (-1)	−3.34	−0.125* (-2)	−2.30	−0.042** (-1)	−2.65	−0.032* (-1)	−2.22
FA	−0.097** (-2)	−2.61	0.095** (-1)	3.07	−0.073* (-2)	−2.14	−0.011 (-2)	−0.55
Size	0.524** (-1)	3.24	0.372** (-4)	5.55	0.155 (-1)	0.89	0.253** (-4)	3.02
ROA	−0.697** (-4)	−6.10	0.001 (-1)	0.00	−0.547** (-4)	−5.00	−0.185** (-2)	−2.94
AbI	−0.131* (-2)	−2.52	−0.193** (-1)	−4.90	−0.052** (-2)	−3.07	0.004 (-2)	0.07
3Mrate	0.109* (-2)	2.38	0.175** (-1)	5.68	0.059 (-2)	1.36	0.121** (-1)	3.81
GDPg	0.319** (-2)	3.63	0.077* (-1)	2.11	0.171+ (-1)	1.92	0.049 (-1)	0.83
Inf	−0.003* (-2)	−2.46	0.037** (-1)	6.89	−0.010+ (-2)	−1.89	0.013* (-1)	2.34
Quarterly Time Trend Dummy	Yes		Yes		Yes		Yes	
Observations	230,575		230,575		230,575		230,575	
N of firms	6503		6503		6503		6503	
Hansen's P-value	0.270		0.528		0.604		0.854	

negatively associated with WC, which indicates that highly profitable firms have a lesser need to offer AR and that they tend to hold inventory while benefiting from suppliers' financing.

Notably, the coefficients of our industry and macro-level variables show interesting results. Firms with high levels of inventory to the sector norm (AbI $>$ 0) become aggressive in lowering those levels. These firms, realizing that they have bloated inventory levels, could offer incentives to customers to take on large orders, causing high inventory levels and longer time to deplete them, increasing the carrying costs (Lazaridis and Tryfonidis, 2006). Another way to lowering inventory levels is to implement efficiency initiatives designed to reduce overall waste and streamline supply chain management (Chen et al., 2005). Firms can reduce the days of inventory, when initially bloated, by contacting designated buyers to garner interest in their products, thereby raising overall demand and lowering initially high inventory levels, thus shortening the inventory cycle (Şen, 2008).

Interestingly, higher interest rates affect WC and inventory positively. Theoretically, the relationship between interest rates and inventory is well established since higher interest rates imply higher carrying costs, which is an opportunity loss of not investing the money elsewhere with a higher return. Nevertheless, Maccini et al. (2007) explained the puzzle of contradiction between empirical findings and theory, by claiming that firms tend to hold more inventory to buffer demand shocks in higher interest rates resulting from contractionary monetary policies. Also, the bank lending channel theory posits that banks tend to offer fewer loans in a contractionary environment. Hence, our results support the notion of a substitution effect between trade credit and bank credit as the impact of higher interest rates is positive on AR. Finally, we find that GDP growth positively impacts the WC, while inflation negatively.

6.2. *Effect of EPU on finished inventory, work-in-process, and raw material*

An implicit assumption common to inventory models discussed in the inventory literature is the continuous availability of supply. However, the random supply disruption of products severely affects a firm's operations. The automobile and semi-conductor manufacturing industries provide examples of the negative impact of uncertain economic conditions on the supply chain's operations (Groenevelt et al., 1992; Moinzadeh and Aggarwal, 1997; Chelbi and Ait-Kadi, 2004). Supply disruptions are even more severe for manufacturers operating just-in-time systems (Parlar, 1997; Snyder et al., 2016), which require specified quantities delivered at specified times.

Supply interruptions resulting from high EPU can produce adverse effects on the production/inventory system of manufacturers (Parlar, 1997). There is a consensus among practitioners and researchers that just-in-time systems, which are a tight lean design, require stable economic conditions to operate, and will fail when the conditions become uncertain or unpredictable. We show in this paper that manufacturing organizations tend to raise the various types of inventory levels as a way to alleviate the impact of uncertain economic conditions.

Next, we expand our analysis to cover the effect of EPU on different inventory types, raw material, work-in-process, and finished inventory. The purpose of doing so is to support the second hypothesis (H2) that high inventory levels of raw materials and finished goods result from high economic uncertainty. To do so requires annualizing all the variables in Eq. (1) since the information about inventory types is available

Table 3
The effect of EPU on types of inventory from 1990 to 2018.

	Model 1		Model 2		Model 3		Model 4	
	Invt	Z	Invfg	Z	Invwip		Invrm	Z
Invt(-1)	0.970** (-1)	102.7					–	–
Invfg (-1)	–	–	0.958** (-1)	72.43			–	–
Invwip (-1)	–				0.943** (-1)	43.91		
Invrm (-1)	–						0.060** (-1)	100.16
EPU	0.025** (-1)	2.83	0.023* (-1)	2.11	0.029+ (-1)	1.72	0.033** (-1)	2.56
CF	0.005* (-1)	2.47	0.017* (-1)	2.27	0.030 (-3)	1.30	0.001 (-1)	0.85
Leverage	−0.005** (-1)	−3.28	−0.008** (-1)	−3.55	−0.004 (-1)	−1.49	−0.002 (-1)	−0.90
Growth	0.042** (-2)	1.24	0.053 (-2)	0.82	0.123 (-2)	1.08	0.003 (-1)	0.94
FA	−0.005+ (-1)	−1.95	−0.005 (-1)	−1.20	−0.011+ (-1)	−1.90	0.004 (-1)	1.15
Size	0.023** (-1)	5.37	0.032** (-1)	5.35	0.031* (-1)	2.43	0.018** (-1)	3.67
ROA	−0.003** (-1)	−0.99	−0.005 (-1)	−0.70	−0.011 (-1)	−1.11	0.006** (-1)	3.41
AbI	−0.001 (-1)	−0.35	0.006 (-1)	1.31	−0.001 (-1)	−0.01	0.01** (-1)	5.14
3Mrate	0.013 (-1)	0.79	0.002 (-1)	0.10	−0.005 (-1)	−0.17	−0.008 (-1)	−0.37
GDPg	0.007* (-1)	2.44	0.005 (-1)	1.22	0.003 (-1)	0.69	0.008+ (-1)	1.84
Inf	−0.009* (-1)	−2.34	−0.009+ (-1)	−1.89	−0.012+ (-1)	−1.73	−0.007 (-1)	−1.33
Quarterly Time Trend Dummy	Yes		Yes		Yes		Yes	
Observations	50,456		41,988		40,691		42,312	
N of firms	5909		5222		5102		5241	
Hansen's P-value	0.563		0.376		0.205		0.313	

only through the annual Compustat database. Note that the definition of the dependent variable differs from the one used in the primary model. Across the four models in this section, we define, respectively, Invt as the natural logarithm, of the standardized total inventory, Invfg as finished goods inventory, Invwip as work-in-progress inventory, and Invrm as raw materials inventory. Unlike model 1, we were unable to use inventory components in days since we do not know the portion of COGS that belongs to each type of inventory. As expected, our results support that manufacturers hold additional raw materials to manage the costs of external supply, as it is an insurance against supply risk with an EPU coefficient of 0.033 significant at the 1% level.

On the other hand, finished goods reflect the firm's relationships with its customers. An increase in EPU increases the inventory of finished goods, with a coefficient of 0.023 and a 5% significance. Our results also show that work-in-progress increases with higher EPU levels with a 10% significance level, implying the accumulation of semi-finished inventory in periods of high uncertainty, which reduces the efficiency of the manufacturer and the supply chain at large. This would result in higher inventory costs. During periods of high uncertainty, manufacturers tend to increase work-in-progress in the hopes of satisfying customer demand and hedging against increased demand uncertainties (Jung et al., 2004). Moreover, when demand is uncertain, manufacturers keep more work-in-progress and less finished product inventories as it is cheaper to hold (Yang et al., 2004).

6.3. Robustness checks

Given that firms are sensitive to financial constraints, we use another newspaper-based index related to MPU, an approach brought forward by Baker et al. (2016) to check for robustness. The MPU index is a subcategory of the EPU index that exclusively captures the uncertainty about Federal Reserve policy actions.

MPU has been the subject of intense debate in the U.S., with many policymakers and researchers expressing their concerns about its negative impact on the economy. Both the Federal Open Market Committee (FOMC) in 2009 and the International Monetary Fund (IMF, 2012; 2013) brought forward the uncertainty of fiscal and monetary policies, and consider MPU's contribution to the economic decline in the 2007–2009 subprime crisis and the slow economic recoveries. However, policymakers worldwide gradually became aware of the economic benefits of monetary policy transparency. They also became less cryptic, and communicate more openly to focus on managing short and long-term market expectations through noise reduction (lowering market uncertainty) and news creation (moving short-term interest rates in the desired direction). Many policymakers acknowledge that MPU negatively affects the economy. An important research question, however, remains: how much of an effect MPU has on WC given that it impacts bank lending channels? The current research supports the existence of a bank lending channel of monetary policy in the U.S. (e.g., Kashyap and Stein, 2000). This policy transmission channel posits that a change in the monetary policy may influence a bank's supply of loans. The rationale behind it is that the changes in interest rates alter the number of loanable funds and adjust the cost of funding. Therefore, in this paper, we expect MPU to affect the financing components of WC as a result of the cost of loans and firm liquidity constraints.

We test the effect of uncertainty on WC as we did in the previous section, but we use MPU instead of EPU while keeping the same model specifications as those of Eq.(1)

Table 4
The effect of MPU on WC components from 1990 to 2018.

	Model 1		Model 2		Model 3		Model 4	
	CCC	Z	DSO	Z	DIH	Z	DPO	Z
CCC(-1)	0.634** (-1)	13.09			–	–		
DSO(-1)	–	–	0.553** (-1)	12.64	–	–		
DIH(-1)	–				0.614** (-1)	9.76		
DPO(-1)	–						0.727** (-1)	15.08
MPU	0.010** (-1)	3.07	0.006** (-1)	3.09	0.007** (-1)	2.66	0.004* (-1)	2.14
CF	0.397** (-2)	4.25	−0.650** (-2)	−3.55	0.276** (-2)	3.27	−0.168** (-1)	−4.90
Leverage	−0.235** (-1)	−6.43	−0.040+ (-1)	−1.87	−0.200** (-1)	−5.61	0.059* (-1)	2.30
Growth	−0.071** (-1)	−3.99	−0.115* (-2)	−2.42	−0.042** (-1)	−2.61	−0.034* (-1)	−2.24
FA	−0.114** (-2)	−3.19	0.090** (-1)	2.83	−0.077* (-2)	−2.29	−0.012 (-2)	−0.64
Size	0.272+ (-1)	1.75	0.341** (-4)	5.33	0.223 (-1)	1.45	0.240** (-4)	2.82
ROA	−0.555** (-4)	−5.58	0.054 (-1)	0.76	−0.592** (-4)	−5.92	−0.185** (-2)	−2.86
AbI	−0.120* (-2)	−2.25	−0.175** (-1)	−4.49	−0.048 (-2)	−1.11	0.004 (-2)	0.08
3Mrate	0.048+ (-1)	1.65	0.164** (-1)	5.29	0.056 (-2)	1.32	0.110** (-1)	3.55
GDPg	0.239** (-1)	2.94	0.081* (-1)	2.30	0.217** (-1)	2.75	0.052 (-1)	0.88
Inf	−0.013** (-2)	−2.72	0.030** (-1)	6.20	−0.011* (-2)	−2.26	0.012* (-1)	2.34
Quarterly Time Trend Dummies	Yes		Yes		Yes		Yes	
Observations	230,575		230,575		230,575		230,575	
N of firms	6503		6503		6503		6503	
Hansen's P-value	0.124		0.963		0.604		0.593	

$$Y_{i,t} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 MPU_t + \beta_3 CF_{i,t} + \beta_4 Leverage_{i,t} + \beta_5 Growth_{i,t+1} + \beta_6 FA_{i,t} + \beta_7 Size_{i,t} + \beta_8 ROA_{i,t} + \beta_9 AbI_{i,t} + \beta_{10} 3Mrate_t + + \beta_{11} GDPg_t + \beta_{12} Inf_t + \delta_t Time_t + \varepsilon_{i,t} \quad (12)$$

In Table 4, we report the results of our regression models, which confirm the findings in Table 2. It is noteworthy that the sign of CF flips in model 2. We interpret this flip in sign as an indicator for omitted variables, since excluding some uncertainties that EPU encompasses, such as fiscal policy, government spending, and unstable trade could be critical determinants of WC. We found that higher MPU levels lead to higher CCC and trade credit activities in the economy and cause inventory to pile up. However, we found that the effect of MPU on CCC was lower than EPU in models 2 to 4 because MPU captures a portion of the total uncertainty, mainly the one that affects market interest rates in the economy, hence making WC more sensitive to EPU than MPU. Thus, our results show how WC is sensitive to uncertainty related to interest rates in the economy. The coefficients of all other variables confirm the findings of the previous sections. The MPU coefficients are, generally, statistically significant at the 1% level, yet they are small, indicating significant, but not substantial effects. This finding also shows that this type of uncertainty affects mainly trade-credit and inventory activities. A DSO coefficient higher than that of DPO implies that manufacturers encounter uncertainty financing their customers' purchases, not necessarily through their AP, by offering them trade credits. This financial support could be because, with higher uncertainty, banks are likely to offer fewer loans (Bordo et al., 2016). As proceeded, the reason could also be simply that higher MPU lowers the demand for the manufacturer's products, which motivates them to give financial incentives to boost their sales. On the other hand, higher DIH implies that higher MPU lowers the demands for a firm's products leading to higher inventory levels.

We also report the results of a subsample from 1990 to 2007, which excludes periods of extreme uncertainty, e.g., the stock market crash in 1987 and the subprime crises in 2008.[11] Similar to the main findings, the presented results reveal that EPU not only affects the CCC but also influences each of its major operational components. We present the estimation of our regression equation above using an alternative proxy for EPU, the MPU index, to confirm the robustness of our results.

7. Conclusion

Supply chain management research has always focused on the control and management of inventory, whereby many papers worked on identifying the factors that motivate changes in the inventory levels of retailers. The literature has paid recently closer attention to the inclusion of the AR and AP components of WC in empirical studies. None of the studies in the literature had addressed the effect that macroeconomic uncertainty risk bears on WC management. This study has linked the operational and financial performances of a firm to its WC management and has analyzed the impact of macroeconomic uncertainty on WC. The results of our study have shown that the relationship between

[11] We also compute the results for the entire sample without the financial crisis period starting from the third quarter of the year 2007 until the last quarter of the year 2009. The results are very similar to the original results for the entire sample years. We do not report these results due to space-related issues. These results are available upon request.

Table 5
The effect of EPU on WC components from 1990 to 2007.

	Model 1		Model 2		Model 3		Model 4	
	CCC	Z	DSO	Z	DIH	Z	DPO	Z
CCC(-1)	0.601** (-1)	13.04			–	–		
DSO(-1)	–	–	0.274** (-1)	3.71	–	–		
DIH(-1)	–				0.511** (-1)	7.93		
DPO(-1)	–						0.815** (-1)	2.61
EPU	0.013** (-1)	3.38	0.013** (-1)	2.69	0.011* (-1)	2.33	0.029* (-1)	2.56
CF	0.524** (-2)	3.57	2.003* (-1)	2.54	0.122 (-2)	1.35	−2.083+ (-2)	−1.76
Leverage	−0.222** (-1)	−6.18	−0.045 (-1)	−1.05	−0.183** (-1)	−3.89	0.277** (-1)	2.71
Growth	−0.068* (-1)	−1.99	−0.063 (-2)	−0.24	−0.044+ (-1)	−1.69	−0.263 (-2)	−0.64
FA	−0.127** (-2)	−3.45	0.113** (-1)	3.33	−0.051 (-2)	−1.41	−0.14 (-4)	−1.20
Size	0.061 (-1)	0.60	0.580** (-4)	6.26	0.04 (-1)	0.21	1.683** (-1)	4.15
ROA	−0.474** (-4)	−5.31	0.474* (-1)	1.99	−0.508** (-4)	−4.24	0.657 (-1)	1.51
AbI	−0.079* (-1)	−2.13	−0.121** (-1)	−2.56	−0.051 (-2)	−1.11	−0.771 (-1)	−1.74
3Mrate	0.094* (-2)	2.20	0.123** (-1)	3.41	0.056 (-2)	1.29	0.015 (-1)	0.15
GDPg	0.069+ (-2)	1.96	0.091* (-1)	2.30	0.112* (-1)	2.16	−0.01 (-1)	−0.09
Inf	−0.014** (-1)	−2.67	0.015** (-1)	2.85	−0.014 (-2)	−1.60	0.007 (-1)	0.66
Quarterly Time Trend Dummy	Yes		Yes		Yes		Yes	
Observations	158,463		158,463		158,463		158,463	
N of firms	5638		5638		5638		5638	
Hansen's P-value			0.229		0.315		0.342	

uncertainty and WC investment depends not only on the strength of a firm's business performance, but also on its business characteristics, and to which industry it belonged. It was found that macroeconomic uncertainty increases WC and inventory levels, hence providing empirical evidence that higher demand uncertainty raises safety stock levels.

The EPU index, and sample data from 6503 U.S. manufacturing firms, were used to investigate the impact of economic uncertainty on WC and inventory levels. The findings suggested that companies need more capital to finance additional investments in WC. Specifically, they showed that EPU affects all the components of WC, by requiring more AR commitments from firms to mitigate the effect of EPU on their customers and sales levels, which leads manufacturing firms to rely more on AP financing. Finally, to test for robustness, a subsample was selected, and an MPU index was used to heighten the sensitivity of WC to monetary policy-related uncertainty. The EPU results were found to be robust, hence suggesting that WC decisions depend on the assessments and degree of uncertainty.

The results also showed that the WC is correlated with a firm's specific variables and macro variables. The results corroborated the findings in the literature that inventory performance is correlated with cash flow, fixed assets, sales growth, and return of assets (Gaur et al., 2005; Chen et al., 2007; Kesavan et al., 2016). The effect of sales growth on inventory level was found to be positive, hence indicating that firms expecting high sales growth tend to keep a large amount of inventory on hand to cope with the anticipated growth, which contradicts the results of Gaur and Kesavan (2015). It was also found that cash flow, which is a proxy for product margin, has a positive impact on inventory levels, hence indicating that firms tend to keep more inventory when product margins are high to avoid stock-out costs. One limitation of this paper is that inventory components are observed only on an annual basis. The EPU dollar economic impact on the production process was not observed because the available data was incomplete, so despite the low coefficients that EPU values exhibit throughout this paper, the delay in CCC even for few days could cost the economy billions of dollars. Hence, this paper provided a robust theoretical relationship between uncertainty and WC and its components. Our robust and statistically significant results clearly show that higher EPU affects WC, and its components, in a direction more harmful to the operating and financial performance of firms.

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