Weather Shocks and Supply Chains

Abstract: We explore the impact of anomalous weather variations in exporting countries on supply chains in importing countries. Focussing on how changes in firms' margins at different stages of supply chains are related, our theoretical framework shows that changes in margins can vary: in principle, they can change in different directions and increases and decreases in margins can co-exist. We derive anomalous temperature and precipitation measures for banana exporting countries as the source of the exogenous shock impacting on supply chains in four importing countries. Applying cumulative local projections impulse responses, our results indicate considerable variation in how margins in supply chains change. The significance of our results highlights that single-stage analysis of food and agricultural markets ignores potentially important distributional impacts within supply chains and uncovers the role of competition within and between stages of supply chains as being more complex than single-stage perspectives.

Keywords: Supply Chains; Competition; Anomalous Weather

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Introduction

When markets are imperfectly competitive, how firms' margins adjust is the key mechanism via which exogenous shocks impact on consumers, retailers, intermediaries and producers. While there is both a theoretical and empirical basis underpinning this mechanism (see, for example, Weyl and Fabinger (2013) and De Loecker *et al.* (2016)), the focus has mainly been on 'single stage' effects thus ignoring the multi-stage features of supply chains which may be characterised by imperfect competition at each stage. As such, the adjustment of firms' margins to exogenous shocks may vary across different stages in supply chains and therefore reflect wider distributional impacts that will not be obvious with the focus on 'single stage' characterisations of firms' adjustments. With the exception of Melo *et al.* (2021), the distributional impact of shocks within supply chains has received little attention. In a similar vein, Cavallo *et al.* (2021) note: "…a more complete understanding of the full supply chain from 'at-the-dock' importers through to final retailers, is required to understand the full implications of any trade policy". Our focus on how margins adjust at different stages in supply chains is particularly pertinent when firms at one stage behave less competitively than firms at another and where the impact of firms' margin adjustments at one stage influences firms' margins at a related stage in the supply chain.

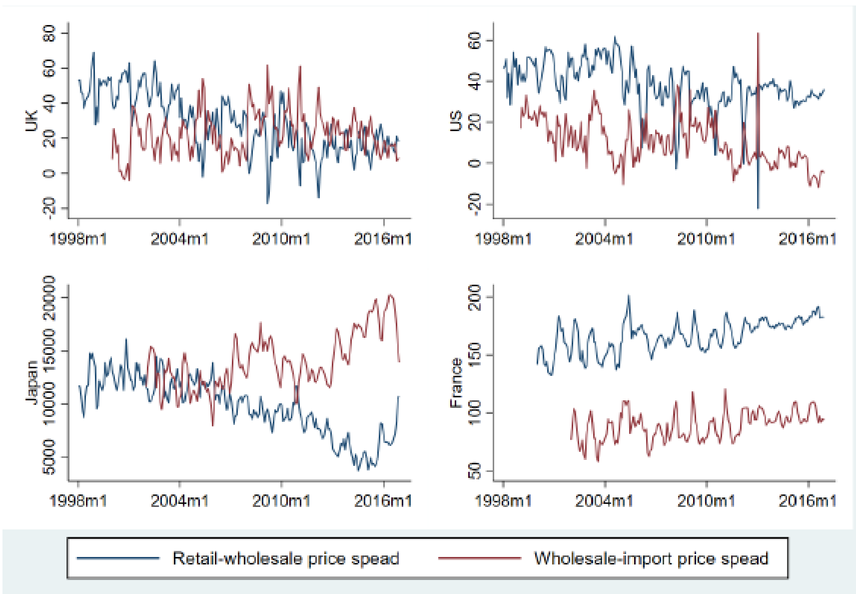
In this paper, we explore ~~focus on~~ the extent to which margins change in multi-stage supply chains in importing countries due to anomalous variations in weather in export countries[1]. We present a model of successive oligopoly where competition at one stage impacts on competition at another; hence the adjustment of margins will be contingent on changes in margins at related stages. Moreover, in the face of a common exogenous shock~~s~~, changes in margins at successive stages can be positive or negative under certain conditions and can also vary between stages.

The data we apply this framework to relates to banana supply chains in four developed countries (the UK, the US, France and Japan) where we have data for prices at different stages and where we can control for other factors that may influence margin adjustment in supply chains. Despite the simplicity of the product (bananas do not undergo processing), banana supply chains are potentially complex from procurement in export countries through to retailing with various intermediaries and retail chains involved (including multinational firms, small scale wholesalers and potentially dominant retail chains). One of the advantages of covering supply chains across four countries, is that ~~they~~ national chains differ; most notably at the retail stage where retail chains are particularly dominant in the UK and US, but ~~where they are~~ less so ~~dominant~~ in Japan. The data we employ allows us to circumvent the issue of export (contract) prices in supplying countries: our data for each of the supply chains relate to country-specific import prices, wholesale and retail prices. Figure 1 below highlights the changes in retail-wholesale and wholesale-import prices across each of the four countries. Given the differences in the behaviour of these margins across each of the four countries, our focus is to determine how competition potentially impacts on the changes in these margins in face of exogenous shocks.

[1] We refer to 'margins' in supply chains as distinct from 'spreads' that are more commonly used in the agricultural economics literature to acknowledge that, when there is the possibility of imperfect competition, there are also potential mark-ups over marginal costs.

A key innovation of the paper is the characterisation of the exogenous shock pertinent to each supply chain: we create measures of anomalous variation in temperature and precipitation based on highly-gridded data for specific exporting countries that supply to each of the four importing countries. We apply a local projections approach that allows us to generate cumulative impulse response functions for each stage in each of the four banana supply chains while controlling for other factors. This method is more flexible than standard VAR-related impulse response functions. We derive local projection impulse response functions for retailing-wholesale and wholesale-import margins in each of the four countries. Our results show substantial variation in margin responses across both stages in supply chains and across countries. Specifically, in the case of the UK, changes in margins at different stages go in opposite directions; for the US, only the retail margin changes; for France, only the wholesale margin changes and; in the case of Japan,the changes in both margins are negative.

Figure 1: Changes in Supply Chain Margins (1998-2017)



The paper is organised as follows. In Section 1, we (briefly) refer to the related literature. We outline the model of margin adjustment in a multi-stage supply chain setting in Section 2. We detail the derivation of the anomalous weather measures that represent the exogenous shocks for each of the supply chains in Section 3. The specification of the local projections approach is outlined in Section 4 and in Section 5 we present the main results. Concluding comments and on-going extensions are presented in Section 6.

1. Related Literature

We refer (briefly) to the literature which the analysis presented here relates. Our approach refers to several distinct strands in the literature on price transmission and competition and to recent literature on the economic consequences of extreme weather.

With reference to the issue of price transmission, there is a long history of measuring the pass-through of price shocks on world markets or farm level price changes to changes in consumer prices. Lloyd (2018) provides a comprehensive review. From the perspective of the approach we outline here, there are three issues that have not been fully addressed in this extant literature. First, most empirical studies do not identify the underlying mechanism that ties price transmission to the role of competition in determining pass-through. As summarised in Weyl and Fabinger (2013) it is the elasticity of firms' mark-ups in face of exogenous shocks which acts as the mechanism through which competition affects prices. Contingent on the characteristics of the demand function, the role of the mark-up elasticity may result in under-shifting (less than perfect price transmission) or over-shifting (price transmission exceeding the extent of the exogenous shock). However, less is known about how the elasticity of the mark-up at one stage influences mark-ups elsewhere in the supply chain, and the role it plays in price transmission. This also matters for determining the distributional impact of exogenous shocks within supply This also matters for determining the distributional impact of exogenous shocks within supply chains: do retailers' margins vary more or less than margins for intermediate firms? Note that, if both stages were competitive, the changes in mark-ups would be constant and price transmission perfect. More generally, the recent literature on global supply chains focuses on the transmission of shocks and the implications for firms participating in supply chains, rather than . . . . ???.

Commented [TL1]: . . .the distributional impacts within the supply chain (?)

Second, most price transmission studies are deficient in determining the exogenous shock. In the context of supply chains, the exogenous shock will determine price changes at all stages (as opposed to imposing an ordering via which upstream price changes precede price changes at the retail stage). With our measure of weather anomalies, the source of the changes in margins at all stages of the supply chain are truly exogenous.

Finally, there is a recent literature on the impact of extreme weather on economic activity. Dell *et al.* (2012, 2014) provided an early review of these issues. More recently, there have been studies on the impact of extreme weather associated with fluctuations in the *El Niño* Southern Oscillation (ENSO) on consumer prices and inflation (e.g. Cashin *et al*., 2017). Cashin *et al.* (2017) also evaluate the impact of ENSO on non-oil commodity and oil prices. Ubilava (2017) focusses on the impact of ENSO on a wide range of commodity market prices while Guittarez (2018) assesses the impact of ENSO on wheat exporting countries. However, the use of ENSO does not measure directly the extreme weather events that arise in specific locations; while ENSO is a relatively accessible measure of extreme weather variation, it is not sufficiently accurate to measure weather anomalies that arise in specific locations and which are specific to the growing conditions of specific commodities.

2. Theoretical Framework

Assumptions

We outline a model of successive oligopoly where there is market power at each stage of the supply chain that is allowed to differ across stages. For simplicity we assume Cournot behaviour at each stage and no buyer power between stages; that would require a different set-up but importantly the approach allows the extent of market power at one stage to impact on the related stage. Vertical aspects of competition are embedded in the framework since the derivation of the inverse derived demand function facing intermediary firms will be determined by the extent of competition at the retail stage. The downstream firms take the wholesale price as given but the price levels at the intermediary stage are contingent on competition at this stage. The technology linking stages is Leontief (i.e. fixed proportions); in our case (i.e. where the supply chains relate to the procurement and distribution of bananas), this is a reasonable assumption.

There are two alternatives to capturing competition at each stage in this set-up. Assuming Cournot behaviour, one is through the number of firms. The other is through a competitiveness parameter which captures a range of competitive outcomes. The latter is more general and allows us to deal with the aggregation issue across all firms at each stage in a more general way. Specifically, from the first order conditions, we will have:

$$q_i p'(Q) = q_i p'(Q)\left[\frac{\delta q_i}{\delta q_i} + \frac{\delta Q_{-i}}{\delta q_i}\right]$$
$$= q_i p'(Q)\theta_i$$

which, when aggregated over *n*-symmetric firms, gives:

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$$Qp'(Q)\theta$$

where θ=θ_i/n. If the stage was competitive, then $\theta = 0$; if Cournot, $\theta = 1/n$; if monopoly, $\theta = 1$.

Framework

Firms in the upstream stage choose quantities, this determines the upstream price (in our case, the wholesale price, p_w, that the downstream firms take as given. With Leontief technology, ($Q^R = Q^w$), retail prices can be determined. We start the framework backwards, by defining profit maximisation at the retail stage and then working at the wholesale stage. Since $Q^R = Q^w$, we use Q throughout. For ease, we use superscript/subscript '*w*' for the wholesale stage only with no corresponding superscripts for the retail stage.

Downstream Stage

Profit for a representative retail firm is given by:

$$\pi_i = (p(Q) - p_w)q_i \tag{1}$$

$$\frac{\delta \pi_i}{\delta q_i} = p(Q) - p_w + p'(Q)q_i\theta_i = 0 \tag{2}$$

After aggregating, gives:

$$p(Q) - p_w + p'(Q)Q\ \theta=0 \tag{3}$$

Totally differentiating with respect to p_w gives:

$$p'(Q)\frac{dQ}{dp_w} - 1 + \theta p'(Q)\frac{dQ}{dp_w} + Qp''(Q)\theta\frac{dQ}{dp_w} \quad (4)$$

So,

$$\frac{dQ}{dp_w} = \frac{1}{p\prime(Q)(1+\theta)+Qp\prime\prime(Q)\theta} \quad (5)$$

The change in the retail price with respect to the wholesale price will be given as:

$$\frac{dp}{dp_w} = p'\frac{dQ}{dp_w} \quad (6)$$

So:

$$\frac{dp}{dp_w} = \frac{p\prime}{p\prime(Q)(1+\theta)+Qp\prime\prime(Q)\theta} \quad (7)$$

Dividing through by *p'*:

$$\frac{dp}{dp_w} = \frac{1}{(1+\theta)+Q(p\prime\prime(Q)/p\prime(Q))\theta} \quad (8)$$

The term $(p''(Q)/p'(Q)$ captures the convexity of the demand function and it is this which gives rise to over-shifting. It is the ***elasticity*** of the slope of the perceived inverse demand function and measures how the slope of the inverse demand function changes. If we have linear demand, $p''(Q) = 0$. If we have monopoly:

$$\frac{dp}{dp_w} = \frac{1}{2+Q(p\prime\prime(Q)/p\prime(Q))} \quad (9)$$

If the demand function is 'sufficiently' convex (the absolute value of $p''(Q)/p'(Q) < -1$), then we would have 'over-shifting'. If we have linear demand and monopoly, pass-through is =1/2 which is what we would expect.

Going back to (8) above, when competition increases, pass-through increases providing the demand function is not too convex. But note that if the demand function was very convex, greater competition increases the possibility of over-shifting. In other words, when we allow for convexity, the effect of competition on pass-through is ambiguous. This differs from standard presumptions about competition; by presuming that competition increases pass-through, we are implicitly presuming that the demand function is not sufficiently convex.

Wholesale Stage

We follow much the same procedure as above but with some amendments. As before, we capture competition at the wholesale stage by the competitiveness parameter which is now given by:

$$\theta^w = \frac{\theta_i^w}{n^w} \quad (10)$$

We assume that upstream firms take the import price (the only cost to wholesale firms), p_m, as given.

The inverse demand function facing wholesale firms is given from (3) above; this is the *inverse derived demand* function (later on, we allow for terms of trade effects *i.e.* changes in the level of imports can impact on the import price).

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$$p_w = p(Q) + p'(Q)Q\,\theta \tag{11}$$

Note that because of the inclusion of θ, the derived demand facing wholesale firms depends on the extent of competition at the retail stage and will determine the slope of the derived demand function. As competition gets less intense, the inverse derived demand function becomes steeper since $p'(Q) < 0$.

Profits for a representative wholesale firm is given by:

$$\pi_i^w = (p_w(Q) - p_m)q_i^w \tag{12}$$

Maximising profits and aggregating gives:

$$p_w(Q) - p_m + p_w'(Q)Q\theta^w \tag{13}$$

Following the same approach as above (totally differentiate with respect to p_m) and rearranging gives:

$$\frac{dQ^w}{dp_m} = \frac{1}{p_w'(Q)(1+\theta^w) + p_w''(Q)Q\theta^w} \tag{14}$$

Pass-through at the wholesale stage is given by:

$$\frac{dp_w}{dp_m} = p_w' \frac{dQ^w}{dp_m} \tag{15}$$

This will give:

$$\frac{dp_w}{dp_m} = \frac{1}{(1+\theta^w) + \frac{p_w''(Q)Q\theta^w}{p_w'(Q)}} \tag{16}$$

The term $\left[\frac{p_w''(Q)Q\theta^w}{p_w'(Q)}\right]$ is the ***elasticity of the slope*** of the inverse derived demand function and will determine the possibility of over-shifting at the wholesale stage. We also allow for the possibility that, in a large country context, the impact of anomalous weather on quantities will change not only domestic (wholesale) prices but also-through a terms of trade effect associated with a large country case, it will change the import price. This is given by the term $\frac{p_m''(Q)}{p_w'(Q)}$.

Commented [TL2]: Does this need a little re-wording? Presumably anomalous weather affects import prices via reducing quantity on world markets anyway (so the large country effect is to some extent offsets the weather effect.

Changes in Supply Chain Margins

Our primary focus relates to how margins at different stages of the supply chain change in response to an exogenous shock where these margins can change simultaneously and where competition at one stage of the supply chain impacts on another. From the above framework, these are given below:

$$\Delta in\ Retail\ Margin = \left(\frac{dp}{dp_w}\right) \text{-} \left(\frac{dp_w}{dp_m}\right) = \left(\frac{1}{(1+\theta) + \frac{Qp''(Q)\theta}{p'(Q)}}\right) \text{-} \left(\frac{1}{(1+\theta^w) + \frac{p_w''(Q)Q\theta^w}{p_w'(Q)} - \frac{p_m''(Q)}{p_w'(Q)}}\right) \tag{19}$$

$$\Delta in\ Wholesale\ Margin = \left(\frac{dp_w}{dp_m}\right) - 1 = \left(\frac{1}{(1+\theta^w) + \frac{p_w''(Q)Q\theta^w}{p_w'(Q)} - \frac{p_m''(Q)}{p_w'(Q)}}\right) - 1 \quad (20)$$

Observations

There are some notable insights from the above framework. First, competition at each stage as well as competition at the related stage will determine which stage is impacted more by the exogenous shock. Second, the changes in the margins will not be equal except under specific circumstances. Third, aside from the potential changes in margins to be unequal, they may also change in different directions contingent on the role of competition at each stage.

Note specifically, that the possibility of 'over-shifting' exists. Although most empirical studies measuring incidence in public finance or industrial organisation or, in the case of agricultural and food markets, report 'under-shifting' (i.e. price transmission less than one), over-shifting is nevertheless a distinct possibility and has also been observed in empirical studies. As Pless and van Benthem (2019) note, pass-through greater than 1 is quite common and has been found for a number of products. See Besley and Rosen (1999), Delipalla and O'Donnell (2001) and Barnett *et al.* (1995) among others. Pless and van Benthem (2019) also report over-shifting of subsidies for solar panels in the US. In these studies, over-shifting arises due to the interaction between the competition and the curvature of the demand function.

The framework outlined above allows for both over-shifting and under-shifting. But note that we have additional mechanisms that can also contribute to over-shifting due to the endogeneity of the response of the wholesale price and the potential for a terms of trade effect. In sum, the framework above allows for both over-shifting and under-shifting at one or more stages and both can exist simultaneously. As far as we are aware, the only other paper that has allowed for different levels of pass-through in a vertically-related market is by Merlo *et al*. (2021). They also report variation in pass-through at various stages. Focussing on the liquid gas sector in Brazil, they report less than perfect pass-through at the distribution level but over-shifting at the retail level. As we show below, the changes in margins that underpin pass-through can also show variation at different stages of supply chains.

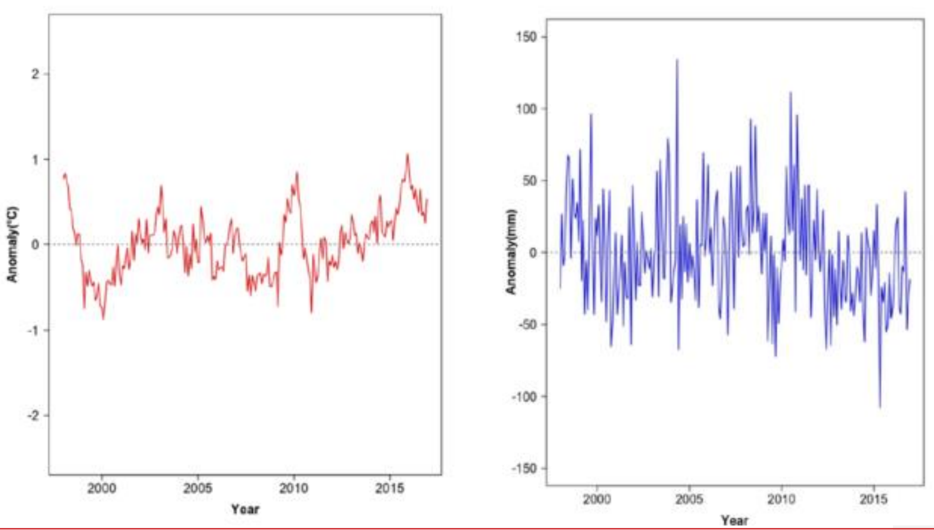
Finally, the framework highlights some implications for the specification of the econometric model since when focusing on changes in the margin at one stage, account should be taken of the (potentially simultaneous and endogenous) change in margins at the related stage in the supply chain.

3. Supply Chain Specific Anomalous Weather Shocks

Fluctuations in the *El Niño* Southern Oscillation (ENSO) index is a commonly used proxy that captures weather variability in the econometric modelling of climate impacts on commodity markets (e.g. Cashin *et al*. 2017; Ubiliva 2017). The attraction of using ENSO anomaly data is that it is easily accessible, and therefore, serves as a useful proxy for weather patterns that can be used to gauge effects on commodity markets. However, as an aggregate global metric, it translates to a variety of weather outcomes across the world (Dai and Wigley 2000; Holmgren *et al.* 2001; Larkin and Harrison 2005). Hence, it may not be precise enough when assessing weather effects on specific commodity markets and/or for a subset of countries within a global import-export network of a commodity.

To address this issue, we use highly detailed temperature and precipitation data between 1996 and 2016 that applies directly to banana growing areas in countries that export to each of the four importing countries. All data were extracted from the CRU TS v.4.01 product (Harris *et al*. 2014; All data were extracted from the CRU TS v.4.01 product (Harris *et al*. 2014; https://crudata.uea.ac.uk/cru/data/hrg/). Data extraction and an elevation-based correction of temperature specific to banana production areas were performed according to Varma and Bebber (2019). These data were used to calculate the month-wise average temperatures and precipitation for each month and for each exporting country. Observed deviations from the corresponding monthly averages represent country-specific monthly anomalies. The monthly temperature and precipitation anomalies were then separately aggregated across the exporting countries weighted by each country's share of the import market to derive a single series for temperature and precipitation anomalies for each of the four importing country supply chains. For example, for the UK, weather data were collated from Colombia, the Dominican Republic, Costa Rica, Ecuador, Belize, Cote d'Ivoire and Cameroon and aggregated to produce the weather anomaly data presented in Figure 2.

Figure 2: Anomalous Weather UK Supply Chain: Temperature (left side) and Precipitation (right side) Anomalies



4. Econometric Framework

To gauge the effects of the weather shocks on the price margins we estimate the impulse response function using local projection methods (Jordà, 2005, 2099), a robust and efficient way to measure the change in one variable (i.e. the measure of a weather shock) on another variable (i.e. the retail-world price spread) while accounting for other factors as control variables (e.g. other costs that influence retail prices). The impulse responses generated from the local projections approach are consistent with those generated from a VAR but offer a number of attractive properties that account for the emerging popularity in the applied literature (Brugnolini, 2018). Local projection proceeds by regressing the same set of variables on a dependent variable that is successively updated by one period forming a set of h regressions over a H period horizon ($h = 0,1,2, ..H$). The impulse response function is formed from the coefficients of each independent variable in these $H+1$ regressions.
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local projection model of the retail-wholesale margin for an importing country which is given by

$$m^{rw}_{t+h} = \alpha_{1,h} + \vartheta_{1,h} STemphock^{Temp}_{t} + \vartheta_{24,h} Prec_t + \sum_{j=1}^{J} \beta_{1,j,h}\, Temp_{t-j}$$
$$\sum_{j=1}^{J} \beta_{1,j,h}\,(m^{wm}_{t+1-j} - m^{wm}_{p-j}) + \sum_{j=10}^{J} \beta_{32,j,h}\, m^{wm}_{t-j} + \sum_{j=0}^{J} \beta_{4,j,h}\, w_{t-j}(w_{t+1-j} - w_{p-j}) + \sum_{j=01}^{J} \beta_{53,j,h}\, er_{t-j}(er^{w}_{t+1-j} - er_{p-j}) + \sum_{j=01}^{J} \beta_{64,j,h} er_{t-j}$$

(21)

With the corresponding specification for the wholesale-import margin given by:

$$m^{wm}_{t+h} = \alpha_{1,h} + \vartheta_{1,h} Temp_t + \vartheta_{2,h} Prec_t + \sum_{j=1}^{J} \beta_{1,j,h}\, Temp_{t-j} + \sum_{j=1}^{J} \beta_{2,j,h}\, Precip_{t-j}$$
$$+ \sum_{j=0}^{J} \beta_{3,j,h}\, m^{rw}_{t-j} + \sum_{j=0}^{J} \beta_{4,j,h}\, w_{t-j} + \sum_{j=0}^{J} \beta_{5,j,h}\, er_{t-j} + \sum_{j=0}^{J} \beta_{6,j,h} er_{t-j} + \varepsilon^{wm}_{t+h}$$

(22)

for $h = 0,1 \ \ldots, H$ where m^{rw}_{t+h} and m^{wm}_{t+h} are the logs of the retail-wholesale and wholesale-import margins at time $t+h$ respectively. All explanatory variables enter the specifications contemporaneously and with lag j (see Plaborg-Møller and Wolf, 2021), J being common merely for notational convenience. Regressors include $Temp_t$, and $Prec_t$ which are our measures of the anomalous variation in temperature and

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precipitation respectively. Attention focusses on the coefficients $\vartheta_{1,h}$ and $\vartheta_{2,h}$ in (21) and (22) for $h = 0,1 \ldots, H$ since these represents the impulse response functions of the margins to anomalous weather shocks.

A number of controls, which also enter contemporaneously and with lag, are included in the specification to account for other factors contemporaneously, and with lag, are included in the specification to account for other factors driving margins , in the supply chain including: other food chain costs w_t ; the import country dollar exchange rate, er_t ; and, to capture demand side changes, the monthly unemployment rate, ur_t .

All series enter (21) and (22) in (trend) stationary form, any non-stationary variable having been first differenced prior to estimation. We also allow for the inclusion of a time trend to capture changes in technology or competition in the supply chain over time.

The impulse responses we generate below are cumulative impulse responses since we are The impulse responses we generate below are cumulative impulse responses since we are primarily interested in how margins at each stage have changed over time.

5. Main Results

The cumulative impulse response functions impacting on margins at different stages of the supply chains across the four countries are presented in Figure 3. In Figure 3(a), we report the results relating to the impact of temperature anomalies; in Figure 3(b), we report the corresponding results for the precipitation anomalies. There are three questions of interest: first, do temperature anomalies have a greater impact than precipitation anomalies? (ii) what are the distributional impacts relating to changes in margins at each stage of the supply chains in our countries? and (iii) what are the net effects?

Regarding what aspects of the weather anomalies matter most, we can see from a comparison of Figures 3(a) and 3(b) that temperature matters more than precipitation anomalies. With precipitation anomalies, across all four supply chains, there are no significant changes in the margins at retail or wholesale levels (with the slight exception of a marginal decline in retail-wholesale margin for the UK).

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Figure 3(a): Changes in Supply Chain Margins Due to Country-Specific Temperature Anomalies
(Cumulative Impulse Responses)

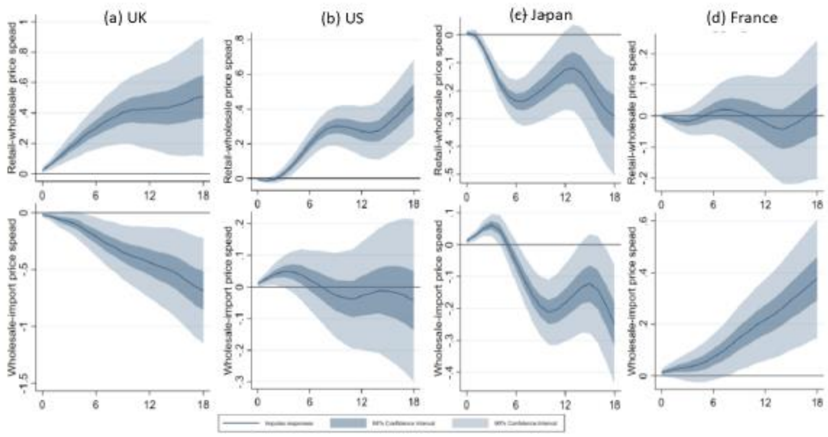
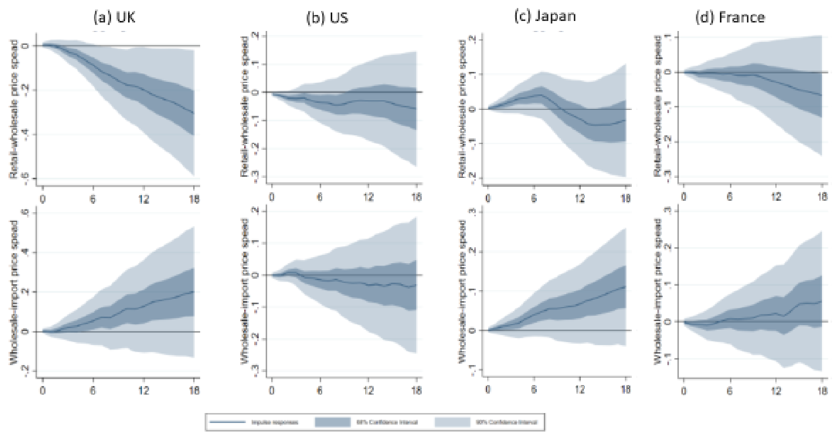


Figure 3(b): Changes in Supply Chain Margins Due to Country-Specific Precipitation Anomalies
(Cumulative Impulse Responses)



Temperature anomalies however show significant changes in margins across the four supply chains with considerable variation in both the direction of the change and magnitudes. For the UK, the retail-wholesale margin increases while the wholesale-import margin decreases; in the US, there is also an increase in the retail-wholesale margin but no significant change in the wholesale-import price margin; for Japan, both retail-wholesale and wholesale-import margins decline; for France, there is no significant change in the retail-wholesale margin but a decline in the wholesale-import price margin. Note that this variation in results across the supply chains is consistent with the framework set out in Section 2 that indicated that margins at either stage of supply chains could increase or decrease and that they could go in opposite directions even within the same supply chain. Factors accounting for this potentially heterogenous response include: the role of competition at either stage, how competition at one stage impacts on competition at another stage coupled with the interaction of the intensity of competition with the (unidentified) functional form of the demand function.

In terms of magnitudes of the margin changes, our findings highlight distributional effects across firms at different stages of the supply chains. For the UK, the cumulative increase in the retail-wholesale margin after 18 months is 50% while the wholesale-import margin declines by 70%. For the US, the retail-wholesale margin increases by 45% but there is no statistically significant change in the wholesale-import price margin; in Japan, both margins decline (by 30% for the retail-wholesale margin and 27% for the wholesale-import margin); for France, only the wholesale-import price margin changes, with an increase in 40%. These changes identify the stage in the supply chain that is gaining or losing from the exogenous shocks in temperatures. They also

We should note that these results are robust to alternative specifications of the econometric framework reported in (21) and (22). Most relevant in this regard is the inclusion of time trends to capture underlying changes in the margins at each stage representing changes in the intensity of competition (in the UK case for example, due to the entry of discount chains) or underlying improvements in technology and allowing for non-contemporaneous changes in the related margins representing possible timing differences in relation to the adjustment of prices in the face of exogenous shocks (due, for example, to contracts).

6. Concluding Remarks

Standard theory in public economics and industrial organisation highlights that, when markets are imperfectly competitive, firms' margins will adjust to ameliorate or (under certain conditions) exacerbate tax or cost changes. We have extended this analysis to the case of supply chains in agricultural/food markets, the key characteristic being that imperfect competition may exist at more than one stage in the supply chain. The theoretical results highlight that margins may indeed decrease or increase in response to a shock but, in the context of a vertically-related supply chain, the changes in margins at either stage may be unequal and, indeed, can go in opposite directions. This highlights the potential for distributional impacts in supply chains in face of exogenous shocks. The exogenous shocks that impact on the four banana supply chains we have data for relate to weather anomalies that are specific to each supply chain. This deviates from much of the price transmission research in agricultural and food markets that does not adequately identify shocks to food supply chains that are truly exogenous.

We employ local projections impulse responses to measure the cumulative change in margins at each stage of the banana supply chains in the UK, the US, Japan and France. Our results suggest significant variation across supply chains and that the distributional impact of exogenous shocks can vary considerably. Even when the net change in the margins can in part offset each other (as in the case of the UK), this net change obscures the practically offsetting changes at different stages in the supply chain. In the case of Japan, changes in the margins at either stage are reinforcing. For the US and France, it is either only the retail-wholesale margin that changes (the US) or the wholesale-import price margin (France).

The results we present here are our first findings and there is considerable scope for expanding the analysis which is on-going. Most notably, variations in the responses of margins may arise at different times. For example, following the food price crises of 2007-08 and 2011, firms in supply chains may respond differently given the time-variant structural change that can arise at certain points in time. Following Ramey and Zubairy (2018), allowing for time varying responses is relatively easy to implement in the local projections approach that we follow here. This will provide more insight into the responses in margins throughout supply chains that may not be constant as global events evolve.

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