Trade Shocks and the Transitional Dynamics of Markups*

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Abstract

Unlike commonly assumed in the trade literature, we show that markups are responding to movements in trade shocks. Empirically, aggregate U.S. markups increase following a positive unanticipated shock to the U.S. import tariffs, but it takes time for them to take off. However, if the tariff shock is anticipated, markups initially fall before they start to rise. To explain this "J-curve" response, we extend the "new" trade theory by merging deep consumption habits with monopolistic competition, thereby producing markups that are time-varying and forward-looking. Expectations about future trade policy are shown to play a crucial role for trade adjustment dynamics and welfare gains from trade.

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1 Introduction

There is a widely held understanding that trade liberalisations come with greater exposure to foreign competition that reduce the monopoly power of the domestic firms. This effect is believed to amplify the traditional welfare gains from trade that are attributable to specialisation, increasing returns to scale, and the expansion of import varieties (Krugman (1979)). In the context of the workhorse modern trade theory that features monopolistic competition, firm heterogeneity, and a large class of homothetic preferences, some argue that these additional welfare gains reflected in variable markups are relatively small (Arkolakis et al. (2012, 2018)). But welfare gains from trade are often assessed using static and deterministic models in which shifts from the steady state of autarky to the free trade equilibrium are instant, zero-probability events, something that Thomas J. Sargent famously calls "MIT shocks". It therefore remains unclear and interesting to see whether the welfare outcomes are any different when we account for a more plausible course of transitional dynamics.

We argue that in the context of forward-looking firms, transitional dynamics are important for at least three empirically-relevant stylized facts. (1) *anticipation*: the outcomes of trade deals are often anticipated in advance as they take months, if not years, to be negotiated (Moser & Rose (2012)). Markups may therefore adjust in the run up to the trade shock, but *ex-ante* it is unclear in which direction. (2) *sequencing*: even when the terms of the new trade deals are eventually hammered out and announced to the public, the actual changes in trade barriers are usually phased in gradually (Chisik (2003), Khan & Khederlarian (2021)). The timing and the magnitude of adjustments in trade flows and markups therefore depends on the immediate or gradual sequencing of the trade shock. (3) *dynamic trade elasticity*: independent of sequencing, trade flows take time to fully adjust in response to trade shocks (Boehm et al. (2020), Alessandria et al. (2021)). Markups may therefore reflect not just the market structure today, but also what it is expected to be in the future.

Our main contribution in this paper is a simple theoretical model that simultaneously accounts for all three of the above stylised facts (a.k.a. Krugman meets Ravn et al.). Our starting point is the ubiquitous "new" trade theory (Krugman (1979, 1980), Melitz (2003)). But we depart from the traditional approach that features constant elasticity of substitution (CES) preferences for domestic and foreign varieties, because as is well known, it implies constant markups. Instead, we augment the standard CES preferences with "deep" habits due to Ravn et al. (2006, 2010). Deep habits are a useful device, because it not only retains the analytical tractability of the standard CES preferences and nests them as a special case, but at the same time introduces a rich mechanism of trade adjustment dynamics into an otherwise run-of-the-mill setup.

With deep habits, individual consumption choices of a specific variety today are influenced by the past choices of their own as well as their friends, family, and neighbours (i.e. the "Joneses"). Consequently, when the trade shock hits the economy and the relative price of the domestic and foreign varieties changes, the initial impact on trade flows is subdued, because "old habits die hard". But as time passes, individuals start to slowly "catch up with the Joneses", which causes trade flows to gradually transition to the new steady state. By construction, this generates a dynamic trade elasticity and explains the stylised fact (3).

Trade in our model is subject to iceberg costs (Samuelson (1954), Krugman (1980)), such that a fraction of imports "melt away" in transit. However, unlike the traditional approach, which assumes that they are exogenous and constant over time, we argue that a fraction of the iceberg costs depends on trade policy, somewhat similar to Steinberg (2019). We capture this by modelling iceberg costs as an AR(1) process, such that their current value depends on: (i) the steady state; (ii) a contemporaneous trade shock; and (iii) the lagged value of the iceberg costs, which controls the sequencing of the trade shock and accounts for the stylised fact (2). We further consider two different types of trade shocks: anticipated and unanticipated. Unanticipated (i.e. stochastic) trade shocks in our model are simply random draws from a time-invariant distribution. By contrast, anticipated trade shocks are announced to all firms and households in advance, such that all agents acquire perfect foresight. The transitional dynamics in our model therefore crucially depend on expectations about future trade policy.

It is not immediately clear which exporters should have systematically heterogeneous expectations about future trade policy. It is also unclear whether exported or non-exported varieties are more addictive. We therefore limit our focus to a simple case of rational expectations adopted by a continuum of exporting firms that in equilibrium set homogeneous markups, which we then map to the aggregate markups in the data.[1]

We argue that if firms are rational and forward-looking, then in theory they should recognise the fact that consumers are addicted to their variety, such that demand for their variety is persistent. And if the firms have some market power, they would choose to set optimally time-varying markups. Specifically, when sales are expected to grow in the future, firms cut markups today, because if they give consumers "a head start" in terms of adjusting their habits, they can boost future sales and keep them elevated for longer. By contrast, when future sales are expected to shrink, firms increase markups today as they exploit the fact that consumers are still "hooked" on their variety, which addresses stylised fact (1). Further connections to the literature on habits and markups are relegated to Section 2.

In Section 3, we provide some stylised empirical evidence on the transitional dynamics of markups following unanticipated shocks to import tariffs using United States (U.S.) data that covers the period of 1960:Q1-2017:Q4. We show that in response to an unanticipated increase in U.S. import tariffs, identified by the theory-consistent sign-restricted vector autoregression (VAR) model, the aggregate U.S. price markups tend to increase significantly, but it takes around one year for them to take off (i.e. "J-curve" response).

Section 4 describes the theoretical model discussed above, which generates an empirically-

[1]The setup of our model therefore follows Krugman (1979, 1980) rather than Melitz (2003), because our model does not feature firm heterogeneity. We focus on the case of homogeneous firms not because we think it is more realistic, but because firm heterogeneity is not necessary to rationalise stylised facts and generate transitional dynamics in our model. This is consistent with the Occam's razor principle that is common in the modern trade literature, in which we often assume identical tastes, technology, and population size in different countries. There is also emerging literature on equivalence properties between dynamic monopolistically competitive heterogeneous firms models and representative firm models that feature externalities (see, for instance, Bhattarai & Kucheryavyy (2020). We leave it for the future research to work out the implications of production, rather than consumption as in our paper, externalities.

consistent "J-curve" response of markups in response to a gradual and unanticipated trade shock. Intuitively, home firm sales adopt an "S-shaped" time path, because changes in trade policy and "catching up with the Joneses" take some time to kick in. Initially, home firms therefore expect future sales to increase by more than their current sales, which explains why markups fall upon impact (i.e. phase 1). But when consumers start to "catch up with the Joneses", home firm sales start to grow at an exponentially diminishing rate, such that the current increase in home firm sales start to exceed their expected future increase, in which case markups rise above the steady state (i.e. phase 2). In the long-run, "catching up with the Joneses" eventually stops and markups reach their new and permanently higher steady state. By contrast, with immediate and unanticipated trade shocks, markups skip phase 1 and start to adjust according to phase 2 as soon as the trade shock hits the economy, which fails to generate the "J-curve" response.

Section 5 presents additional empirical evidence on the transitional dynamics of U.S. markups following anticipated shocks to the U.S. import tariffs. We employ sign and zero restrictions to identify anticipated trade shocks. We show that in the long-run, U.S. markups increase by around the same magnitude whether the increase in U.S. import tariffs is anticipated or unanticipated. However, if the increase in U.S. import tariffs is anticipated, then following the initial impulse, which corresponds to the date of the trade policy announcement, U.S. markups fall and start to rise only around one year after, thereby making the aforementioned "J-curve" response even more pronounced.

Our theoretical model generates an analogous decrease in markups in the run up to an anticipated increase in iceberg costs. But contrary to the empirical evidence, when markups start to rise upon impact, they gradually revert to the pre-shock steady state and never rise above the steady state. This outcome holds in the case of both immediate and gradual sequencing of the anticipated trade shocks. We reconcile this discrepancy by arguing that in practice trade policy announcements contain "noisy" information that some firms may be unable to process and take into the account when planning ahead, in which case some firms respond to all trade shocks as if they caught them by surprise. The aggregate markup response in theory would then closely correspond to that inferred from the data.

Section 6 shows that the theoretical estimates of the dynamic trade elasticity in our model are virtually independent of anticipation, whereas shock sequencing matters only somewhat in the medium-run, but not the short-run or the long-run. On average, depending on the intensity of deep habits, the short-run trade elasticity is between -2 and -3 and the long-run trade elasticity is between -6 and -9. Without deep habits, our model is static and generates a trade elasticity of -5. The trade elasticity estimates in our model are within the domain of estimates documented in the related literature.[2]

We move on to present the theoretical estimates of the welfare cost of trade shocks measured as percentage changes in real units of consumption in Section 7. Without deep habits, the welfare cost of a 10% increase in iceberg costs is around 0.7%, which is in the

[2] For instance, Anderson & van Wincoop (2004) and Arkolakis et al. (2012) review the literature on the static trade elasticity estimates and conclude that it ranges between -5 and -10. Alessandria et al. (2021) present a theoretical model with fixed markups and a dynamic trade elasticity that is equal to around -4 in the short-run and -11 in the long-run. The empirical estimates of Boehm et al. (2020) are somewhat lower at -1.75 in the short-run and -2.25 in the long-run.

ballpark of the ubiquitous Arkolakis et al. (2012) estimates. But depending on a more general intensity of deep habits, the sequencing of the trade shocks, and anticipation, the welfare cost can more than double. Around two-thirds of this welfare cost amplification is attributable to the dynamic trade elasticity and around one-third to the time-varying markups. The most costly trade shocks are unanticipated and immediate (i.e. "cold turkey") and the least costly are anticipated and gradual. However, gradual sequencing of the trade shocks goes a long way in terms of closing the gap between anticipated and unanticipated trade shocks. Finally, in Section 8 we provide concluding remarks while Appendix collects all technical details and supporting material.

2 Related Literature

2.1 Habits

To the best of our knowledge, our paper is the first to study trade adjustment dynamics driven by deep habits in consumer preferences. But habits are not just a useful analytical tool that allows us to replicate empirical trade patterns using a simple model. In fact, there is a large body of empirical literature that supports our choice of modelling consumer preferences with inter-temporal non-separabilities. Specifically, empirical studies on consumer behaviour find that consumer choices across different brands or for the overall basket of goods are affected by past consumption choices (Heckman (1981), Chaloupka (1991), Naik & Moore (1996), Chintagunta (1998), Chintagunta et al. (2001), Seetharaman (2004), Carrasco et al. (2005), Alvarez-Cuadrado et al. (2016), Raval & Rosenbaum (2018)). Much of the above empirical literature is motivated by the early theoretical work on consumption habits (Pollak (1970), Spinnewyn (1981), Boyer (1978, 1983), Becker & Murphy (1988)). Thereafter, consumption habits became a well-established framework in the macro-finance literature as a vehicle for generating rich persistence mechanisms that resolve a number of puzzles observed in the data (e.g. Campbell & Deaton (1989), Abel (1990), Constantinides (1990), Campbell & Cochrane (1999), Fuhrer (2000), Carroll et al. (2000), Carrasco et al. (2017)). And more recent work in the business cycle literature utilises the deep habit framework to study the dynamics of firm price markups in the context of unanticipated shocks (Ravn et al. (2006, 2010), Di Pace & Faccini (2012), Jacob & Uusküla (2019)). Given their popularity, especially in macroeconomics, Havranek et al. (2017) conduct meta-analysis of quantitative models with consumption habits.

2.2 Trade Adjustment Dynamics

Our theoretical model generates a dynamic trade elasticity, which is lower (in absolute value) in the short-run than in the long-run. This result is consistent with many other studies (Baldwin (1992), Hooper et al. (1998), Gallaway et al. (2003), Alessandria & Choi (2007), Yotov & Olivero (2012), Boehm et al. (2020), Anderson et al. (2020), Bhattarai & Kucheryavyy (2020), Alessandria et al. (2021)). But unlike the previous theoretical studies that mostly rely on the neo-classical theory of capital accumulation to induce trade adjustment dynamics, our model is based on deep habits of the consumers. However, our time-averaged trade elasticity estimates are similar to the well-established static trade elasticity estimates (see Anderson & van Wincoop (2004), Arkolakis et al. (2012), Head & Mayer (2014), Imbs & Mejean (2015), Feenstra et al. (2018)). Expectations about future trade policy play a central role for the transitional dynamics in our model. We therefore recognise a buoyant new line of research that studies the interaction between trade, announcements, and uncertainty (Crowley et al. (2018, 2020), Caldara et al. (2020), Novy & Taylor (2020), Douch & Edwards (2021)). There are also others that address the prospect of pro-competitive effects of trade in anticipation of trade reforms (Staiger et al. (1994), Tharakan (1995), Handley & Limão (2017), Alessandria et al. (2019), Khan & Khederlarian (2021), Metiu (2021)).

With the increased availability of the micro-level data on firm inventories, Novy & Taylor (2020) and Douch & Edwards (2021) show that a prominent channel through which anticipation and uncertainty affect trade is business confidence, which among other factors, is reflected in stockpiling of durable imported inputs during episodes of policy turmoils. And recently, Khan & Khederlarian (2021) show that in the case of NAFTA in 1994, U.S. firms ran down their inventories of imported inputs as they expected further tariff reductions in the future, such that trade temporarily "got worse before it got better". They do not discuss the adjustment of markups. However, our model with deep habits not only generates an analogous response of trade volumes without incorporating firm inventories, but also characterises the transitional dynamics of markups.[3]

2.3 Markups

The welfare amplification effects of markups goes all the way back to Krugman (1979). Some argue that the welfare gains from variable markups are relatively large (Simonovska & Waugh (2014), Edmond et al. (2018)). But Arkolakis et al. (2018) provides a compelling framework and shows that in the context of static and deterministic models with homothetic preferences, the welfare gains from variable markups are relatively small. In fact, they can even be negative if consumer preferences are non-homothetic. Our model is different, because it generates trade adjustment dynamics and time-varying markups with deep habits, which is a special case of homothetic preferences that escapes this argument. There are also other models of time-varying markups (Bilbiie et al. (2019), Peters (2020)) or markups that are related to market size (Melitz & Ottaviano (2008)), but their purpose is not directed at the anticipation effects of future trade policy changes. Another channel through which exporter markups adjust is strategic complementarities in the context of oligopolistic competition (Krugman (1986), Atkeson & Burstein (2008), Rodriguez-Lopez (2011), Simonovska (2015), de Blas & Russ (2015), Amiti et al. (2019)). Deep habits are therefore not needed to show that home price markups rise when import tariffs increase. But without deep habits or

[3]Given that the U.S. ratified and implemented the first round of NAFTA tariff reductions within the first 40 days, but some of the tariffs took up to 15 years to phase out, we argue that NAFTA corresponds to an unanticipated and gradual trade shock in our model. Section 4.9 of our paper describes the implied transitional dynamics of trade volumes in our model, except note that (i) we consider an increase, not a decrease, in trade barriers throughout the paper; and (ii) trade volumes or output x_t in our model is inversely related to markups μ_t, such that the dynamic response of trade volumes, up to first order, is a mirror image of that for markups.

any other source of time-varying markups, there is no motive for consumer demand to be persistent and therefore, without any other source of persistence in the model, anticipation of future trade shocks does not play any role for the optimal markup response. In terms of the empirical literature, markups are generally unobservable and notoriously difficult to measure, but De Loecker & Warzynski (2012) propose a novel method of estimating exporter markups using plant-level production data based on a limited set of observables. Feenstra & Weinstein (2017) provide a useful summary of the earlier literature on markups and trade liberalisations, especially in developing countries, and presents new evidence of welfare gains from variable markups in the United States. And Ding (2021) presents a detailed overview of the literature on variable markups, firm heterogeneity, and trade policy.

3 Empirical Evidence: Unanticipated Trade Shocks

We study the transitional dynamics of U.S. markups following shocks to U.S. import tariffs using data that covers the period of 1960:Q1-2017:Q4. Due to the potentially endogenous relationship between markups and tariffs, we focus on a multivariate model that allows us to carefully identify the variation in markups owing to trade shocks. Our empirical strategy involves modelling the simultaneous dynamics of four variables: (i) aggregate price markups (MKP_t) measured as the inverse labour share and obtained from Nekarda & Ramey (2020); (ii) import tariffs (TRF_t) measured as a ratio between customs duties and imports less customs duties; (iii) import penetration ratio (IPR_t), which captures the relative demand for home goods and foreign imports; and (iv) real aggregate consumption (CON_t), which captures shifts in aggregate demand for home goods and foreign imports. All variables are expressed in natural logarithms and de-trended using standard methods in the literature.[4] A more detailed description of the data is shown in Table 3 of Appendix H.

We infer the transitional dynamics of markups using Impulse Response Functions (IRFs), which we obtain by estimating a Structural Vector Autoregression (SVAR). We identify trade shocks using the following strategy. Let $h = \{0, 1, 2, ...\}$ denote the time horizon following a trade shock and $\text{IRF}_h^{\text{TRF}}$ denote the impulse response function of the import tariff. We argue that upon impact, when $h = 0$, positive trade shocks cause not only an increase in TRF_t, but also a simultaneous decrease in CON_t and IPR_t. Our identification strategy therefore restricts the signs of $\text{IRF}_0^{\text{CON}} < 0$, $\text{IRF}_0^{\text{IPR}} < 0$, and $\text{IRF}_0^{\text{TRF}} > 0$, but only upon the impact of the trade shock, thereby allowing them to adjust freely thereafter. We do not restrict the impulse response of MKP_t in any way as we are interested in studying its transitional dynamics and allow the data to "speak for itself". We adopt the sign-restricted SVAR approach of identifying trade shocks by closely following the footsteps of a long line of the macro-finance literature,[5] though there is also an emerging set of applications in international macroeconomics and trade (see, An & Wang (2012), Di Pace et al. (2021),

[4] The cyclical components are extracted using the linear projection approach of Hamilton (2018). In Appendix H, we show that the baseline results are qualitatively similar when re-estimating the SVAR using alternative de-trending methods, such as the one-sided HP filter due to Meyer-Gohde (2010) and the more popular two-sided HP filter due to Hodrick & Prescott (1997).

[5] See, for instance, Faust (1998), Canova & Nicolo (2002), Uhlig (2005), Mountford & Uhlig (2009), Rubio-Ramírez et al. (2010), Arias et al. (2018, 2019), Granziera et al. (2018).

Lippi & Nobili (2012), among others). In line with the canonical representation of our model in (4.7)-(4.9), as well as following a seminal contribution by Blanchard & Perotti (2002), we order trade tariff first, acknowledging that policy takes time to get implemented. A more formal description of the empirical methodology is provided in Appendix G. We leave it for the future research to explore news and narrative approaches for the trade shock identification.

Figure 1 shows the estimated impulse responses following an unanticipated TRF_t shock. As expected, upon impact, $\text{IRF}_0^{\text{TRF}}$ rises, while $\text{IRF}_0^{\text{CON}}$ and $\text{IRF}_0^{\text{IPR}}$ both fall. Both consumption and import penetration ratio converge back to zero after more than two years, whereas an unexpected tariff change reverts back after three years. Based on this identification strategy, we show that consistent with the conventional wisdom, positive trade shocks cause $\text{IRF}_h^{\text{MKP}}$ to increase significantly, but it takes around 3-4 quarters for it to "take off". This "J-curve" impulse response therefore suggests that markups are not only endogenous and time-varying, but they are persistent and sluggish to respond to trade shocks. To the best of our knowledge, none of the existing trade theories are able to explain such transitional dynamics of markups. We therefore provide a theoretical model of our own that generates impulse responses that closely match the ones we infer from the data.

4 Theoretical Model

Consider two countries: (i) home (H); and (ii) foreign (F) that trade final goods with each other and evolve over discrete time $t = \{1, 2, ...\}$. Each country is populated by a continuum of households indexed by $\psi \in [0, \Psi + \Psi^*]$, where $\Psi, \Psi^* > 0$ is the mass of home and foreign populations, respectively. Households are subject concave preferences and derive utility from consumption of home and foreign varieties. In addition, preferences exhibit "deep habits". There exists a continuum of monopolistically-competitive firms indexed by $\omega \in [0, \Omega + \Omega^*]$, where $\Omega, \Omega^* > 0$. Firms service the world market subject to fixed production costs and require labour as the sole non-tradable factor of production. There are trade barriers and their size is subject to shocks. All foreign variables are henceforth denoted with an asterisk "$*$", but most derivations are provided for home only as identical results apply to foreign.

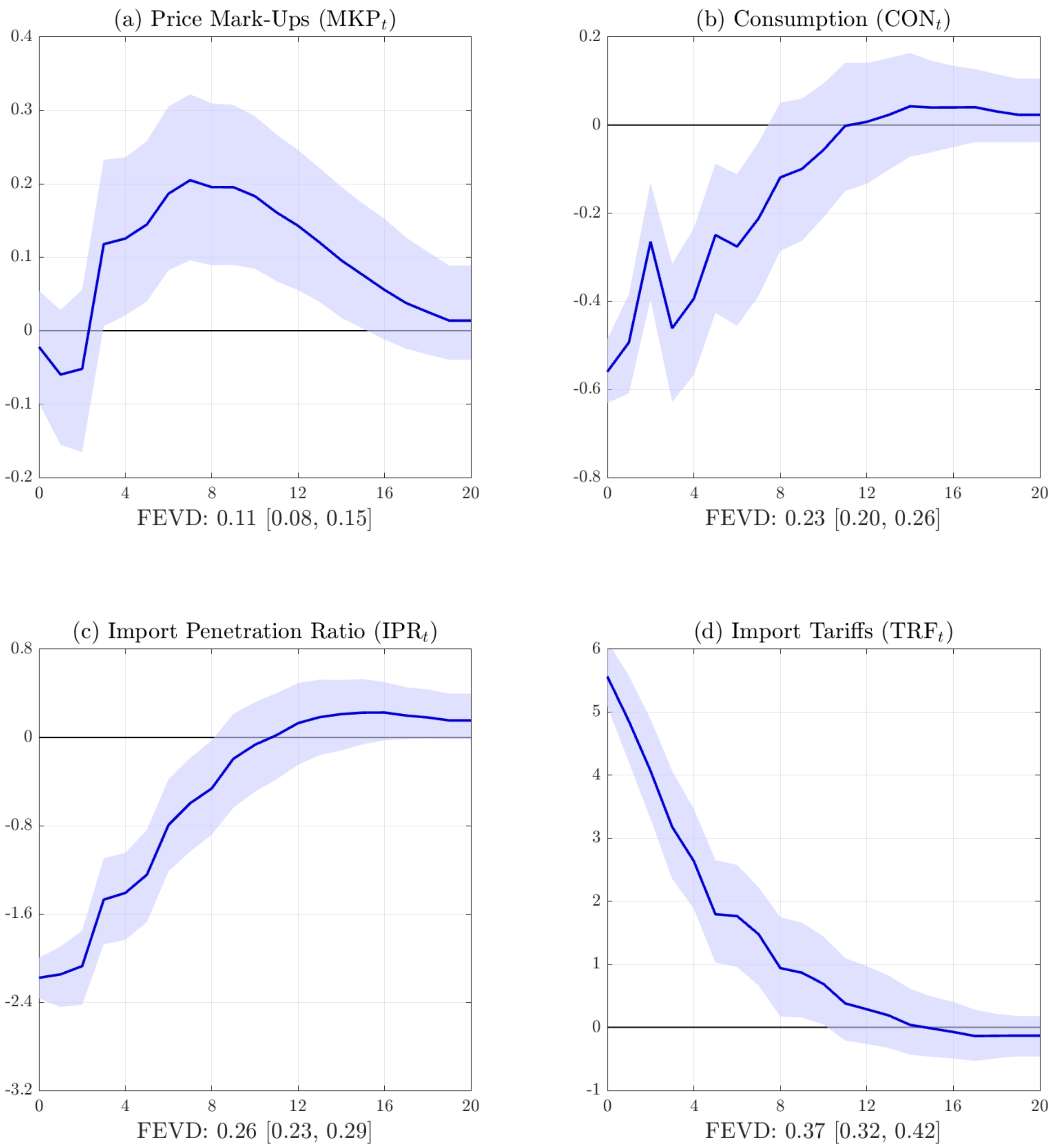
4.1 Preferences

Households derive utility from consumption of home and foreign varieties characterised by the Dixit & Stiglitz (1977) Constant Elasticity of Substitution (CES) preferences that are augmented with deep habits similar to Ravn et al. (2006):

$$C_t(\psi) = \left[\int_0^{\Omega} C_{H,t}(\psi,\omega)^{1-1/\eta} d\omega + \int_0^{\Omega^*} C_{F,t}(\psi,\omega)^{1-1/\eta} d\omega \right]^{1/(1-1/\eta)}, \tag{4.1}$$

$$C_{i,t}(\psi,\omega) = X_{i,t}(\psi,\omega) X_{i,t-1}(\omega)^{\theta}, \tag{4.2}$$

Figure 1: Transitional Dynamics with Unanticipated Trade Shocks (SVAR)



The figure displays impulse responses following an unanticipated shock to the U.S. import tariffs equal to the size of one standard deviation. The horizontal axes measure the time horizon $h = \{0, 1, 2, ...\}$ and the vertical axes indicate the log scale for the cyclical components of each variable. The solid lines are the point-wise posterior medians. The shaded areas are the 68 percent equal-tailed point-wise probability bands. Each figure is based on 1000 independent draws using a Bayesian approach due to Uhlig (2005). The cyclical components of each variable are obtained using the Hamilton (2018) filter. The SVAR model is estimated with a lag order of 4 quarters and includes a constant term in each equation. The Forecast Error Variance Decomposition (FEVD) displayed underneath each IRF measures the share of variation in that variable explained by unanticipated trade shocks with confidence bands displayed in square brackets.

where $i = \{H, F\}$, $C_t(\psi) > 0$ is the real consumption of the home household $\psi \in [0, \Psi]$, $\eta > 1$ is the intra-temporal elasticity of substitution, $X_{i,t}(\psi, \omega) > 0$ measures the consumption of variety ω from country i by individual ψ at date t, $X_{i,t-1}(\omega) > 0$ is the stock of habit, and $\theta > 0$ measures the intensity of habits. These CES preferences exhibit two properties: (i) "love-of-variety" if $\eta > 0$, since it ensures that $C_{i,t}(\psi)$ is increasing in Ω and Ω^* (i.e. concavity); and (ii) "deep habits" if $\theta > 0$ that imply $C_t(\psi)$ is increasing in $X_{i,t-1}(\omega)$. The stock of habits $X_{i,t-1}(\omega)$ is specific to each variety, not just specific to the country as a whole, thereby distinguishing the "deep" habit framework from other existing models of "shallow" habits that are applied to aggregate quantities.

4.2 Technology

Following Krugman (1979, 1980), varieties are produced by monopolistically-competitive firms that use labour-intensive production technology with increasing returns to scale:

$$X_{i,t}(\omega) = \begin{cases} \phi[L_{i,t}(\omega) - \alpha] & \text{if} \quad L_{i,t}(\omega) > \alpha, \\ 0 & \text{if} \quad L_{i,t}(\omega) \leq \alpha, \end{cases} \tag{4.3}$$

where $\alpha, \phi > 0$ are constants and $L_{i,t}(\omega) > 0$ is the non-tradable labour input supplied by home households inelastically.

4.3 Trade Shocks

Shipping one unit of a foreign variety to home costs an additional $\tau_t - 1 > 0$ units of the good (i.e. Samuelson's "iceberg costs"). This means that $P^*_{H,t} = \tau_t P_{H,t}$, where $P_{H,t}$ and $P^*_{H,t}$ stand for the "F.O.B." and the "C.I.F." prices of home exports, respectively. Iceberg costs are exogenous to both firms and households and consist not only of the time-invariant geographic distance or (maritime) transport costs, but also incorporate shocks to the size of the import tariffs. We capture all of this in τ_t through an AR(1) process:

$$\tau_t = (1 - \rho)\bar{\tau} + \rho\tau_{t-1} + \sigma\varepsilon_t, \tag{4.4}$$

where $\bar{\tau} > 1$, $-1 < \rho < 1$ and $\sigma > 0$. There are two ways to think about trade shocks ε_t in this model: (i) unanticipated (i.e. stochastic shocks that are drawn at random, such that $\varepsilon_t \sim \text{iid}(0, 1)$); and (ii) anticipated (i.e. announced deterministic time paths of $\{\varepsilon_t\}_{t=0}^{\infty}$ known to all at all times, such that all firms and households acquire perfect foresight).

4.4 General Equilibrium

The general equilibrium is defined as a set of dynamic processes of allocations for both home and foreign $\{C_t(\psi), C^*_t(\psi), C_{i,t}(\psi, \omega), C^*_{i,t}(\psi, \omega), X_{i,t}(\psi, \omega), X^*_{i,t}(\psi, \omega), L_{i,t}(\psi, \omega), L^*_{i,t}(\psi, \omega)\}_{t=1}^{\infty}$, prices $\{P_t, P^*_t, P_{i,t}(\omega), P^*_{i,t}(\omega), W_t, W^*_t\}_{t=1}^{\infty}$, and the mass of varieties $\{\Omega, \Omega^*\}_{t=1}^{\infty}$ conditional on the dynamic processes of both home and foreign state (i.e. pre-determined) variables $\{\tau_{t-1}, \tau^*_{t-1}, X_{i,t-1}(\omega), X^*_{i,t-1}(\omega)\}_{t=1}^{\infty}$ and exogenous state (i.e. shock) variables $\{\varepsilon_t, \varepsilon^*_t\}_{t=1}^{\infty}$, where $i = \{H, F\}$ and $\omega \in [0, \Omega + \Omega^*]$, such that (i) home maximises utility by choosing

$\{X_{i,t}(\psi,\omega)\}_{t=1}^{\infty}$ taking $\{P_{i,t}(\omega), P_t\}_{t=1}^{\infty}$, and $\Omega, \Omega^* > 0$ as given (analogous for foreign); (ii) home firms maximise profits by choosing $\{P_{H,t}(\omega), X_{H,t}(\omega), X^*_{H,t}(\omega), L_{H,t}(\omega), L^*_{H,t}(\omega)\}$ taking W_t, $\Omega, \Omega^* > 0$, and the prices, inputs, and output of all other home and foreign varieties as given (analogous for foreign); (iii) the mass of varieties $\Omega, \Omega^* > 0$ is such that all home firms break-even (analogous for foreign), which implies that prices and output of each variety are such that there is no new firm entry or exit; (iv) feasibility constraints are satisfied, such that $P_tC_t(\psi) = W_th(\psi)$ and $P_tC_t(\psi) = \int_0^{\Omega} P_{H,t}(\omega)X_{H,t}(\psi,\omega)d\omega + \int_0^{\Omega^*} P_{F,t}(\omega)X_{F,t}(\psi,\omega)d\omega$, where P_t is the aggregate consumer price index; and (v) all markets clear.

4.5 Recursive Demand

Due to the deep habits in consumer preferences, demand for each variety takes time to adjust in the face of shocks to the iceberg costs. To see this, note that households maximise their utility captured by (4.1) and (4.2) subject to a budget constraint $W_th_t(\psi) = \int_0^{\Omega} P_{H,t}(\omega)X_{H,t}(\psi,\omega)d\omega + \int_0^{\Omega^*} P_{F,t}(\omega)X_{F,t}(\psi,\omega)d\omega$ by choosing $X_{i,t}(\psi,\omega)$ for $i = \{H, F\}$ taking $\{P_{i,t}(\omega), P_t\}_{t=1}^{\infty}$ and $\Omega, \Omega^* > 0$ as given, which leads to a recursive demand for each variety (see online appendix A for technical details):

$$X_{i,t}(\psi,\omega) = \left[\frac{P_{i,t}(\omega)}{P_t}\right]^{-\eta} C_t(\psi)X_{i,t-1}(\omega)^{\theta(\eta-1)}. \tag{4.5}$$

With $\eta > 1$ and $\theta > 0$, the current individual-specific demand for variety $X_{i,t}(\psi,\omega)$ is increasing in the past demand for that variety by all individuals $X_{i,t-1}(\omega)$ (i.e. "catching up with the Joneses good-by-good"). Without deep habits, such that $\theta = 0$, demand for each variety is static. But in either case, demand is increasing in the overall consumption $C_t(\psi)$ (i.e. income effect) and decreasing in the price of that variety $P_{i,t}(\omega)$ relative to the aggregate consumer price index P_t (i.e. substitution effect).

4.6 Forward-Looking Price Markups

Each firm is rational, forward-looking, and recognises the persistence of consumer demand that comes with deep habits. Firms choose to exploit consumer habits for their variety by setting an optimally time-varying price markup in response (or in anticipation) to trade shocks. Formally, for a given rate of time preference $0 < \beta < 1$, the optimal price $P_{H,t}(\omega)$ and output $X_{H,t}(\omega)$ are chosen simultaneously so as to maximise the expected value of the firm $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t(P_{H,t}(\omega)X_{H,t}(\omega) - W_tL_{H,t}(\omega))$ subject to the production technology (4.3) and the demand for their variety (4.7). The first-order conditions give rise to the optimal price markup (see online appendix B.2 for derivations):

$$\frac{\phi P_{H,t}(\omega)}{W_t} = \left(\frac{\eta}{\eta-1}\right)\frac{P_{H,t}(\omega)X_{H,t}(\omega)}{P_{H,t}(\omega)X_{H,t}(\omega) + \theta\beta\mathbb{E}_t[P_{H,t+1}(\omega)X_{H,t+1}(\omega)]}, \tag{4.6}$$

Hence, the marginal cost for home firms is equal to $W_t/\phi > 0$ and $\phi P_{H,t}(\omega)/W_t \geq 1$ is the gross price markup. Unlike static trade models with monopolistic competition in which markups are fully pinned down by $\eta > 1$, deep habits introduce a mechanism for markups to vary over time. Specifically, when expected future sales $\mathbb{E}_t[P_{H,t+1}(\omega)X_{H,t+1}(\omega)]$ grow relative to the current sales $P_{H,t}(\omega)X_{H,t}(\omega)$, markup falls, because firms know that "old habits die hard" and if they give consumers "a head start" in terms of adjusting their stock of habits, they can boost future sales further and keep them elevated for longer. By contrast, when future sales are expected to shrink relative to the current sales, markup rises, as firms take advantage of the fact that their customers are still addicted to their variety. This forward-looking property of the markups generates transitional dynamics and fundamentally different adjustment paths following anticipated and unanticipated trade shocks that static trade models are unable to capture. Unannounced import tariff hikes lead to rising home price markups upon impact. But announced future import tariff hikes may lead to temporary domestic markup decreases in the run up to the trade shock.

Deep habits are not needed to show that home price markups rise when import tariffs increase. This can also arise in an oligopolistically-competitive market structure without deep habits (e.g. Atkeson & Burstein (2008)). But without deep habits, there is no motive for consumer demand to be persistent and therefore, without any other source of persistence, anticipation of future trade shocks does not play any role for the optimal markup response. In the context of monopolistic competition, Krugman (1979) also argues that markups fall when moving from autarky to free trade, but does not explicitly specify the underlying preferences that would generate this response. We show that this arises when we incorporate the deep habit framework of Ravn et al. (2006) into an otherwise standard new trade theory.

4.7 Canonical Representation

Our theory can easily be mapped to the empirical model presented in Section 3. First, consistent with Krugman (1979, 1980), we assume that: (i) countries use identical technology, such that $\alpha = \alpha^*$ and $\phi = \phi^*$; (ii) firms are symmetrical, such that all prices $P_{i,t}(\omega)$ and output $X_{i,t}(\omega)$ are identical across firms within each country; (iii) countries are equally-sized, such that $L = L^*$, $\Psi = \Psi^*$, and $\Omega = \Omega^*$; (iv) there is full employment $L = \Psi$ and $L^* = \Psi^*$; (v) iceberg costs are identical shipping inwards and outwards, such that $\tau_t = \tau_t^*$, which rules out international arbitrage opportunities; (vi) trade is balanced at all times, which imposes an aggregate feasibility constraint $\int_0^\Psi P_t C_t(\psi)d\psi = \int_0^\Psi W_t h(\psi)d\psi$; (vii) tastes are identical across individuals and across countries, such that in equilibrium $C_t = \int_0^\Psi C_t(\psi)d\psi$ and $X_{i,t}(\omega) = \int_0^\Psi X_{i,t}(\psi,\omega)d\psi$; (viii) home wage is the *numeraire*, such that $W_t = 1$; and (ix) labour is supplied inelastically, such that $h(\psi) = 1$ at all times.

Second, if we define $S_{F,t}(\omega) = (P_{F,t}(\omega)X_{F,t}(\omega))/(P_t C_t)$ as the import penetration ratio (IPR) and $S_{H,t}(\omega) = (P_{H,t}(\omega)X_{H,t}(\omega))/(P_t C_t)$, then the feasibility constraint of the households implies that $S_{H,t} + S_{F,t} = 1$, where $S_{H,t} = \int_0^\Omega S_{H,t}(\omega)d\omega$ and $S_{F,t} = \int_0^{\Omega^*} S_{F,t}(\omega)d\omega$. And due to the perfect cross-border symmetry, we have $P_{F,t} = P_{H,t}^* = \tau_t P_{H,t}$, $X_{H,t} = X_{F,t}^*$, $X_{F,t} = X_{H,t}^*$, which implies that $S_{H,t} = S_{F,t}^* = 1 - S_{H,t}^*$. Using these assumptions and the production technology, it can easily be shown that $L = \int_0^\Omega [L_{H,t}(\omega) + L_{H,t}^*(\omega)]d\psi = \Omega$ (see Appendix C). Hence, in equilibrium, the size of the economy is fixed, which implies that prices and output adjust so as to satisfy the zero firm entry or exit condition. The zero profit condition of the firms then implies that $S_{i,t} = \alpha + X_{i,t}/(\Omega\phi)$, such that the equilibrium stock of habits $X_{i,t-1} = \Omega\phi(S_{i,t-1} - \alpha)$ becomes a function of the lagged consumption share $S_{i,t-1}$, the mass of varieties Ω, and the size of the fixed production costs α.

We now suppress the country-specific subscripts by denoting $S_{H,t} := s_t$, $\phi P_{H,t} := \mu_t$, and $C_t := c_t$. Then because τ_t is determined exogenously (see equation (4.4)), we establish a simple canonical representation model that involves just three equations:[6]

$$\text{PP:} \quad \mu_t = \left(\frac{\eta}{\eta - 1}\right) \frac{s_t}{s_t + \theta\beta\mathbb{E}_t\left[s_{t+1}\right]}, \tag{4.7}$$

$$\text{SS:} \quad s_t = \Gamma_s \left(\mu_t c_t\right)^{1-\eta} \left(s_{t-1} - \alpha\right)^{\theta(\eta-1)}, \tag{4.8}$$

$$\text{CC:} \quad \mu_t c_t = \Gamma_c \left[(s_{t-1} - \alpha)^{\theta(\eta-1)} + \tau_t^{1-\eta}(1 - s_{t-1} - \alpha)^{\theta(\eta-1)}\right]^{1/(\eta-1)}, \tag{4.9}$$

where $\Gamma_s = (\Omega\phi)^{(1+\theta)(\eta-1)} > 0$ and $\Gamma_c = \Omega^{1/(\eta-1)}(\Omega\phi)^{1+\theta} > 0$ are constants. PP fully characterises the optimal time-varying price markup $\mu_t > 1$; SS represents the consumer demand for home varieties that with habits $\theta > 0$ generates a persistent adjustment of the IPR (measured as $1 - s_t$); and CC combines consumer preferences (4.1) with the demand for home and foreign varieties and the aggregate feasibility constraint, which in general equilibrium simplifies to $C_t = L/P_t$ (see Appendix C). Ultimately, real consumption C_t and the consumer price index P_t are inversely related, which is a common result in the modern trade literature (see Arkolakis et al. (2012)).

Markups are time-varying if and only if there are deep habits $\theta > 0$ and if there are trade shocks $\varepsilon_t \neq 0$. To see this, note that without deep habits, such that $\theta \to 0$, and without iceberg costs, such that $\tau_t \to 1$, the model is static, which implies fixed markups $\mu_t = \bar{\mu} = \eta/(\eta - 1)$, fixed consumption $\bar{c} = 2^{1/(\eta-1)}\Omega^{1/(\eta-1)}\Omega\phi/\bar{\mu}$, and fixed IPR given by $1 - \bar{s} = (2\Omega - 1)/(2\Omega)$. This can be regarded as the "first-best" allocation of the benevolent social planner. With iceberg costs and shocks, such that $\tau_t > 1$ and $\varepsilon_t \neq 0$, but without habits $\theta \to 0$, it is easy to see that markups remain fixed $\mu_t = \bar{\mu} = \eta/(\eta - 1)$.[7]

4.8 Parameter Calibration

Table 1 presents the values of the calibrated parameters in our model. We set $\beta = 0.95$ in line with the standard real business cycle literature. We normalise the level of productivity to unity, such that $\phi = 1$. The value of the import penetration ratio (IPR) measured as $1 - \bar{s} = 0.07$ is taken from Arkolakis et al. (2012), such that the home bias parameter $\bar{s} = 0.93$. The price markup is set equal 20%, such that $\mu = 1.2$, which implies the standard value for the elasticity of substitution $\eta = 6$ absent of habits (i.e. when $\theta \to 0$). We set the steady state value of the iceberg costs $\bar{\tau}$ equal to 1.678, which corresponds closely to the trade cost estimates of Anderson & van Wincoop (2004). We set the scale of fixed costs γ equal to 0.03, which satisfies the non-negativity constraint for foreign output in the steady

[6]Using the definition of $s_t = p_t x_t = \alpha + x_t/\Omega\phi$, where $P_{H,t} := p_t$ and $X_{H,t} := x_t$, we can show that $\mu_t = 1 + \Omega\phi\alpha/x_t$, which is analogous to what Krugman (1979) refers to as the downward-sloping ZZ relationship only it describes the two-dimensional space of (p_t, x_t).

[7]When there are habits $\theta > 0$, but there are no trade shocks, is a situation that describes the steady state, in which markups are fixed, but lower than in the model without habits by a factor of $1/(1 + \theta\beta)$. For this reason, we calibrate the steady state markup $\bar{\mu}$ to a standard value in the literature and choose the habit intensity parameter θ, which restricts the price elasticity of demand $\eta = \bar{\mu}(1 + \theta\beta)/(\bar{\mu}(1 + \theta\beta) - 1)$.

state (i.e. $1-(1+\gamma)\bar{s}>0$). Following Ravn et al. (2006), we set the baseline value for the habit intensity θ equal to 0.1, such that $\eta \simeq 4.18$ keeping $\mu = 1.2$ fixed. For the sake of robustness, we present the simulation results with both higher and lower values of θ (i.e. $\theta = 0$ and $\theta = 0.2$). In order to examine how much trade persistence habits generate, we initially set $\rho = 0$, such that the law of motion for the iceberg costs simplifies to a MA(1) process. We also explore the role of the more empirically relevant gradual trade cost adjustments, where we set $\rho = 0.7$. Finally, we set $\sigma = 0.01 \times (1-\rho)$, which allows us to generate a one percentage point rise in the iceberg costs in the case when their shocks are immediate (i.e. $\rho = 0$) and when they are gradual (i.e. $\rho = 0.7$).

Table 1: Baseline Calibration of Parameters

Parameter	Value	Description
β	0.95	Time Preference
ϕ	1	Productivity
μ	1.2	Gross Price Markup
γ	0.03	Scale of Fixed Entry Costs
$1-\bar{s}$	0.07	Import Penetration Ratio (IPR)
$\bar{\tau}$	1.678	Iceberg Costs
ρ	$[0, 0.7]$	Shock Persistence
σ	0.01	Size of Shocks
θ	$[0, 0.1, 0.2]$	Habit Intensity

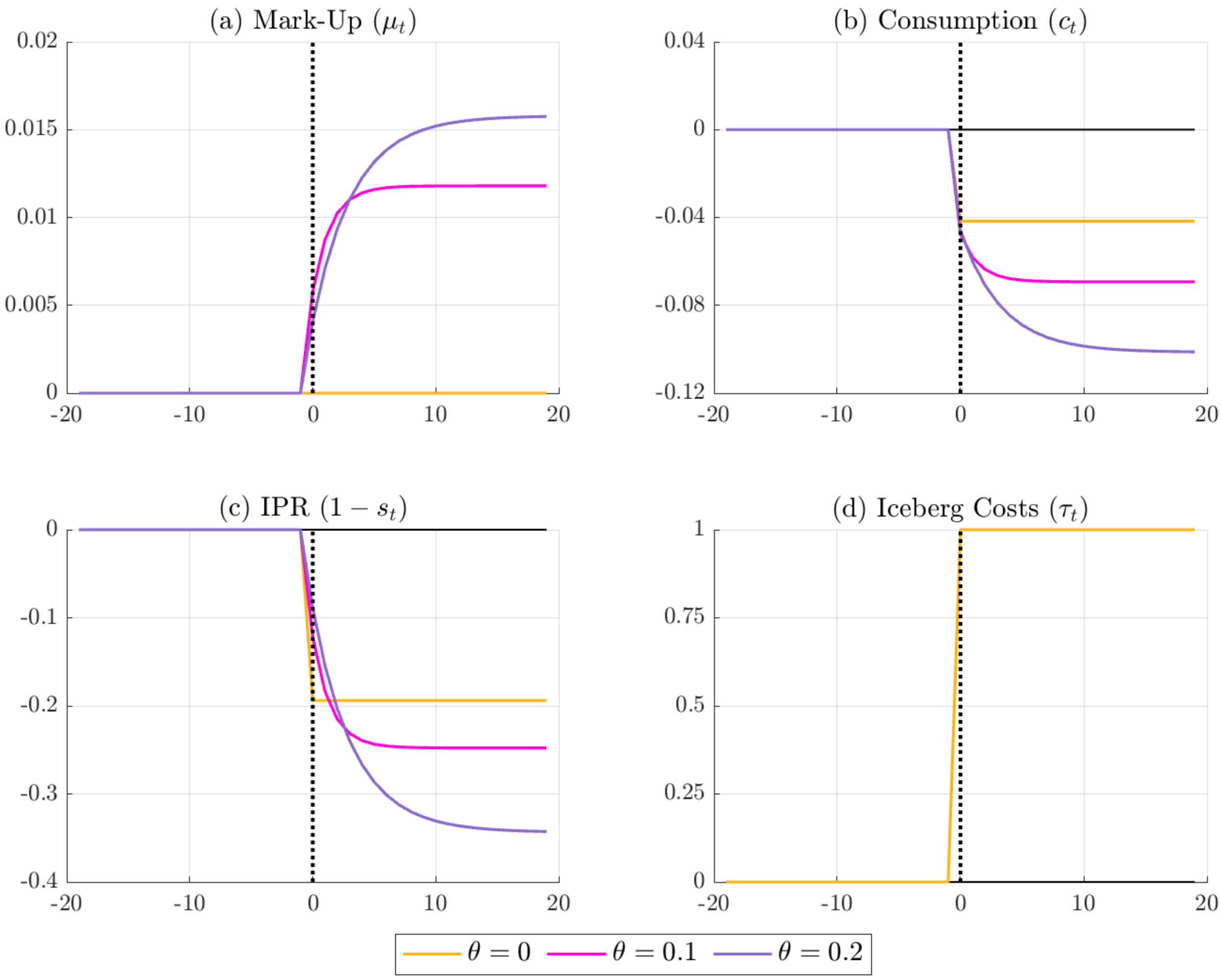
4.9 Transitional Dynamics: Unanticipated Trade Shocks

Consider an exogenous and unanticipated 1% rise in the level of the iceberg costs τ_t. We study how the PP-SS-CC model responds: (i) with and without deep habits $\theta \geq 0$; and (ii) when the iceberg costs rise by 1% immediately or gradually $\rho \geq 0$. Figure 2 presents the impulse responses for different levels of the habit intensity θ assuming that the shock to the iceberg costs is immediate, such that $\rho = 0$. Conversely, Figure 3 presents the impulse responses when the shock to the iceberg costs is gradual, such that $\rho = 0.7$, which takes around 10-15 periods for τ_t to rise by 1%. All shocks to the iceberg costs in what follows are permanent. This means that shocks to the iceberg costs cause the economy to move from the initial steady state to the new steady state and stay there permanently. The transitional dynamics in-between those steady states are fully characterised by the impulse responses.

(i) Without deep habits ($\theta = 0$)**.** When habits are switched off, Figures 2 and 3 show that the transitional dynamics are driven solely by the sequencing of the shock to the iceberg costs (see yellow solid line). With immediate shocks $\rho = 0$, there are no transitional dynamics. Instead, there is an abrupt rise in the iceberg costs of 1% at date $t = 0$ (Figure 2(d)). IPR falls by around 0.2% and stays there indefinitely (Figure 2(c)). Consumption falls by around 0.04% and also stays permanently lower (Figure 2(b)). With gradual shocks $\rho = 0.7$, there are transitional dynamics insofar as it takes 10-15 periods for the iceberg costs to rise by 1% from date $t = 0$ onwards (Figure 3(d)). Similarly, it takes time for IPR and consumption to fall by around 0.2% and 0.04%, respectively, but eventually they fall by the exact same magnitude as if shocks to the iceberg costs were immediate. Without habits, markups remain fixed with both immediate and gradual shocks, because the price elasticity of demand $\eta > 1$ is constant (Figures 2(a) and 3(a)). Intuitively, the rise in iceberg costs pushes up the price of home imports from foreign; home imports less foreign goods overall, but continues to consume an equal amount of each foreign variety; and home consumption falls, because the aggregate consumer price at home rises (i.e. income effect).

(ii) With deep habits ($\theta > 0$) **and immediate trade shocks** ($\rho = 0$)**.** Figure 2 shows how the transitional dynamics change when we set $\theta = 0.1$ and $\theta = 0.2$, but for now we keep $\rho = 0$ (see pink and purple solid lines). First, notice that even if shocks are immediate, there are transitional dynamics, such that the higher the value of θ, the longer it takes for the economy to transition from the initial steady state to the new steady state.

Figure 2: Permanent, Immediate, and Unanticipated 1% Increase in Iceberg Costs

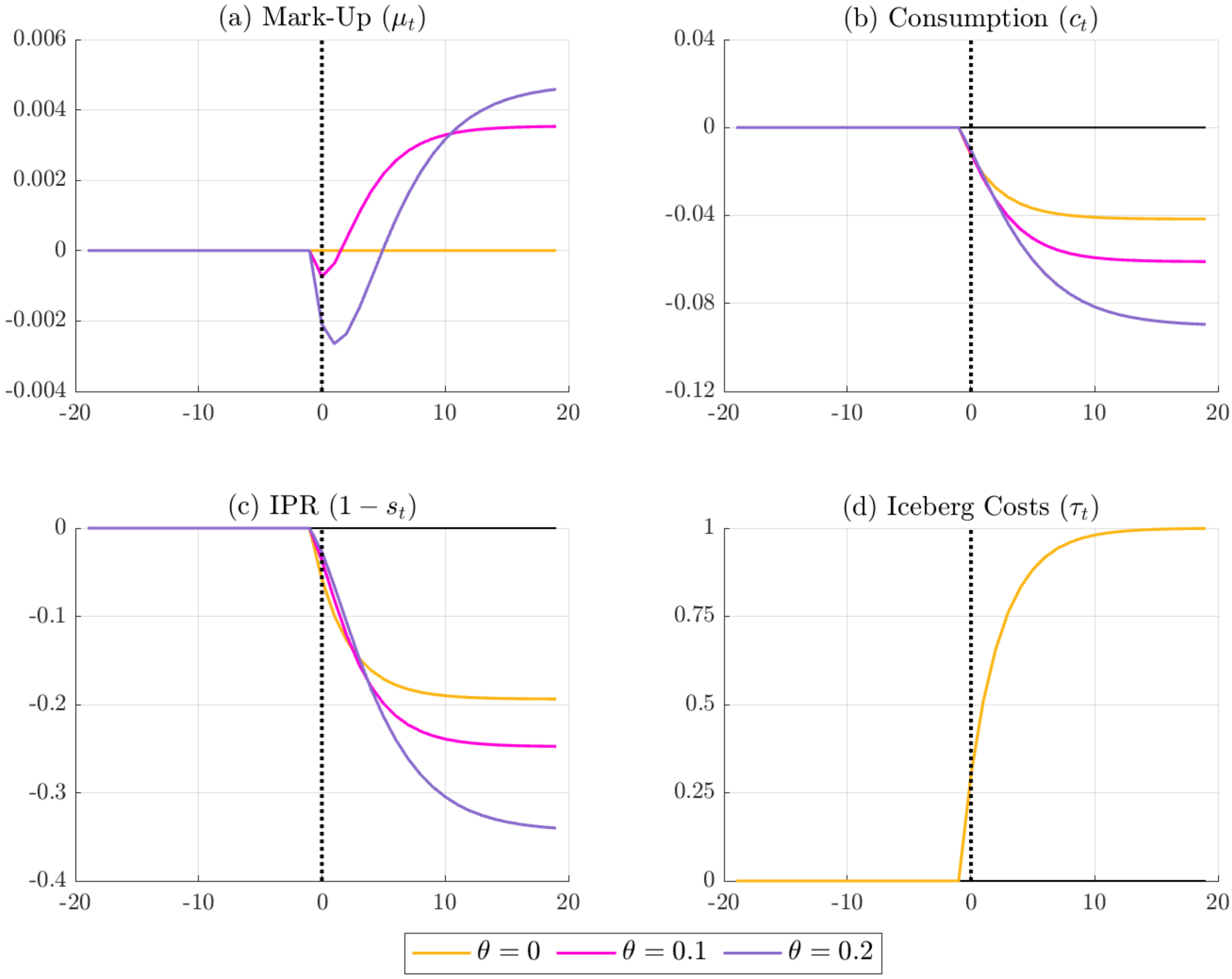


The figure displays impulse response functions (IRFs) following a permanent, immediate, and unanticipated one percentage point rise in the iceberg costs at date $t = 0$, such that $\Delta\tau_0 = 0.01$ and $\rho = 0$. The vertical axis measures percentage point deviations from the steady state. The horizontal axis indicates discrete time periods. The IRFs are depicted for the home price markup (μ_t), consumption (c_t), and home bias (s_t). There are three different cases: (i) no habits (i.e. yellow line when $\theta = 0$); (ii) baseline habit intensity (i.e. pink line when $\theta = 0.1$); and (iii) high intensity of habits (i.e. purple line when $\theta = 0.2$). When the shocks to the iceberg costs are unanticipated, we solve the model using a first-order perturbation to the policy function (Schmitt-Grohé & Uribe (2004)). This approach amounts to deriving the laws of motion for each so-called *control* variable (i.e. μ_t, c_t, s_t, τ_t) in terms of the *state* variables (i.e. s_{t-1}, τ_{t-1}) and the stochastic shock (i.e. ε_t). Because our equilibrium conditions are non-linear, a closed form solution to the model does not exist. Instead, we focus on a linear approximation around the steady state, which is the standard approach in the real business cycle literature (see online appendix E for technical details).

Second, observe that with higher values of θ, the initial impulse responses of the markup and the IPR are noticeably subdued, but the long-run responses of all endogenous variables are all significantly amplified. Specifically, with $\theta = 0.2$, consumption eventually falls by more than 0.1%, which is more than double the response when habits were switched off (compare Figure 2(b) for $\theta = 0$ and $\theta = 0.2$). Intuitively, consumers with deep habits do not switch from consuming foreign to consuming home varieties right away, because "old habits die hard". This explains the subdued initial response of the IPR. But over time, the "Joneses" start to shift their consumption from foreign to home varieties. The "Smiths" observe this shift in consumer sentiment and slowly follow suit. The "Joneses" observe that the "Smiths" shifted their consumption and they start to "catch up" with the "Smiths". This feedback loop continues until eventually the "Joneses" and the "Smiths" "catch up" with one another, at which point the economy reaches the new steady state. This "catching up with the Joneses" explains why the long-run response of the IPR is amplified. In turn, home firms face growing demand for home varieties due to the shrinking IPR. But home firm sales grow at an exponentially diminishing rate, because "catching up with the Joneses" eventually stops. Their optimal response is to raise markups upon the impact of the shock and keep gradually raising them until it stops. Hence, if firms raise markups all the way to the new steady state at once, prices are initially too high, and they prevent some of the "Joneses" from switching, which in turn fewer "Smiths" follow suit. This invites new firms to enter the home market and thus cannot be the optimal response of the incumbents. If firms instead keep markups fixed, prices are initially too low, the unit costs exceed the marginal revenue, and firms fail to maximise profits, which is again a sub-optimal response.

(iii) With deep habits ($\theta > 0$) **and gradual trade shocks** ($\rho > 0$)**.** Figure 3 illustrates the case of non-zero habit intensity $\theta > 0$ and gradual shocks $\rho = 0.7$ (see pink and purple solid lines), such that there are two different sources of transitional dynamics. First, notice that markups adopt a "J-curve" response consistent with the SVAR model predictions presented in Section 3 (compare Figures 1(a) and 3(a)). The only cause for caution is that the empirical IRFs from the SVAR portray a temporary trade shock, while the theoretical (cumulative) IRFs describe a permanent shock. However, with greater habit intensity $\theta > 0$, markups initially fall by more, but also rise by more in the long-run. Overall, markups rise by less if shocks are gradual than when shocks are immediate (compare Figures 2(a) and 3(a) for $\theta = 0.1$ and $\theta = 0.2$). Second, observe that the IPR adopts an "S-shaped" response, such that it takes longer for it to start falling when shocks are gradual, but eventually it nonetheless falls by around the same magnitude as when shocks were immediate (compare Figures 2(c) and 3(c)). Third, consumption takes longer to reach the new steady state and it falls noticeably less, namely less than 0.09% when shocks are gradual compared to just over 0.1% when shocks were immediate (compare Figures 2(b) and 3(b)). Intuitively, with gradual shocks, "catching up with the Joneses" takes longer to start, because the initial change in the iceberg costs is much lower. This explains why the IPR adopts an "S-shaped" response. Firms therefore initially cut markups, because they initially expect future sales to grow faster than they do upon impact. But when "catching up with the Joneses" starts, the timing of which depends on the values of parameters $\theta > 0$ and $\rho > 0$, firms start to gradually raise markups, because they expect future sales to grow at a slower rate. Markups therefore rise by less in the long-run, because with gradual shocks, there is a time window when "catching up with the Joneses" gradually intensifies before it subsides and ultimately stops. Hence, the "S-shaped" adjustment path of the IPR fully characterises the "J-curve" response of the markup. And because the markup ultimately rises by less, consumption also falls by less. Consequently, when preferences are subject to deep habits, welfare, measured in units of consumption, crucially depends on the sequencing of the trade shocks, such that a gradual phase in of an increase in iceberg costs leads to a superior welfare outcome compared to a "cold-turkey" trade shock.

Figure 3: Permanent, Gradual, and Unanticipated 1% Increase in Iceberg Costs



The figure displays impulse response functions (IRFs) following a permanent, gradual, and unanticipated one percentage point rise in the iceberg costs at date $t = 0$, such that $\Delta\tau_0 = 0.01 \times (1 - \rho)$ and $\rho = 0.7$. The vertical axis measures percentage point deviations from the steady state. The horizontal axis indicates discrete time periods. The IRFs are depicted for the home price (p_t), consumption (c_t), and home bias (s_t). There are three different cases: (i) no habits (i.e. yellow line when $\theta = 0$); (ii) baseline habit intensity (i.e. pink line when $\theta = 0.1$); and (iii) high intensity of habits (i.e. purple line when $\theta = 0.2$). When the shocks to the iceberg costs are unanticipated, we solve the model using a first-order perturbation to the policy function (Schmitt-Grohé & Uribe (2004)). This approach amounts to deriving the laws of motion for each so-called *control* variable (i.e. μ_t, c_t, s_t, τ_t) in terms of the *state* variables (i.e. s_{t-1}, τ_{t-1}) and the stochastic shock (i.e. ε_t). Because our equilibrium conditions are non-linear, a closed form solution to the model does not exist. Instead, we focus on a linear approximation around the steady state, which is the standard approach in the real business cycle literature (see online appendix E for technical details).

5 Anticipated Trade Shocks

Not all trade shocks come to the firms and households as a complete surprise. In fact, Moser & Rose (2012) show that many large scale Free Trade Agreements (FTAs) take months, if not years, to negotiate. And even when the terms of the new trade deals are eventually hammered out, the actual changes in policy-based measures of trade barriers, such as import tariffs, are usually announced well in advanced and phased in gradually. Therefore, we now study what role, if any, anticipation of trade shock plays for the transitional dynamics of the price markups. We first revisit the empirical SVAR model and propose a structural way of identifying anticipated trade shocks in the data. We then infer the empirical impulse responses and compare the transitional dynamics of the price markups with and without anticipation. After that, we go back to our theoretical model with deep habits and solve for the transitional time paths of each variable in the context of perfect foresight about the expected future size of the iceberg costs, which mimics our empirical identification strategy.

5.1 Empirical Impulse Responses: Anticipated Trade Shocks

As before, we infer the transitional dynamics of markups following anticipated trade shocks using IRFs obtained by estimating a SVAR with the exact same dataset. However, anticipated trade shocks are identified using a different strategy. Recall that we identify unanticipated trade shocks as an increase in TRF_t and a simultaneous decrease in CON_t and IPR_t. We now argue that anticipated trade shocks upon impact cause the exact same simultaneous decrease in CON_t and IPR_t, but initially TRF_t remains unchanged. In other words, the macroeconomy reacts to the trade shock before it realises – an anticipated shock. Our identification strategy therefore relies on restricting the signs of $\text{IRF}_0^{\text{CON}} < 0$, $\text{IRF}_0^{\text{IPR}} < 0$, and setting $\text{IRF}_0^{\text{TRF}} = 0$, but only upon the impact of the trade shock, thereby allowing them to adjust freely thereafter. We adopt this simultaneous sign- and zero-restriction approach by following the footsteps of Mountford & Uhlig (2009), who implement this identification strategy in the context of anticipated fiscal policy shocks. However, our approach is arguably less restrictive (i.e. more "agnostic"), because they restrict the IRF of government spending to equal zero for four consecutive quarters after the announcement of the shock. By contrast, we only restrict IRFs upon the impact of the shock, not thereafter. Arias et al. (2019) adopt a similar approach of identifying anticipated monetary policy shocks.

Figure 4 presents the estimated impulse responses following an anticipated TRF_t shock (refer to Appendix H for the evidence with alternatively de-trended variables). As expected, upon impact, $\text{IRF}_0^{\text{CON}}$ and $\text{IRF}_0^{\text{IPR}}$ both fall and $\text{IRF}_0^{\text{TRF}}$ stays equal to zero. However, as time goes on, $\text{IRF}_h^{\text{TRF}}$ rises significantly above zero before eventually taking the turn back towards zero in the long-run (Figure 4(d)). And as discussed above, this "hump-shaped" impulse response of TRF_t aptly characterises the gradual and anticipated nature of many trade shocks observed practice. By contrast, when trade shocks were unanticipated, $\text{IRF}_h^{\text{TRF}}$ increased upon impact and gradually decayed to zero (Figure 1(d)). Based on this "hump-shaped" impulse response of TRF_t, we see that the transitional dynamics of MKP_t are fundamentally different during the initial 4 quarters, but near-identical after 8-12 quarters (compare Figures 1(a) and 4(a)). Specifically, $\text{IRF}_h^{\text{MKP}}$ continues to exhibit the shape of a "J-curve", but with anticipated trade shocks, it first falls significantly below zero before it starts to rise. By contrast, with unanticipated trade shocks, $\text{IRF}_h^{\text{MKP}}$ initially remains in the neighbourhood of zero before it starts to rise. The empirical evidence therefore suggests that with anticipated trade shocks, markups may actually fall in the run up to the realisation of that trade shock, but they do nonetheless "take off" after the shock hits the economy similar to the unanticipated trade shock scenario.

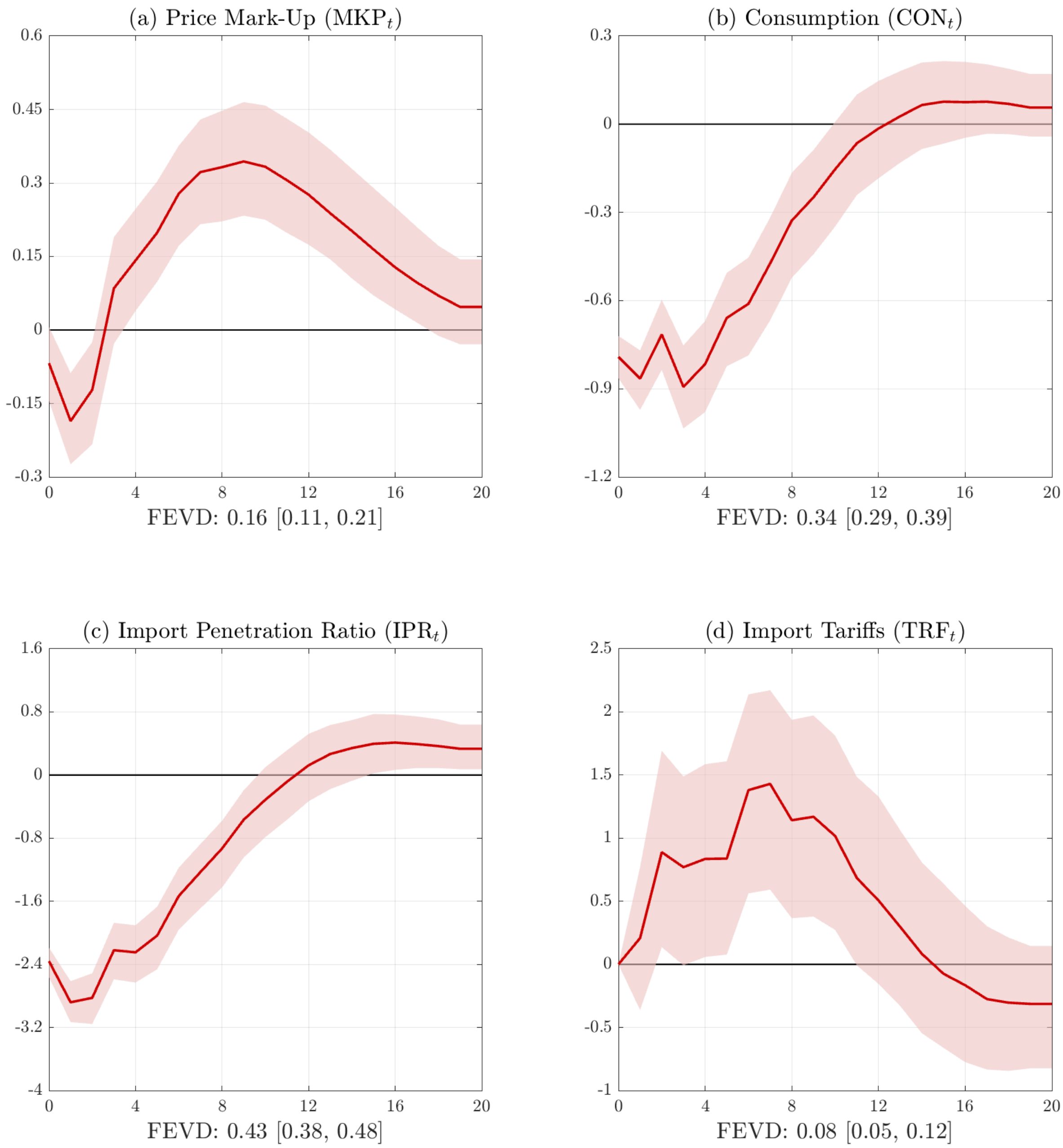
We are not the first to document the fact that anticipation of trade shocks plays a role in terms of trade adjustment dynamics. For instance, Khan & Khederlarian (2021) analyse the anticipation effects of NAFTA and show that there was a significant decline of U.S. import volumes in the run up to the U.S. import tariff cuts. They argue that trade slowed down, because firms started to run down their inventories of intermediate imports in anticipation of lower trade costs in the future, which explains why "trade got worse before it got better" with a particular emphasis on the extensive margin (i.e. volumes). We acknowledge that firm inventories play an important role in trade adjustment dynamics, but show that the same adjustment patterns apply to the intensive margin (i.e. markups), which suggests that anticipation effects may be even larger than previously thought. Specifically, in the context of an anticipated trade liberalisation, our empirical model predicts that markups first rise in the run up to the trade shock and fall after the shock hits the economy, such that "trade gets much worse before it gets much better". Quantifying the magnitude of exactly by how much goes beyond the scope of this paper, but our analysis shows that trade shocks explain around 10-15% of the variation in markups depending on whether shocks are anticipated or unanticipated (see FEVD numbers in Figures 1(a) and 4(a)). This suggests that the intensive margin of trade adjustment dynamics can also be important, because small changes in markups can lead to considerable welfare gains.

5.2 Theoretical Time Paths: Anticipated Trade Shocks

We now study the transitional dynamics predicted by our theoretical model with deep habits following anticipated trade shocks in order to see how well they match the predictions of the empirical impulse responses. As before, we consider how the PP-SS-CC model responds: (i) with and without deep habits $\theta \geq 0$; and (ii) when the iceberg costs rise by 1% immediately or gradually $\rho \geq 0$. The difference is that now the rise in iceberg costs is known to both firms and households in advance, such that they acquire perfect foresight about the iceberg costs throughout the transition from the initial to the new steady state. Figure 5 presents the time paths for different levels of habit intensity θ assuming that the shocks to the iceberg costs are anticipated, but immediate, such that $\rho = 0$. Conversely, Figure 6 presents the time paths when the shock to the iceberg costs is anticipated and gradual, such that $\rho = 0.7$.

Without deep habits ($\theta = 0$)**.** When habits are switched off, Figures 5 and 6 once again show that the only other source of transitional dynamics is the sequencing of the shock to the iceberg costs (see yellow solid line). However, notice that the theoretical responses following anticipated trade shocks without habits are exactly identical to the ones where shocks were unanticipated irrespective of whether shocks are immediate or gradual (compare

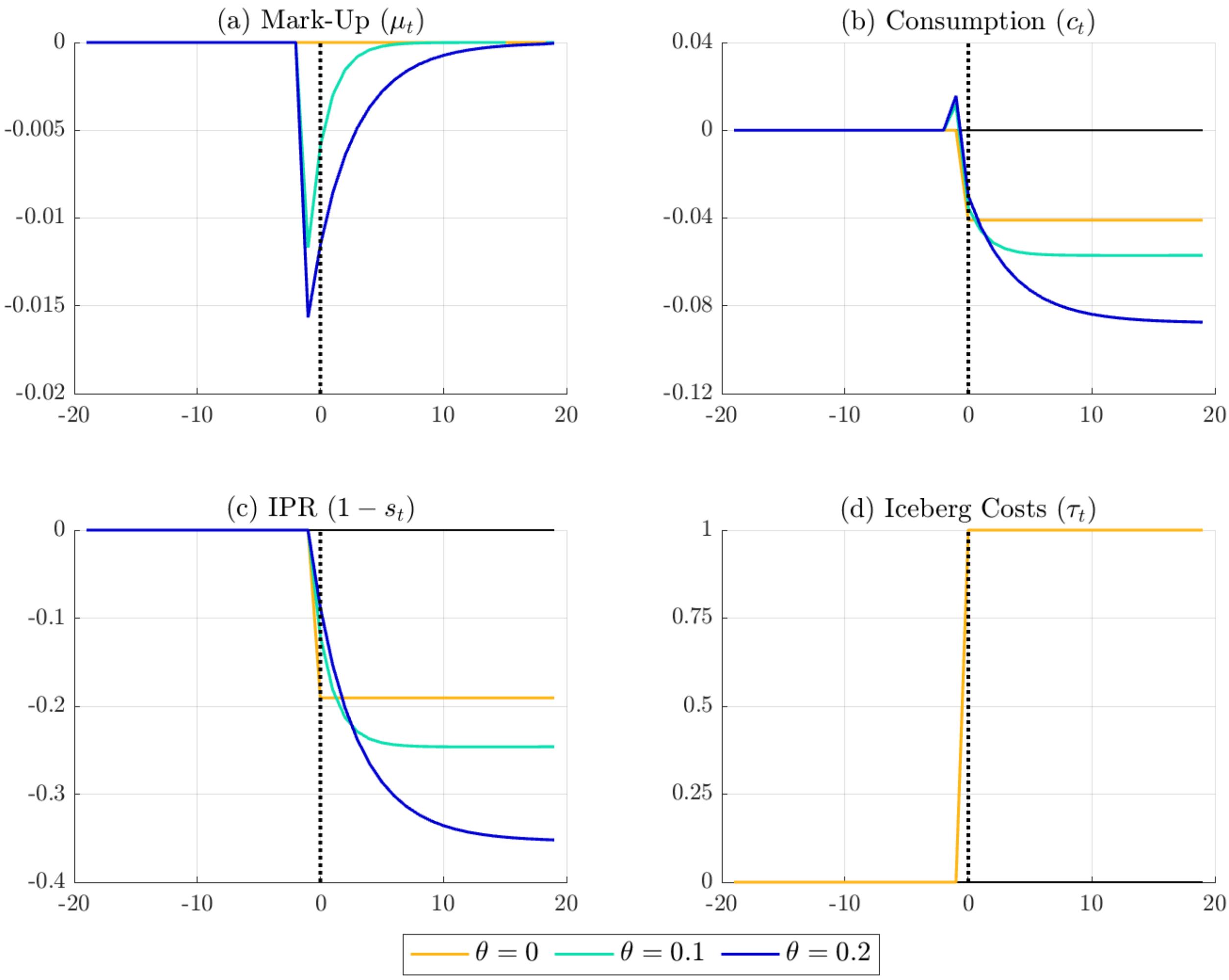
Figure 4: Transitional Dynamics with Anticipated Trade Shocks (SVAR)



The figure displays impulse responses following an anticipated shock to the U.S. import tariffs equal to the size of one standard deviation. The horizontal axes measure the time horizon $h = \{0, 1, 2, ...\}$ and the vertical axes indicate the log scale for the cyclical components of each variable. The solid lines are the point-wise posterior medians. The shaded areas are the 68 percent equal-tailed point-wise probability bands. Each figure is based on 1000 independent draws obtained using a Bayesian approach due to Uhlig (2005). The cyclical components of each variable are obtained using the Hamilton (2018) filter. The SVAR model is estimated with a lag order of 4 quarters and includes a constant term in each equation. The Forecast Error Variance Decomposition (FEVD) displayed underneath each IRF measures the share of variation in that variable explained by anticipated trade shocks with confidence bands displayed in square brackets.

Figures 2 with 5 and Figures 3 with 6). This is because without deep habits, expectations about the future size of the iceberg costs do not play any role in trade adjustment dynamics. Hence, without deep habits, consumer preferences and the resulting demand for varieties are both static, such that firms have no motive to optimise inter-temporally, a result which is consistent with the bulk of the modern trade literature. However, this result seems to be at odds with the data for two reasons. First, without habits, the theory predicts that markups are fixed, but our estimated impulse responses from the data suggests that they adjust in response to trade shocks. Second, because without habits, anticipation plays no role in our theory, but empirical impulse responses are significantly different under the two different identification strategies that we propose.

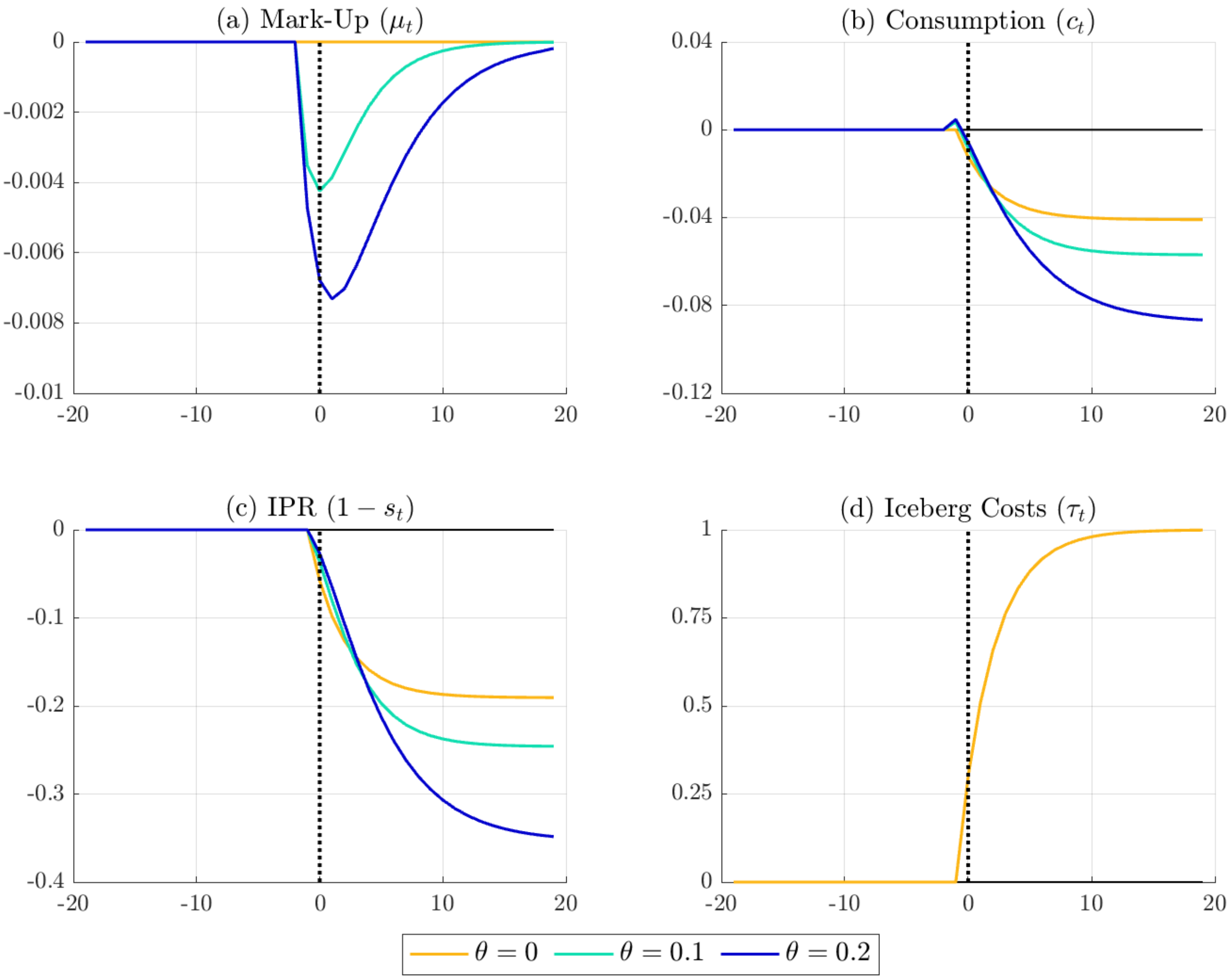
Figure 5: Permanent, Immediate, and Anticipated 1% Increase in Iceberg Costs



The figure displays endogenous variable time paths conditional on a permanent, immediate, and anticipated one percentage point rise in the iceberg costs at date $t = 0$, such that $\Delta\tau_0 = 0.01$ and $\rho = 0$. The vertical axis measures percentage point deviations from the steady state. The horizontal axis indicates discrete time periods. The time paths are depicted for the home markup (μ_t), consumption (c_t), and home bias (s_t). There are three different cases: (i) no habits (i.e. yellow line when $\theta = 0$); (ii) baseline habit intensity (i.e. turquoise line when $\theta = 0.1$); and (iii) high intensity of habits (i.e. blue line when $\theta = 0.2$). When shocks to the iceberg costs are anticipated, firms and households acquire perfect foresight and the transitional dynamics with rational expectations are deterministic and can be solved for directly by conditioning the system of equations on the time path of the shocks (Laffargue (1990), Boucekkine (1995), Juillard (1996)). But just as in the case of unanticipated shocks, a closed form solution to the time paths does not exist as the equilibrium conditions of the model are non-linear. Our chosen solution method therefore applies an iterative *Newton-Raphson* algorithm, which generates a first-order accurate solution to the time paths (see online appendix F for technical details). The results from the unanticipated and anticipated shock scenarios are directly comparable.

With deep habits ($\theta > 0$) **and immediate trade shocks** ($\rho = 0$). Figure 5 shows how the transitional dynamics are shaped when shocks to the iceberg costs are anticipated and when we set $\theta = 0.1$ and $\theta = 0.2$ keeping $\rho = 0$ (see turquoise and blue solid lines). First, notice that with habits $\theta > 0$, the initial response of the IPR is subdued, but the long-run response is amplified, which is near-identical to the case when trade shocks were immediate and unanticipated (compare Figures 2(c) and 5(c)). This can be explained by the fact that initially "old habits die hard", but over time, the "Smiths" are "catching up with the Joneses". Second, observe that exactly one period before the shock to the iceberg costs is realised, markups fall and consumption rises, which is starkly different from the adjustment dynamics when shocks were unanticipated (compare Figures 2(a) and 5(a) with

Figure 6: Permanent, Gradual, and Anticipated 1% Increase in Iceberg Costs



The figure displays impulse response functions (IRFs) following a permanent, gradual, and anticipated one percentage point rise in the iceberg costs at date $t = 0$, such that $\Delta\tau_0 = 0.01 \times (1 - \rho)$ and $\rho = 0.7$. The vertical axis measures percentage point deviations from the steady state. The horizontal axis indicates discrete time periods. The time paths are depicted for the home markup (μ_t), consumption (c_t), and home bias (s_t). There are three different cases: (i) no habits (i.e. yellow line when $\theta = 0$); (ii) baseline habit intensity (i.e. turquoise line when $\theta = 0.1$); and (iii) high intensity of habits (i.e. blue line when $\theta = 0.2$). When shocks to the iceberg costs are anticipated, firms and households acquire perfect foresight and the transitional dynamics with rational expectations are deterministic and can be solved for directly by conditioning the system of equations on the time path of the shocks (Laffargue (1990), Boucekkine (1995), Juillard (1996)). But just as in the case of unanticipated shocks, a closed form solution to the time paths does not exist as the equilibrium conditions of the model are non-linear. Our chosen solution method therefore applies an iterative *Newton-Raphson* algorithm, which generates a first-order accurate solution to the time paths (see online appendix F for technical details). The results from the unanticipated and anticipated shock scenarios are directly comparable.

2(b) and 5(b))). However, thereafter, markups start to rise and consumption falls, which is similar to the case when shocks were unanticipated. Intuitively, when home firms anticipate an increase in future sales, the home markup falls, because firms know that "old habits die hard" and if they give consumers "a head start" in terms of adjusting their stock of habits, they can boost future sales further and keep them elevated for longer. As markups fall both at home and foreign before the shock hits the economy due to their symmetry, household consumption of home and foreign varieties increases, which explains why consumption (i.e. welfare) "gets better before it gets worse", but IPR remains intact in the run up to the shock (Figure 5(c)). When the shock to the iceberg costs actually hits the economy, the "Joneses" start to switch from consuming foreign to home varieties and the "Smiths" follow suit as per usual, which causes home sales and markups to grow at an exponentially diminishing rate over time. Our model can therefore explain why the empirical impulse response of the markup initially falls before it starts to rise when trade shocks are anticipated (Figure 4). However, the theoretical model predicts that in anticipation of the trade shock markups fall so much so that in the long-run they return to the initial steady state, which is different from the our empirical findings. We argue that this can be explained by the fact that, in practice, not all firms are fully rational or the fact that trade policy announcements may contain "noisy" information that takes time and resources to process. Consequently, some firms may respond to nearly all trade shocks as if it caught them by surprise, in which case their markups adjust in line with Figure 2(a), while some respond closer to a fully-rational case and follow the adjustment path in Figure 5(a). The aggregate response would then closely correspond to the empirical impulse response depicted in Figure 4(a). We relegate the technical details of this heterogeneous firm case to future research.

With deep habits ($\theta > 0$) and gradual trade shocks ($\rho = 0$). Figure 6 presents the case of non-zero habits $\theta > 0$ with anticipated and gradual shocks to the iceberg costs $\rho = 0.7$ (see turquoise and blue solid lines). First, observe that the transitional dynamics of the IPR are once again near-identical to the case of gradual unanticipated shocks and adopts the "S-shaped" response (compare Figures 3(c) and 6(c)). We therefore conclude that in our theory, only habits, but not anticipation, can significantly alter the transitional dynamics of the IPR. More formally, this can be seen from equations (4.8) and (4.9), whose combination leads to a level of IPR that depends entirely on its lagged values and the contemporaneous iceberg costs, which are exogenous in theory. Second, notice that markups fall in the run up to the trade shock even if they are phased in gradually. And, with higher habit intensity $\theta = 0$, markups continue to fall for 1-2 periods after the shock hits the economy (Figures 6(a)). However, the scale of the initial fall in markups is considerably smaller. Consequently, consumption rises significantly less in the run up to the trade shock, such that "welfare does not get noticeably better before it gets worse".

Given that most trade shocks in practice are gradual and anticipated in advance, our theory suggests that anticipatory consumption dynamics in the run up to trade shocks are likely to be negligible. This is an important result for two reasons. First, our theory predicts that the welfare gains that come from the anticipation of trade shocks are unlikely to be economically significant. Second, it validates our empirical identification strategy, which defines anticipated trade shocks as a simultaneous decrease in consumption and IPR keeping import tariffs fixed upon impact. And because our theory suggests that consumption remains largely intact in the run up to the trade shock, especially when trade shocks are phased in gradually, we argue that the transitional dynamics in Figure 4 are in fact characterising an anticipated trade shock.

6 Dynamic Trade Elasticity

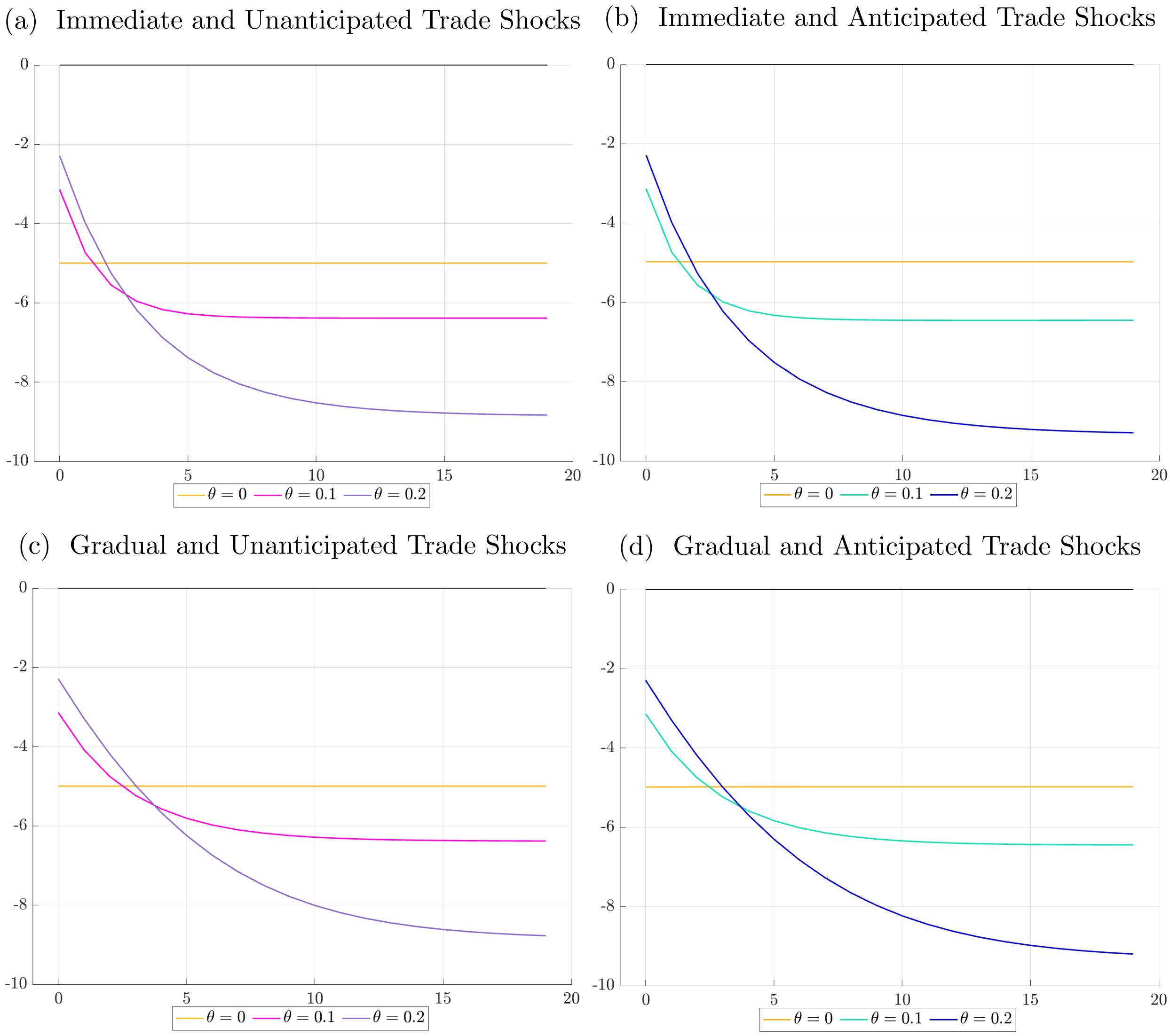
We turn to the discussion about the theoretical effects of deep habits and anticipation on the so-called *trade elasticity* as it is often used to assess the welfare gains from trade (see Anderson & van Wincoop (2004), Arkolakis et al. (2012), Head & Mayer (2014), Imbs & Mejean (2015), Feenstra et al. (2018), Boehm et al. (2020)). The trade elasticity measures the percentage change in the value bilateral trade flows due to a percentage change in trade costs. Arkolakis et al. (2012) famously show that in a wide class of static trade models, the trade elasticity is constant and equal to $1 - \eta < 0$, where $\eta > 1$ is the *Armington elasticity*. But more recently, some argue that trade elasticity is dynamic and increasing (in absolute value) over time, such that in the short-run, trade flows are less responsive to trade costs than in the long-run (Boehm et al. (2020), Alessandria et al. (2021)).

Figure 7 shows the theoretical predictions of the trade elasticity in our model: (i) with and without deep habits $\theta \geq 0$; (ii) with immediate and gradual shocks $\rho \geq 0$; and (iii) with anticipated and unanticipated shocks to the iceberg costs. First, we find that without deep habits, such that $\theta = 0$, the trade elasticity is constant, independent of the sequencing or the anticipation of trade shocks, and equal to around -5, which is a value that is consistent with the well-established static trade elasticity estimates (e.g. Anderson & van Wincoop (2004), Arkolakis et al. (2012), Head & Mayer (2014), Imbs & Mejean (2015)). Hence, without deep habits, the IPR adjusts proportionately to the iceberg costs. Therefore, regardless of whether trade shocks are phased in gradually or immediately, the trade elasticity stays fixed. Second, we find that with deep habits $\theta > 0$, there is no short-run or long-run differences in trade elasticities, it only takes longer to transition from the old steady state to the new steady state, which affects the medium-run trade elasticity. Intuitively, with gradual shocks, IPR adjusts less upon impact, but iceberg costs also rise by less upon impact, keeping the trade elasticity independent of shock sequencing. However, because trade costs initially adjust by less, it takes longer for the "Smiths" to start "catching up with the Joneses". But once they start to "catch up" and the rise in iceberg costs is fully phased in, in the long-run, the IPR adjusts by the exact same magnitude as if shocks were immediate. Third, we find that with deep habits $\theta > 0$, the trade elasticity is initially smaller (in absolute value) than the static trade elasticity, because "old habits die hard", but in the long-run, due to the "catching up with the Joneses", the trade elasticity is significantly larger (in absolute value). Hence, deep habits subdue the initial response of the IPR to shocks, but over time, they also cause a feedback loop between the "Smiths" that are "catching up with the Joneses" and the "Joneses" that are "catching up with the Smiths", which amplifies the long-run trade elasticity. The more intense are the deep habits (i.e. the higher the value of parameter θ), the greater is the discrepancy between the short-run and the long-run trade elasticities. Fourth, we find that the trade elasticity is marginally greater in the long-run (in absolute value) when shocks to the iceberg costs are anticipated than when they are unanticipated. However, this last discrepancy between the long-run trade elasticities is economically significant only for implausibly high values of θ.

7 Welfare

There are three main factors that determine the size of the welfare gains from trade in our model: (i) anticipated or unanticipated nature of the trade shocks; (ii) immediate or gradual sequencing of the trade shocks $\rho \geq 0$; and (iii) the intensity of deep habits $\theta \geq 0$.

Figure 7: Dynamic Trade Elasticity



The vertical axes measure the magnitude of the trade elasticity and the horizontal axes denote discrete time periods after the shocks to the iceberg costs. We calculate the trade elasticities numerically using the dynamic responses presented in Figures 2, 3, 5, and 6. Consistent with Alessandria et al. (2021), we first calculate the trade elasticity upon the initial impact of the shock to the iceberg costs, such that $e_0 = [\ln((1-s_0)/s_0) - \ln((1-\bar{s})/\bar{s})]/[\ln(\tau_0) - \ln(\bar{\tau})]$. Then in order to track the trade elasticity dynamics, we calculate the cumulative sum $\bar{e}_t = e_0 + \Delta e_1 + \Delta e_2 + \cdots + \Delta e_t = e_0 + \sum_{\iota=1}^{t} \Delta e_\iota$. Each subplot in this figure presents our estimates of the cumulative trade elasticity $\bar{e}_t$. If shocks to the iceberg costs are immediate (gradual), we set $\rho = 0$ ($\rho = 0.7$).

As per usual, we measure the welfare gains from trade as percentage changes in real units of consumption. We argue that when the trade shocks are not immediate $\rho > 0$ and preferences are subject to deep habits $\theta > 0$, which implies that the trade elasticity is dynamic, a closed form solution to the welfare gains from trade does not exist and applying the ubiquitous Arkolakis et al. (2012) formula in general leads to biased estimates. This point is also echoed by Alessandria et al. (2021), who assess welfare gains from trade in the context of a neo-classical trade model. Instead, we assess the welfare gains from trade in our model numerically by measuring them directly from the dynamic responses that we calculate in Figures 2, 3, 5, and 6. In keeping with the previous sections of this paper, we henceforth refer to the welfare gains from trade as the welfare cost, because we focus on trade shocks that lead to import tariff increases rather than decreases. However, in practice, the welfare gains and costs can be referred to interchangeably, because up to first order, they are equal to the additive inverse of one another.

In what follows, we discuss three different settings of our model: (i) without deep habits, in which we set $\theta = 0$; (ii) with deep habits and variable markups, which corresponds to the standard PP-SS-CC model described in equations (4.7), (4.8), and (4.9); and (iii) with deep habits, but fixed markups, in which we set $\mu_t = \bar{\mu}$ at all times. We introduce the fixed markup setting of our model in order to distinguish the welfare consequences of markups from the welfare consequences of dynamic IPR adjustment (i.e. dynamic trade elasticity). This can easily be implemented in our model, because in equilibrium, the IPR is independent of markups (substitute (4.9) into (4.8) to see this). We can therefore separate the welfare cost into the traditional static trade elasticity component, the dynamic trade elasticity component, and also the price markup component.

Table 2 presents the theoretical estimates of the welfare cost in a number of hypothetical trade shock scenarios. First, we show that without deep habits, the welfare cost of an immediate 10% increase in iceberg costs is equal to 0.7% and it is independent of anticipation or timing. With gradual sequencing of the same 10% trade shock, the short-run welfare cost is only 0.21%, but in the long-run, the welfare cost reaches the same magnitude of 0.7% as in the case of immediate trade shocks. We henceforth call this the static trade elasticity component of the welfare cost. Second, we show that with deep habits and fixed markups, the welfare cost of an immediate 10% increase in iceberg costs is also equal to 0.7% and it is also independent of anticipation, but in the long-run it increases by up to 0.96% (1.43%) if we set $\theta = 0.1$ ($\theta = 0.2$). With gradual sequencing of the same 10% trade shock, the short-run welfare cost falls to the same magnitude of 0.21% as in the absence of deep habits, but in the long-run the welfare cost rises to 0.96% (1.43%). We henceforth call this the dynamic trade elasticity component of the welfare cost. Clearly, the difference between the static and the dynamic trade elasticity components of the welfare cost is negligible in the short-run, but substantial in the long-run. Third, with deep habits and variable markups the welfare cost of an immediate 10% increase in iceberg costs upon impact is equal to 0.77-0.79% or 0.50-0.59% if the shock is unanticipated and anticipated, respectively. But in the long-run, the welfare cost rises to 1.17-1.70% and 0.95-1.50%, respectively, depending on the intensity of deep habits. With gradual sequencing of the same 10% trade shock, the short-run welfare cost is 0.18-0.20% or 0.10-0.14% if the shock is unanticipated and anticipated, respectively. But in the long-run, the welfare cost rises to 1.02-1.50% and 0.95-1.48%, respectively, depending on the intensity of deep habits. The price markup component of the welfare cost is therefore positive upon impact, increasing over time, and non-negligible in the long-run. We therefore conclude that deep habits significantly amplify the welfare cost of trade shocks, because depending on the intensity of deep habits, the sequencing of the trade shocks, and anticipation, they can more than double. Around two-thirds of the welfare cost amplification from deep habits is attributable to the dynamic trade elasticity component and around one-third to the price markup component. The most costly trade shocks are unanticipated and immediate and the least costly are anticipated and gradual. However, gradual sequencing of the trade shocks goes a long way in terms of closing the gap between the welfare cost of anticipated and unanticipated trade shocks.

8 Concluding Remarks

This paper studies the transitional dynamics of price markups following trade shocks. We present empirical evidence that an increase in U.S. import tariffs causes U.S. price markups to increase, but it takes around one year for them to take off. In the long-run, markups increase by around the same magnitude whether the trade shock is anticipated or unanticipated. However, if the trade shock is anticipated in advance, markups fall in the run up to the realisation of the trade shock and start to rise only thereafter (i.e. "J-curve" response).

Table 2: Trade Shocks, Markup Adjustments, and Welfare Gains from Trade

	(i) No Habits	(ii) Deep Habits			
		(1) Variable Markups		(2) Fixed Markups	
Trade Shocks	$\theta = 0$	$\theta = 0.1$	$\theta = 0.2$	$\theta = 0.1$	$\theta = 0.2$
(a) Unanticipated and Immediate ($\rho = 0$)					
Short-Run ($h = 0$)	-0.70%	-0.79%	-0.77%	-0.70%	-0.70%
Long-Run ($h = 20$)	-0.70%	-1.17%	-1.70%	-0.96%	-1.43%
(b) Unanticipated and Gradual ($\rho = 0.7$)					
Short-Run ($h = 0$)	-0.21%	-0.20%	-0.18%	-0.21%	-0.21%
Long-Run ($h = 20$)	-0.70%	-1.02%	-1.50%	-0.96%	-1.43%
(c) Anticipated and Immediate ($\rho = 0$)					
Short-Run ($h = 0$)	-0.70%	-0.59%	-0.50%	-0.70%	-0.70%
Long-Run ($h = 20$)	-0.70%	-0.95%	-1.50%	-0.96%	-1.43%
(d) Anticipated and Gradual ($\rho = 0.7$)					
Short-Run ($h = 0$)	-0.21%	-0.14%	-0.10%	-0.21%	-0.21%
Long-Run ($h = 20$)	-0.70%	-0.95%	-1.48%	-0.96%	-1.43%

The figure displays theoretical estimates of the welfare cost of a 10% increase in iceberg costs, such that $\Delta \ln \tau = 10\%$, which we measure as the percentage loss in real units of consumption $\Delta \ln c$. We calculate the welfare cost at different time horizons $h = \{0, 1, 2, ...\}$ based on the dynamic responses calculated in Figures 2, 3, 5, and 6.

To the best of our knowledge, the existing empirical studies focus primarily on the long-run, but not the short-run, adjustment of markups in response to trade shocks and there are no existing trade theories that would account for the transitional dynamics that we document. We argue that understanding the transitional dynamics of markups is important, because small changes in markups can have large effects on welfare gains from trade.

We develop a simple theoretical model that closely replicates the empirical impulse responses of markups inferred from the data. Our theoretical model extends the ubiquitous "new" trade theory of Krugman (1979, 1980) by incorporating deep habits into consumer preferences due to Ravn et al. (2006, 2010). Consumption habits are a widely-established empirical phenomenon and a popular analytical tool in the macro-finance literature, but we are not aware of any existing applications in the modern trade literature. With deep habits, we show that the initial impact of trade shocks is subdued, because "old habits die hard", but as time passes, consumers start to "catch up with the Joneses", which amplifies the adjustment of trade flows in the long-run. This not only helps us characterise the transitional dynamics of markups, but also generates trade elasticity dynamics similar to those documented in the recent empirical literature (Boehm et al. (2020)).

We argue that if firms are rational and forward-looking, they recognise the fact that demand for their variety is persistent due to deep habits and, if they have market power, they choose to set optimally time-varying markups. Specifically, when sales are expected to grow in the future, firms cut markups today, because if they give consumers "a head start" in terms of adjusting their habits, they can boost future sales and keep them elevated for longer. By contrast, when future sales are expected to shrink, firms increase markups today as they exploit the fact that consumers are still addicted to their variety.

We show that with deep habits, markups fall in the run up to anticipated trade shocks and rise thereafter, which is consistent with the evidence. But although markups start rising, they never rise above the steady state and, in the long-run, return to the initial steady state. By contrast, if the trade shock is unanticipated and phased in gradually, then markups initially fall, but after around 3-4 quarters, they start rise above the steady state, thereby generating the "J-curve" response similar to the empirical evidence. We conclude that deep habits can replicate the empirical impulse responses of markups when trade shocks are unanticipated. But when trade shocks are anticipated, the model provides a good description of the data only if some firms respond to nearly all trade shocks as if it caught them by surprise. This can occur if trade policy announcements contain "noisy" information that some firms may be unable to process and take into the account when planning ahead. The aggregate markup responses in theory would then closely correspond to those inferred from the data.

We show that deep habits significantly amplify the welfare cost of trade shocks. Using the baseline calibration of the model, we show that without deep habits, the static trade elasticity is around -5 and the welfare cost of a 10% increase in trade costs is around 0.7% of real units of consumption, which is in the ballpark of the ubiquitous Arkolakis et al. (2012) estimates. But depending on the intensity of deep habits, the sequencing of the trade shocks, and anticipation, they can more than double. We further show that around two-thirds of the welfare cost amplification from deep habits is attributable to the dynamic trade elasticity and around one-third to the time-varying price markups. The most costly trade shocks are unanticipated and immediate and the least costly are anticipated and gradual. However, gradual sequencing of the trade shocks goes a long way in terms of closing the gap between the welfare cost of anticipated and unanticipated trade shocks.

References

Abel, A. (1990), 'Asset Prices under Habit Formation and Catching Up with the Joneses', *American Economic Review* **80**(2), 38–42.

Alessandria, G. A., Khan, S. Y. & Khederlarian, A. (2019), Taking Stock of Trade Policy Uncertainty: Evidence from China's Pre-WTO Accession, Technical report, National Bureau of Economic Research.

Alessandria, G. & Choi, H. (2007), 'Do Sunk Costs of Exporting Matter for Net Export Dynamics?', *The Quarterly Journal of Economics* **122**(1), 289–336.

Alessandria, G., Choi, H. & Ruhl, K. J. (2021), 'Trade Adjustment Dynamics and the Welfare Gains from Trade', *Journal of International Economics* **131**, 103458.

Alvarez-Cuadrado, F., Casado, J. M. & Labeaga, J. M. (2016), 'Envy and Habits: Panel Data Estimates of Interdependent Preferences', *Oxford Bulletin of Economics and Statistics* **78**(4), 443–469.

Amiti, M., Itskhoki, O. & Konings, J. (2019), 'International Shocks, Variable Markups, and Domestic Prices', *Review of Economic Studies* **86**(6), 2356–2402.

An, L. & Wang, J. (2012), 'Exchange Rate Pass-Through: Evidence Based on Vector Autoregression with Sign Restrictions', *Open Economies Review* **23**(2), 359–380.
URL: *https://ideas.repec.org/a/kap/openec/v23y2012i2p359-380.html*

Anderson, J. E., Larch, M. & Yotov, Y. V. (2020), 'Transitional Growth and Trade with Frictions: A Structural Estimation Framework', *The Economic Journal* **130**(630), 1583–1607.

Anderson, J. E. & van Wincoop, E. (2004), 'Trade Costs', *Journal of Economic Literature* **42**(3), 691–751.

Arias, J. E., Caldara, D. & Rubio-Ramírez, J. F. (2019), 'The Systematic Component of Monetary Policy in SVARs: An Agnostic Identification Procedure', *Journal of Monetary Economics* **101**, 1–13.

Arias, J. E., Rubio-Ramírez, J. F. & Waggoner, D. F. (2018), 'Inference Based on Structural Vector Autoregressions Identified With Sign and Zero Restrictions: Theory and Applications', *Econometrica* **86**(2), 685–720.

Arkolakis, C., Costinot, A., Donaldson, D. & Rodríguez-Clare, A. (2018), 'The Elusive Pro-Competitive Effects of Trade', *The Review of Economic Studies* **86**(1), 46–80.

Arkolakis, C., Costinot, A. & Rodríguez-Clare, A. (2012), 'New Trade Models, Same Old Gains?', *American Economic Review* **102**(1), 94–130.

Atkeson, A. & Burstein, A. (2008), 'Pricing-to-Market, Trade Costs, and International Relative Prices', *American Economic Review* **98**(5), 1998–2031.

Baldwin, R. E. (1992), 'Measurable Dynamic Gains from Trade', *Journal of Political Economy* **100**(1), 162–174.

Becker, G. S. & Murphy, K. M. (1988), 'A Theory of Rational Addiction', *Journal of Political Economy* **96**(4), 675–700.

Bernanke, B. (1986), 'Alternative Explanations of the Money-Income Correlation', *Carnegie-Rochester Conference Series on Public Policy* **25**(1), 49–99.

Bhattarai, S. & Kucheryavyy, K. (2020), A Unified Model of International Business Cycles and Trade, CESifo Working Paper Series 8130, CESifo.

Bilbiie, F. O., Ghironi, F. & Melitz, M. J. (2019), 'Monopoly Power and Endogenous Product Variety: Distortions and Remedies', *American Economic Journal: Macroeconomics* **11**(4), 140–74.

Blanchard, O. J. & Kahn, C. M. (1980), 'The Solution of Linear Difference Models Under Rational Expectations', *Econometrica* **48**(5), 1305–1311.

Blanchard, O. J. & Quah, D. (1989), 'The Dynamic Effects of Aggregate Demand and Supply Disturbances', *American Economic Review* **79**(4), 655–673.

Blanchard, O. J. & Watson, M. W. (1986), Are Business Cycles All Alike?, *in* 'The American Business Cycle: Continuity and Change', NBER Chapters, National Bureau of Economic Research, Inc, pp. 123–180.

Blanchard, O. & Perotti, R. (2002), 'An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output', *The Quarterly Journal of Economics* **117**(4), 1329–1368.
URL: *https://ideas.repec.org/a/oup/qjecon/v117y2002i4p1329-1368..html*

Boehm, C. E., Levchenko, A. A. & Pandalai-Nayar, N. (2020), The Long and Short (Run) of Trade Elasticities, NBER Working Papers 27064, National Bureau of Economic Research, Inc.

Boucekkine, R. (1995), 'An Alternative Methodology for Solving Nonlinear Forward-Looking Models', *Journal of Economic Dynamics and Control* **19**(4), 711–734.

Boyer, M. (1978), 'A Habit Forming Optimal Growth Model', *International Economic Review* **19**(3), 585–609.

Boyer, M. (1983), 'Rational Demand and Expenditures Patterns Under Habit Formation', *Journal of Economic Theory* **31**(1), 27–53.

Caldara, D., Iacoviello, M., Molligo, P., Prestipino, A. & Raffo, A. (2020), 'The Economic Effects of Trade Policy Uncertainty', *Journal of Monetary Economics* **109**(C), 38–59.

Campbell, J. & Deaton, A. (1989), 'Why is Consumption So Smooth?', *The Review of Economic Studies* **56**(3), 357–373.

Campbell, J. Y. & Cochrane, J. H. (1999), 'By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior', *Journal of Political Economy* **107**(2), 205–251.

Canova, F. & Nicolo, G. D. (2002), 'Monetary Disturbances Matter for Business Fluctuations in the G-7', *Journal of Monetary Economics* **49**(6), 1131–1159.

Carrasco, R., Labeaga, J. M. & López-Salido, J. D. (2005), 'Consumption and Habits: Evidence from Panel Data', *The Economic Journal* **115**(500), 144–165.

Carrasco, R., Labeaga, J. M. & López-Salido, J. D. (2017), 'Consumption Habits and Humps', *Economic Theory* **64**, 305–330.

Carroll, C. D., Overland, J. & Weil, D. N. (2000), 'Saving and Growth with Habit Formation', *American Economic Review* **90**(3), 341–355.

Chaloupka, F. (1991), 'Rational Addictive Behavior and Cigarette Smoking', *Journal of Political Economy* **99**(4), 722–742.

Chintagunta, P. K. (1998), 'Inertia and Variety Seeking in a Model of Brand-Purchase Timing', *Marketing Science* **17**(3), 253–270.

Chintagunta, P., Kyriazidou, E. & Perktold, J. (2001), 'Panel Data Analysis of Household Brand Choices', *Journal of Econometrics* **103**(1), 111–153.

Chisik, R. (2003), 'Gradualism in Free Trade Agreements: A Theoretical Justification', *Journal of International Economics* **59**(2), 367–397.

Constantinides, G. (1990), 'Habit Formation: A Resolution of the Equity Premium Puzzle', *Journal of Political Economy* **98**(3), 519–43.

Crowley, M. A., Exton, O. & Han, L. (2020), 'The Looming Threat of Tariff Hikes: Entry into Exporting under Trade Agreement Renegotiation', *AEA Papers and Proceedings* **110**, 547–51.

Crowley, M., Meng, N. & Song, H. (2018), 'Tariff Scares: Trade Policy Uncertainty and Foreign Market Entry by Chinese Firms', *Journal of International Economics* **114**, 96–115.

de Blas, B. & Russ, K. N. (2015), 'Understanding Markups in the Open Economy', *American Economic Journal: Macroeconomics* **7**(2), 157–80.

De Loecker, J. & Warzynski, F. (2012), 'Markups and Firm-Level Export Status', *American Economic Review* **102**(6), 2437–71.

Di Pace, F. & Faccini, R. (2012), 'Deep Habits and the Cyclical Behaviour of Equilibrium Unemployment and Vacancies', *Journal of Economic Dynamics and Control* **36**(2), 183–200.

Di Pace, F., Juvenal, L. & Petrella, I. (2021), Terms-of-trade shocks are not all alike, Bank of England working papers 901, Bank of England.
URL: *https://ideas.repec.org/p/boe/boeewp/0901.html*

Ding, Z. (2021), 'Firm Heterogeneity, Variable Markups, and Multinational Production: A Review from Trade Policy Perspective', *Journal of Economic Surveys* .

Dixit, A. K. & Stiglitz, J. E. (1977), 'Monopolistic Competition and Optimum Product Diversity', *American Economic Review* **67**(3), 297–308.

Douch, M. & Edwards, T. H. (2021), 'The Bilateral Trade Effects of Announcement Shocks: Brexit as a Natural Field Experiment', *Journal of Applied Econometrics* .

Edmond, C., Midrigan, V. & Xu, D. Y. (2018), How Costly Are Markups?, NBER Working Papers 24800, National Bureau of Economic Research, Inc.

Faust, J. (1998), 'The Robustness of Identified VAR Conclusions About Money', *Carnegie-Rochester Conference Series on Public Policy* **49**, 207–244.

Feenstra, R. C., Luck, P., Obstfeld, M. & Russ, K. N. (2018), 'In Search of the Armington Elasticity', *The Review of Economics and Statistics* **100**(1), 135–150.

Feenstra, R. C. & Weinstein, D. E. (2017), 'Globalization, Markups, and US Welfare', *Journal of Political Economy* **125**(4), 1040–1074.

Fuhrer, J. C. (2000), 'Habit Formation in Consumption and Its Implications for Monetary-Policy Models', *The American Economic Review* **90**(3), 367–390.

Gallaway, M. P., McDaniel, C. A. & Rivera, S. A. (2003), 'Short-Run and Long-Run Industry-Level Estimates of U.S. Armington Elasticities', *The North American Journal of Economics and Finance* **14**(1), 49–68.

Granziera, E., Moon, H. R. & Schorfheide, F. (2018), 'Inference for VARs Identified With Sign Restrictions', *Quantitative Economics* **9**(3), 1087–1121.

Hamilton, J. D. (2018), 'Why You Should Never Use the Hodrick-Prescott Filter', *The Review of Economics and Statistics* **100**(5), 831–843.

Handley, K. & Limão, N. (2017), 'Policy Uncertainty, Trade, and Welfare: Theory and Evidence for China and the United States', *American Economic Review* **107**(9), 2731–83.

Havranek, T., Rusnak, M. & Sokolova, A. (2017), 'Habit Formation in Consumption: A Meta-Analysis', *European Economic Review* **95**, 142–167.

Head, K. & Mayer, T. (2014), Chapter 3 - Gravity Equations: Workhorse, Toolkit, and Cookbook, *in* G. Gopinath, E. Helpman & K. Rogoff, eds, 'Handbook of International Economics', Vol. 4 of *Handbook of International Economics*, Elsevier, pp. 131–195.

Heckman, J. (1981), Heterogeneity and State Dependence, *in* 'Studies in Labor Markets', National Bureau of Economic Research, Inc, pp. 91–140.

Hodrick, R. J. & Prescott, E. C. (1997), 'Postwar U.S. Business Cycles: An Empirical Investigation', *Journal of Money, Credit and Banking* **29**(1), 1–16.

Hooper, P., Johnson, K. H. & Marquez, J. R. (1998), Trade Elasticities for G-7 Countries, International Finance Discussion Papers 609, Board of Governors of the Federal Reserve System (U.S.).

Imbs, J. & Mejean, I. (2015), 'Elasticity Optimism', *American Economic Journal: Macroeconomics* **7**(3), 43–83.

Jacob, P. & Uusküla, L. (2019), 'Deep Habits and Exchange Rate Pass-Through', *Journal of Economic Dynamics and Control* **105**, 67–89.

Juillard, M. (1996), Dynare: A Program for the Resolution and Simulation of Dynamic Models with Forward Variables Through the Use of a Relaxation Algorithm, CEPREMAP Working Papers (Couverture Orange) 9602, CEPREMAP.

Khan, S. Y. & Khederlarian, A. (2021), 'How Does Trade Respond to Anticipated Tariff Changes? Evidence from NAFTA', *Journal of International Economics* **133**, 103538.

Klein, P. (2000), 'Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model', *Journal of Economic Dynamics and Control* **24**(10), 1405 – 1423.

Krugman, P. (1980), 'Scale Economies, Product Differentiation, and the Pattern of Trade', *American Economic Review* **70**(5), 950–959.

Krugman, P. R. (1979), 'Increasing Returns, Monopolistic Competition, and International Trade', *Journal of International Economics* **9**(4), 469 – 479.

Krugman, P. R. (1986), 'Pricing to Market When the Exchange Rate Changes'.

Laffargue, J.-P. (1990), 'Résolution d'Un Modèle Macroéconomique Avec Anticipations Rationnelles', *Annales d'Économie et de Statistique* **17**, 97–119.

Lippi, F. & Nobili, A. (2012), 'Oil And The Macroeconomy: A Quantitative Structural Analysis', *Journal of the European Economic Association* **10**(5), 1059–1083.
URL: *https://ideas.repec.org/a/bla/jeurec/v10y2012i5p1059-1083.html*

Melitz, M. J. (2003), 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', *Econometrica* **71**(6), 1695–1725.

Melitz, M. J. & Ottaviano, G. I. P. (2008), 'Market Size, Trade, and Productivity', *Review of Economic Studies* **75**(1), 295–316.

Metiu, N. (2021), 'Anticipation Effects of Protectionist U.S. Trade Policies', *Journal of International Economics* **133**, 103536.

Meyer-Gohde, A. (2010), 'Matlab Code for One-Sided HP-Filters', QM&RBC Codes, Quantitative Macroeconomics & Real Business Cycles.

Moser, C. & Rose, A. K. (2012), 'Why Do Trade Negotiations Take So Long?', *Journal of Economic Integration* **27**(2), 280–290.

Mountford, A. & Uhlig, H. (2009), 'What are the Effects of Fiscal Policy Shocks?', *Journal of Applied Econometrics* **24**(6), 960–992.

Naik, N. Y. & Moore, M. J. (1996), 'Habit Formation and Intertemporal Substitution in Individual Food Consumption', *The Review of Economics and Statistics* **78**(2), 321–28.

Nekarda, C. J. & Ramey, V. A. (2020), 'The Cyclical Behavior of the Price-Cost Markup', *Journal of Money, Credit and Banking* **52**(S2), 319–353.

Novy, D. & Taylor, A. M. (2020), 'Trade and Uncertainty', *The Review of Economics and Statistics* **102**(4), 749–765.

Peters, M. (2020), 'Heterogeneous Markups, Growth, and Endogenous Misallocation', *Econometrica* **88**(5), 2037–2073.

Pollak, R. A. (1970), 'Habit Formation and Dynamic Demand Functions', *Journal of Political Economy* **78**(4), 745–763.

Raval, D. & Rosenbaum, T. (2018), 'Why Do Previous Choices Matter for Hospital Demand? Decomposing Switching Costs from Unobserved Preferences', *Review of Economics and Statistics* **100**(5), 906–915.

Ravn, M., Schmitt-Grohé, S. & Uribe, M. (2006), 'Deep Habits', *The Review of Economic Studies* **73**(1), 195–218.

Ravn, M., Schmitt-Grohé, S. & Uribe, M. (2010), 'Incomplete Cost Pass-Through under Deep Habits', *Review of Economic Dynamics* **13**(2), 317–332.

Rodriguez-Lopez, A. (2011), 'Prices and Exchange Rates: A Theory of Disconnect', *Review of Economic Studies* **78**(3), 1135–1177.

Rubio-Ramírez, J. F., Waggoner, D. F. & Zha, T. (2010), 'Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference', *Review of Economic Studies* **77**(2), 665–696.

Samuelson, P. A. (1954), 'The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments', *The Economic Journal* **64**(254), 264–289.

Schmidt-Grohé, S. & Uribe, M. (2017), *Open Economy Macroeconomics*, Princeton, New Jersey: Princeton University Press.

Schmitt-Grohé, S. & Uribe, M. (2004), 'Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function', *Journal of Economic Dynamics and Control* **28**(4), 755–775.

Seetharaman, P. B. (2004), 'Modeling Multiple Sources of State Dependence in Random Utility Models: A Distributed Lag Approach', *Marketing Science* **23**(2), 263–271.

Simonovska, I. (2015), 'Income Differences and Prices of Tradables: Insights from an Online Retailer', *Review of Economic Studies* **82**(4), 1612–1656.

Simonovska, I. & Waugh, M. E. (2014), Trade Models, Trade Elasticities, and the Gains from Trade, NBER Working Papers 20495, National Bureau of Economic Research, Inc.

Sims, C. A. (1980), 'Macroeconomics and Reality', *Econometrica* **48**(1), 1–48.

Spinnewyn, F. (1981), 'Rational Habit Formation', *European Economic Review* **15**(1), 91–109.

Staiger, R. W., Wolak, F. A., Litan, R. E., Katz, M. L. & Waverman, L. (1994), 'Measuring Industry-Specific Protection: Antidumping in the United States', *Brookings Papers on Economic Activity: Microeconomics* **1994**, 51–118.

Steinberg, J. B. (2019), 'Brexit and the Macroeconomic Impact of Trade Policy Uncertainty', *Journal of International Economics* **117**, 175–195.

Tharakan, P. M. (1995), 'Political Economy and Contingent Protection', *The Economic Journal* **105**(433), 1550–1564.

Uhlig, H. (2005), 'What are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure', *Journal of Monetary Economics* **52**(2), 381–419.

Yotov, Y. V. & Olivero, M. (2012), 'Dynamic Gravity: Endogenous Country Size and Asset Accumulation', *Canadian Journal of Economics* **45**(1), 64–92.

Online Appendix
(Not For Publication)

A Households

The optimal demand for domestic and foreign varieties is derived by minimising the intra-period consumption expenditure subject to the intra-temporal CES utility function:

$$
\begin{aligned}
\max_{\{X_{H,t}(\psi,\omega),\, X_{F,t}(\psi,\omega)\}} \quad & P_t C_t(\psi) = \int_0^{\Omega} P_{H,t}(\omega) X_{H,t}(\psi,\omega) d\omega + \int_0^{\Omega^*} P_{F,t}(\omega) X_{F,t}(\psi,\omega) d\omega, \\
\text{s.t.} \quad & C_t(\psi) = \left[\int_0^{\Omega} C_{H,t}(\psi,\omega)^{1-1/\eta} d\omega + \int_0^{\Omega^*} C_{F,t}(\psi,\omega)^{1-1/\eta} d\omega \right]^{1/(1-1/\eta)}, \\
\text{s.t.} \quad & C_{H,t}(\psi,\omega) = X_{H,t}(\psi,\omega) X_{H,t-1}(\omega)^{\theta}, \\
\text{s.t.} \quad & C_{F,t}(\psi,\omega) = X_{F,t}(\psi,\omega) X_{F,t-1}(\omega)^{\theta}.
\end{aligned}
$$

The first-order conditions for $i = \{H, F\}$ are given by

$$
\text{FOC}(X_{i,t}(\psi,\omega))\text{: } P_t(\psi) C_t(\psi)^{1/\eta} (X_{i,t}(\psi,\omega) X_{i,t-1}(\omega)^{\theta})^{-1/\eta} X_{i,t-1}(\omega)^{\theta} - P_{i,t}(\psi,\omega) = 0. \tag{A.1}
$$

Alternatively,

$$
X_{i,t}(\psi,\omega) = \left[\frac{P_{i,t}(\omega)}{P_t} \right]^{-\eta} C_t(\psi) X_{i,t-1}(\omega)^{\theta(\eta-1)}. \tag{A.2}
$$

I assume that all home and foreign individuals have identical taste, such that $C_t = \int_0^{\Psi} C_t(\psi) d\psi$. Consequently,

$$
X_{i,t}(\omega) = \int_0^{\Psi} X_{i,t}(\psi,\omega) d\psi = \left[\frac{P_{i,t}(\omega)}{P_t} \right]^{-\eta} C_t X_{i,t-1}(\omega)^{\theta(\eta-1)}. \tag{A.3}
$$

Notice that the above implies that

$$
X_{i,t}(\omega) X_{i,t-1}(\omega)^{\theta} = \left[\frac{P_{i,t}(\omega)}{P_t X_{i,t-1}(\omega)^{\theta}} \right]^{-\eta} C_t. \tag{A.4}
$$

The consumer price index P_t is then solved for by substituting the above into the CES preferences as follows:

$$
\begin{aligned}
C_t &= \left[\int_0^{\Omega} (X_{H,t}(\omega) X_{H,t-1}(\omega)^{\theta})^{(\eta-1)/\eta} d\omega + \int_0^{\Omega^*} (X_{F,t}(\omega) X_{F,t-1}(\omega)^{\theta})^{(\eta-1)/\eta} d\omega \right]^{\eta/(\eta-1)}, \\
1 &= \left[\int_0^{\Omega} \left[\frac{P_{H,t}(\omega)}{P_t X_{H,t-1}(\omega)^{\theta}} \right]^{1-\eta} d\omega + \int_0^{\Omega^*} \left[\frac{P_{F,t}(\omega)}{P_t X_{F,t-1}(\omega)^{\theta}} \right]^{1-\eta} d\omega \right]^{1/(1-\eta)}, \\
P_t &= \left[\int_0^{\Omega} \left(P_{H,t}(\omega) X_{H,t-1}(\omega)^{-\theta} \right)^{1-\eta} d\omega + \int_0^{\Omega^*} \left(P_{F,t}(\omega) X_{F,t-1}(\omega)^{-\theta} \right)^{1-\eta} d\omega \right]^{1/(1-\eta)}.
\end{aligned} \tag{A.5}
$$

B Firms

B.1 Labour Demand

The optimal labour demand is derived directly from the production technology:

$$X_{i,t}(\omega) = \phi[L_{i,t}(\omega) - \alpha] \quad \Rightarrow \quad L_{i,t}(\omega) = \alpha + \frac{X_{i,t}(\omega)}{\phi}. \tag{B.1}$$

The total, the average and the marginal costs of production, respectively, are thus given by

$$\text{TC} := \ W_t L_{i,t}(\omega) = W_t\alpha + \frac{W_t X_{i,t}(\omega)}{\phi} > 0, \tag{B.2}$$

$$\text{AC} := \ \frac{W_t L_{i,t}(\omega)}{X_{i,t}(\omega)} = \frac{W_t\alpha}{X_{i,t}(\omega)} + \frac{W_t}{\phi} > 0, \tag{B.3}$$

$$\text{MC} := \ \frac{\partial(W_t L_{i,t}(\omega))}{\partial X_{i,t}(\omega)} = \frac{W_t}{\phi} > 0. \tag{B.4}$$

B.2 Pricing-to-Habits

Each home firm chooses the price and output that maximises the present discounted value of profits taking their technology and the demand for their variety at home as given. The foreign demand facing home firms is treated as if it is exogenous. Optimisation problem:

$$\max_{\{P_{H,t}(\omega),\, X_{H,t}(\omega)\}} \quad \mathbb{E}_t \sum_{\iota=0}^{\infty} \beta^{\iota}(P_{H,t+\iota}(\omega)X_{H,t+\iota}(\omega) - W_{t+\iota}L_{H,t+\iota}(\omega)),$$

$$\text{s.t.} \quad L_{H,t+\iota}(\omega) = \alpha + \frac{X_{H,t+\iota}(\omega)}{\phi},$$

$$\text{s.t.} \quad X_{H,t+\iota}(\omega) = \left[\frac{P_{H,t+\iota}(\omega)}{P_{t+\iota}}\right]^{-\eta} C_{t+\iota}X_{H,t+\iota-1}(\omega)^{\theta(\eta-1)}.$$

Consider the current value Lagrangian for the profit maximisation problem above:

$$\max_{\{P_{H,t}(\omega),\, X_{H,t}(\omega)\}} \quad \mathbb{E}_t \sum_{\iota=0}^{\infty} \beta^{\iota} \left\{ P_{H,t+\iota}(\omega)X_{H,t+\iota}(\omega) - W_{t+\iota}\alpha - \frac{W_{t+\iota}X_{H,t+\iota}(\omega)}{\phi} \right.$$
$$\left. - \ \lambda_{H,t+\iota}(\omega)\left[X_{H,t+\iota}(\omega) - \left[\frac{P_{H,t+\iota}(\omega)}{P_{t+\iota}}\right]^{-\eta} C_{t+\iota}X_{H,t+\iota-1}(\omega)^{\theta(\eta-1)}\right].\right\} \tag{B.5}$$

The first order conditions with respect to the price and output, respectively, are given by:

$$\text{FOC}(P_{H,t}(\omega))\colon X_{H,t}(\omega) - \frac{\eta\lambda_{H,t}(\omega)X_{H,t}(\omega)}{P_{H,t}(\omega)} = 0, \tag{B.6}$$

$$\text{FOC}(X_{H,t}(\omega))\colon P_{H,t}(\omega) - \frac{W_t}{\phi} - \lambda_{H,t}(\omega) + \theta\beta(\eta-1)\mathbb{E}_t\left[\frac{\lambda_{H,t+1}(\omega)X_{H,t+1}(\omega)}{X_{H,t}(\omega)}\right] = 0. \tag{B.7}$$

Rearranging the above gives

$$
\begin{aligned}
P_{H,t}(\omega) &= \frac{W_t}{\phi} + \lambda_{H,t}(\omega) - \theta\beta(\eta-1)\mathbb{E}_t\left[\frac{\lambda_{H,t+1}(\omega)X_{H,t+1}(\omega)}{X_{H,t}(\omega)}\right], \\
P_{H,t}(\omega) &= \frac{W_t}{\phi} + \underbrace{\frac{P_{H,t}(\omega)}{\eta}}_{\lambda_{H,t}(\omega)} - \theta\beta(\eta-1)\mathbb{E}_t\left[\underbrace{\frac{P_{H,t+1}(\omega)}{\eta}}_{\lambda_{H,t+1}(\omega)}\frac{X_{H,t+1}(\omega)}{X_{H,t}(\omega)}\right], \\
P_{H,t}(\omega)\left(\frac{\eta-1}{\eta}\right) &= \frac{W_t}{\phi} - \theta\beta\left(\frac{\eta-1}{\eta}\right)\mathbb{E}_t\left[\frac{P_{H,t+1}(\omega)X_{H,t+1}(\omega)}{X_{H,t}(\omega)}\right], \\
P_{H,t}(\omega) &= \frac{W_t}{\phi}\left(\frac{\eta}{\eta-1}\right) - \theta\beta\mathbb{E}_t\left[\frac{P_{H,t+1}(\omega)X_{H,t+1}(\omega)}{X_{H,t}(\omega)}\right], \\
P_{H,t}(\omega) &= \frac{W_t}{\phi}\left(\frac{\eta}{\eta-1}\right)\frac{P_{H,t}(\omega)X_{H,t}(\omega)}{P_{H,t}(\omega)X_{H,t}(\omega) + \theta\beta\mathbb{E}_t[P_{H,t+1}(\omega)X_{H,t+1}(\omega)]}. \qquad \text{(B.8)}
\end{aligned}
$$

C Equilibrium Conditions

C.1 Consumption

In financial autarky, the aggregate feasibility constraint requires that the aggregate consumption expenditure is equal to the aggregate wage bill (i.e. $\int_0^\Psi P_t C_t(\psi)d\psi = \int_0^\Psi W_t h(\psi)d\psi$). We implicitly assume that there are complete financial markets within each country that in equilibrium diversify all idiosyncratic risk. But there are no international financial markets. We also assume that tastes are identical across all households in each country, which implies that in equilibrium we have $C_t = \int_0^\Psi C_t(\psi)d\psi$ and $X_{i,t}(\omega) = \int_0^\Psi X_{i,t}(\psi,\omega)d\psi$. Therefore, aggregate real consumption at home equals the aggregate real wage bill given by:

$$
C_t = \int_0^\Psi C_t(\psi)d\psi = \int_0^\Psi \frac{W_t h(\psi)}{P_t}d\psi = \frac{L}{P_t}, \qquad \text{(C.1)}
$$

where the last equality follows from the fact that: (i) there is full employment in each country at all times, such that $\Psi = L$; (ii) $W_t = 1$ is the *numeraire*; and (iii) labour supply is inelastic, such that $h = 1$. Rise in P_t therefore means C_t falls and *vice versa*.

C.2 Symmetry

All home firms are equally productive $\phi > 0$ and incur identical iceberg costs when shipping their varieties overseas. Without any source of idiosyncratic risk, prices and output in general equilibrium are symmetrical across all home firms, such that $P_{H,t} = \int_0^\Omega P_{H,t}(\omega)d\omega$ and $X_{H,t} = \int_0^\Omega X_{H,t}(\omega)d\omega$. Now let $S_{F,t}(\omega) = (P_{F,t}(\omega)X_{F,t}(\omega))/(P_tC_t)$ denote the import penetration ratio (IPR) and $S_{H,t}(\omega) = (P_{H,t}(\omega)X_{H,t}(\omega))/(P_tC_t)$. Then in the symmetric equilibrium, we have $S_{H,t} = \int_0^\Omega S_{H,t}(\omega)d\omega$ and $S_{F,t} = \int_0^{\Omega^*} S_{F,t}(\omega)d\omega$. It is easy to see that substituting this result into the intra-temporal feasibility constraint of the household $P_tC_t(\psi) = \int_0^\Omega P_{H,t}(\omega)X_{H,t}(\psi,\omega)d\omega + \int_0^{\Omega^*} P_{F,t}(\omega)X_{F,t}(\psi,\omega)d\omega$ gives $S_{H,t} + S_{F,t} = 1$.

C.3 International Prices

We impose "tit-for-tat" iceberg cost retaliation between home and foreign, such that $\varepsilon_t = \varepsilon_t^*$ and $\tau_t = \tau_t^*$, which means that home trade restrictions on foreign are always fully reciprocated and *vice versa*. We further assume that $P_{i,t}^* = \tau_t P_{i,t}$ for $i = \{H, F\}$ holds in equilibrium, such that international arbitrage forces are perfectly efficient and there is no "pricing-to-market". Finally, we assume that both countries are equally-sized, such that $L = L^*$, have identical fixed costs $\alpha = \alpha^*$, and they are equally productive $\phi = \phi^*$. Under these assumptions, home and foreign are perfectly symmetrical and consistent with Krugman (1979) exhibit balanced trade and zero net debt at all times. Due to perfect cross-border symmetry, we have $P_{F,t} = P_{H,t}^* = \tau_t P_{H,t}$, $X_{H,t} = X_{F,t}^*$, $X_{F,t} = X_{H,t}^*$, and $\Omega = \Omega^*$, which implies that $S_{H,t} = \Omega(P_{H,t}X_{H,t})/(P_t C_t) \equiv \Omega P_{H,t}X_{H,t}/L$. And also notice that it now follows from above that $S_{H,t} = S_{F,t}^* = 1 - S_{H,t}^*$.

C.4 Price Markup

In the symmetric equilibrium, the home price markup is identical across all home firms, but it remains optimally time-varying. To see this, note that substituting $P_{H,t}X_{H,t} = LS_{H,t}/\Omega$ from above into the optimal price markup gives:

$$\frac{\phi P_{H,t}}{W_t} \equiv \phi P_{H,t} = \left(\frac{\eta}{\eta - 1}\right) \frac{S_{H,t}}{S_{H,t} + \theta\beta\mathbb{E}_t[S_{H,t+1}]}, \tag{C.2}$$

such that when the current IPR falls (i.e. $S_{H,t}$ rises), the price markup rises, and when the expected future IPR falls (i.e. $\mathbb{E}_t[S_{H,t+1}]$ rises), the price markup falls.

C.5 Zero Profit Condition

Aggregating output across all firms using the production technology defines the equilibrium demand for labour:

$$X_{i,t} = \int_0^\Omega X_{i,t}(\omega)d\omega = \phi \int_0^\Omega [L_{i,t}(\omega) - \alpha]d\omega = \Omega\phi[L_{i,t} - \alpha] \quad \Rightarrow \quad L_{i,t} = \alpha + \frac{X_{i,t}}{\Omega\phi}. \tag{C.3}$$

Consistent with Krugman (1979), entry is free and the price of the incumbent firm for each variety is driven down to the average cost of production:

$$P_{i,t} = \int_0^\Omega P_{i,t}(\omega)d\omega = \int_0^\Omega \frac{W_t L_{i,t}(\omega)}{X_{i,t}(\omega)}d\omega \equiv \frac{\alpha}{X_{i,t}} + \frac{1}{\Omega\phi}, \tag{C.4}$$

because $W_t = 1$ is the *numeraire*. The zero profit condition therefore requires that the total sales equal to the total wage bill given by:

$$P_{i,t}X_{i,t} = \alpha + \frac{X_{i,t}}{\Omega\phi} = L_{i,t}. \tag{C.5}$$

C.6 Labour Market Clearing Condition

Substituting the above results into the aggregate labour market clearing condition gives

$$
\begin{aligned}
L = & \int_0^{\Omega} [L_{H,t}(\omega) + L^*_{H,t}(\omega)] d\omega = \Omega(L_{H,t} + L^*_{H,t}) = \Omega(P_{H,t}X_{H,t} + P^*_{H,t}X^*_{H,t}), \\
= & \Omega(S_{H,t} + S^*_{H,t}) = \Omega(S_{H,t} + 1 - S_{H,t}) = \Omega.
\end{aligned}
\tag{C.6}
$$

And since L is endowed exogenously, the mass of varieties Ω is tied directly to the size of the population (i.e. $L = \Psi = \Omega$). This result follows from the fact that there is free entry and firms are homogeneous in line with Krugman (1979, 1980). Under these conditions, the market price and output adjust in response to temporary shocks to the iceberg costs in order to prevent new firm entry, thereby keeping the mass of varieties fixed over time.

C.7 Consumer Price Index

The combination of the zero profit condition and the labour market clearing condition allows us to express the stock of habit as follows:

$$
S_{i,t} = P_{i,t}X_{i,t} = \alpha + \frac{X_{i,t}}{\Omega\phi} \quad \Rightarrow \quad X_{i,t-1} = \Omega\phi(S_{i,t-1} - \alpha), \tag{C.7}
$$

Substituting this into the aggregate consumer price index P_t and evaluating it in the symmetric equilibrium gives a solution in terms of $P_{H,t}$ and $S_{H,t-1}$ as follows:

$$
\begin{aligned}
P_t = & \left[\int_0^{\Omega} \left(P_{H,t}(\omega)X_{H,t-1}(\omega)^{-\theta}\right)^{1-\eta} d\omega + \int_0^{\Omega^*} \left(P_{F,t}(\omega)X_{F,t-1}(\omega)^{-\theta}\right)^{1-\eta} d\omega \right]^{1/(1-\eta)}, \\
= & \left[P_{H,t}^{1-\eta} X_{H,t-1}^{\theta(\eta-1)} \Omega + P_{F,t}^{1-\eta} X_{F,t-1}^{\theta(\eta-1)} \Omega^* \right]^{1/(1-\eta)}, \\
= & \Omega^{1/(1-\eta)} P_{H,t} \left[X_{H,t-1}^{\theta(\eta-1)} + \tau_t^{1-\eta} X_{F,t-1}^{\theta(\eta-1)} \right]^{1/(1-\eta)}, \\
= & \Omega^{1/(1-\eta)} P_{H,t} \left[(\Omega\phi(S_{H,t-1} - \alpha))^{\theta(\eta-1)} + \tau_t^{1-\eta} (\Omega\phi(1 - S_{H,t-1} - \alpha))^{\theta(\eta-1)} \right]^{1/(1-\eta)}, \\
= & \Omega^{1/(1-\eta)} (\Omega\phi)^{-\theta} P_{H,t} \left[(S_{H,t-1} - \alpha)^{\theta(\eta-1)} + \tau_t^{1-\eta} (1 - S_{H,t-1} - \alpha)^{\theta(\eta-1)} \right]^{1/(1-\eta)}.
\end{aligned}
\tag{C.8}
$$

Now recall that $C_t = L/P_t$ and combined with the labour market clearing condition we have $P_t = \Omega/C_t$. Therefore,

$$
\begin{aligned}
\frac{\Omega}{C_t} = & \Omega^{1/(1-\eta)} (\Omega\phi)^{-\theta} P_{H,t} \left[(S_{H,t-1} - \alpha)^{\theta(\eta-1)} + \tau_t^{1-\eta} (1 - S_{H,t-1} - \alpha)^{\theta(\eta-1)} \right]^{1/(1-\eta)}, \\
\phi P_{H,t} C_t = & \Omega^{1/(\eta-1)} (\Omega\phi)^{1+\theta} \left[(S_{H,t-1} - \alpha)^{\theta(\eta-1)} + \tau_t^{1-\eta} (1 - S_{H,t-1} - \alpha)^{\theta(\eta-1)} \right]^{1/(\eta-1)}.
\end{aligned}
\tag{C.9}
$$

C.8 Recursive Demand

Substituting the above stock of habits definition into the optimal demand for each variety gives a recursive relationship that governs the transitional dynamics of the IPR:

$$
\begin{aligned}
S_{H,t} = P_{H,t} X_{H,t} &= \left(\frac{P_{H,t}}{P_t}\right)^{1-\eta} X_{H,t-1}^{\theta(\eta-1)}, \\
&= \left(\frac{P_{H,t} C_t}{L}\right)^{1-\eta} (\Omega\phi)^{\theta(\eta-1)} (S_{H,t-1} - \alpha)^{\theta(\eta-1)}, \qquad \text{(C.10)} \\
&= (\phi P_{H,t} C_t)^{1-\eta} (\Omega\phi)^{(1+\theta)(\eta-1)} (S_{H,t-1} - \alpha)^{\theta(\eta-1)}. \qquad \text{(C.11)}
\end{aligned}
$$

C.9 Canonical Representation

Combining the above results together leads to the PP-SS-CC canonical representation of the model:

$$
\text{PP: } \phi P_{H,t} = \left(\frac{\eta}{\eta-1}\right) \frac{S_{H,t}}{S_{H,t} + \theta\beta\mathbb{E}_t\left[S_{H,t+1}\right]}, \qquad \text{(C.12)}
$$

$$
\text{SS: } S_{H,t} = (\phi P_{H,t} C_t)^{1-\eta} (\Omega\phi)^{(1+\theta)(\eta-1)} (S_{H,t-1} - \alpha)^{\theta(\eta-1)}, \qquad \text{(C.13)}
$$

$$
\text{CC: } \phi P_{H,t} C_t = \Omega^{1/(\eta-1)} (\Omega\phi)^{1+\theta} \left[(S_{H,t-1} - \alpha)^{\theta(\eta-1)} + \tau_t^{1-\eta} (1 - S_{H,t-1} - \alpha)^{\theta(\eta-1)}\right]^{1/(\eta-1)}. \qquad \text{(C.14)}
$$

Now let $\phi P_{H,t} := \mu_t$, $S_{H,t} := s_t$, and $C_t := c_t$. The model can therefore be expressed as:

$$
\text{PP: } \quad \mu_t = \left(\frac{\eta}{\eta-1}\right) \frac{s_t}{s_t + \theta\beta\mathbb{E}_t\left[s_{t+1}\right]}, \qquad \text{(C.15)}
$$

$$
\text{SS: } \quad s_t = \Gamma_s (\mu_t c_t)^{1-\eta} (s_{t-1} - \alpha)^{\theta(\eta-1)}, \qquad \text{(C.16)}
$$

$$
\text{CC: } \quad \mu_t c_t = \Gamma_c \left[(s_{t-1} - \alpha)^{\theta(\eta-1)} + \tau_t^{1-\eta} (1 - s_{t-1} - \alpha)^{\theta(\eta-1)}\right]^{1/(\eta-1)}, \qquad \text{(C.17)}
$$

where $\Gamma_s = (\Omega\phi)^{(1+\theta)(\eta-1)} > 0$ and $\Gamma_c = \Omega^{1/(\eta-1)}(\Omega\phi)^{1+\theta} > 0$ are constants.

D Steady State

D.1 Change-of-Variable Approach

Suppose we calibrate $s = \bar{s}$ and set $\alpha = \gamma\bar{s}$, where $0 < \gamma < 1$ is a calibrated constant, such that $\bar{s} - \alpha = (1-\gamma)\bar{s} > 0$. Suppose further that $p = \bar{p} = \mu/\phi$, where $\mu > 1$ is another calibrated constant. Notice that this restriction determines the value of $\eta > 1$, but $\theta > 0$ is chosen freely. If we substitute PP and CC into the SS under these restrictions, then the "change-of-variable" principle pins down the level of $\Omega = L = \Psi$. Once $\Omega = \bar{\Omega} > 0$ is determined, it can be substituted into CC together with $\bar{p}$, $\bar{\tau}$, $\bar{s}$, α, and ϕ in order to pin down the value of $c = \bar{c}$.

D.2 Analytical Solution

First, notice that PP in the steady state implies:

$$\bar{\mu} = \left(\frac{\eta}{\eta - 1}\right)\frac{1}{1+\theta\beta} \quad \Rightarrow \quad \eta = \frac{\bar{\mu}(1+\theta\beta)}{\bar{\mu}(1+\theta\beta)-1} > 1, \tag{D.1}$$

because we calibrate $\bar{\mu}$ in the steady state. Second, consider rearranging CC as follows:

$$\begin{aligned}
\bar{\mu}c &= \bar{\Omega}^{1/(\eta-1)}(\bar{\Omega}\phi)^{1+\theta}\left[(\bar{s}-\alpha)^{\theta(\eta-1)} + \bar{\tau}^{1-\eta}(1-\bar{s}-\alpha)^{\theta(\eta-1)}\right]^{1/(\eta-1)}, \\
\bar{\mu}\bar{c} &= \bar{\Omega}^{1/(\eta-1)}(\bar{\Omega}\phi)^{1+\theta}\underbrace{\left[((1-\gamma)\bar{s})^{\theta(\eta-1)} + \bar{\tau}^{1-\eta}(1-(1+\gamma)\bar{s})^{\theta(\eta-1)}\right]^{1/(\eta-1)}}_{\Xi^{1/(\eta-1)}>0}, \\
\bar{c} &= \frac{\bar{\Omega}^{1/(\eta-1)}\Xi^{1/(\eta-1)}(\bar{\Omega}\phi)^{1+\theta}}{\bar{\mu}} > 0.
\end{aligned} \tag{D.2}$$

This implies that

$$\begin{aligned}
(\bar{\mu}\,\bar{c})^{1-\eta} &= \left(\bar{\Omega}^{1/(\eta-1)}\Xi^{1/(\eta-1)}(\bar{\Omega}\phi)^{1+\theta}\right)^{1-\eta}, \\
(\bar{\mu}\,\bar{c})^{1-\eta}(\bar{\Omega}\phi)^{(1+\theta)(\eta-1)} &= \frac{1}{\bar{\Omega}\Xi} > 0.
\end{aligned} \tag{D.3}$$

Substituting this into SS pins down $\bar{\Omega}$ as follows:

$$\begin{aligned}
\bar{s} &= (\bar{\mu}\,\bar{c})^{1-\eta}(\bar{\Omega}\phi)^{(1+\theta)(\eta-1)}(\bar{s}-\alpha)^{\theta(\eta-1)}, \\
&= \frac{1}{\bar{\Omega}\Xi}(\bar{s}-\alpha)^{\theta(\eta-1)}, \\
\bar{\Omega} &= \frac{(1-\gamma)^{\theta(\eta-1)}\bar{s}^{\theta(\eta-1)-1}}{\Xi}.
\end{aligned} \tag{D.4}$$

Finally, for the sake of completeness, we can derive the steady state of output using the zero profit condition, namely $\bar{\mu} = \bar{\Omega}\phi\alpha/\bar{x} + 1$, such that $\bar{x} = \bar{\Omega}\phi\alpha/(\bar{\mu}-1) > 0$.

E Solution Method: Unanticipated Shocks

The PP-SS-CC model is characterised by a system of non-linear stochastic difference equations. The closed-form solution to this system of equations does not exist, but there exists an approximate numerical solution. Following Schmitt-Grohé & Uribe (2004), the model is solved by linear approximation of the equilibrium conditions around the non-stochastic steady state using a first-order Taylor series expansion.

Consider re-stating the PP-SS-CC equilibrium conditions in compact form:

$$\mathbb{E}_t[f(\mathbf{y}_{t+1}, \mathbf{y}_t, \mathbf{x}_{t+1}, \mathbf{x}_t)] = 0, \tag{E.1}$$

where $f(\cdot)$ is known as the *policy function*, while $\mathbf{y}_{t+1}$, $\mathbf{y}_t$, $\mathbf{x}_{t+1}$, $\mathbf{x}_t$ are the forward-looking and contemporaneous vectors of *control* and *state* variables, respectively. In particular, the PP-SS-CC model solution is characterised by 4 control variables, namely $\{\mu_t, c_t, s_t, s_t^a\}$, 2 state variables, namely $\{s_{t-1}, \tau_{t-1}\}$, and 1 stochastic shock ε_t, where s_t^a is an auxiliary variable. Hence, in the PP-SS-CC model, s_t is both forward-looking and backward-looking (i.e. *mixed*). For this reason, we introduce an auxiliary variable and an auxiliary equation to the model, namely $\mathbb{E}_t[s_{t+1}] = s_t^a$. Assuming that $\mathbf{y}$ and $\mathbf{x}$ denote the steady state values of the control and state variable vectors, respectively, the first-order Taylor series expansion of the policy function around the steady state is given by:

$$f_{\mathbf{y}'}\mathbb{E}_t[\hat{\mathbf{y}}_{t+1}] + f_{\mathbf{y}}\hat{\mathbf{y}}_t + f_{\mathbf{x}'}\mathbb{E}_t[\hat{\mathbf{x}}_{t+1}] + f_{\mathbf{x}}\hat{\mathbf{x}}_t = 0, \tag{E.2}$$

where $\hat{\mathbf{y}}_{t+1} = \mathbf{y}_{t+1} - \mathbf{y}$, $\hat{\mathbf{y}}_t = \mathbf{y}_t - \mathbf{y}$, $\hat{\mathbf{x}}_{t+1} = \mathbf{x}_{t+1} - \mathbf{x}$, and $\hat{\mathbf{x}}_t = \mathbf{x}_t - \mathbf{x}$ measure the absolute deviations of the control and state variables from the steady state, and $f_{\mathbf{y}'} = \partial f/\partial \mathbf{y}_{t+1}|_{\mathbf{y}_{t+1}=\mathbf{y}}$, $f_{\mathbf{y}} = \partial f/\partial \mathbf{y}_t|_{\mathbf{y}_t=\mathbf{y}}$, $f_{\mathbf{x}'} = \partial f/\partial \mathbf{x}_{t+1}|_{\mathbf{x}_{t+1}=\mathbf{x}}$, $f_{\mathbf{x}} = \partial f/\partial \mathbf{x}_t|_{\mathbf{x}_t=\mathbf{x}}$ are the matrices of policy function partial derivatives evaluated at the steady state.

The solution to a forward-looking linear system of difference equations characterised by rational expectations is defined as the law of motion for the state variables and the terminal condition for the control variables, respectively:

$$\hat{\mathbf{x}}_{t+1} = \mathscr{B}\hat{\mathbf{x}}_t + \boldsymbol{\Sigma}\boldsymbol{\varepsilon}_{t+1}, \quad \text{for} \quad t = \{0, 1, 2, ..., T-1\} \tag{E.3}$$

$$\hat{\mathbf{y}}_t = \mathscr{A}\hat{\mathbf{x}}_t, \quad \text{for} \quad t = 1, 2, 3, ..., T, \tag{E.4}$$

where $\boldsymbol{\Sigma}$ is a 2×2 diagonal matrix, $\boldsymbol{\varepsilon}_{t+1}$ is a 2×1 vector of stochastic shocks, while $\mathscr{B}$ and $\mathscr{A}$ are the 2×2 and 4×4 matrices, respectively, that are obtained numerically from the analytical partial derivatives $f_{\mathbf{y}'}$, $f_{\mathbf{y}}$, $f_{\mathbf{x}'}$, and $f_{\mathbf{x}}$. The remaining part of this Section demonstrates the $\mathscr{B}$ and $\mathscr{A}$ matrices are derived and explains the assumptions imposed along the way that deliver the saddle-path stable solution.

Let $\mathbf{A} = [f_{\mathrm{x}'}, f_{\mathrm{y}'}]$, $\mathbf{B} = -[f_{\mathrm{x}}, f_{\mathrm{y}}]$, and $\mathbf{w}_t = [\hat{\mathbf{x}}_t', \hat{\mathbf{y}}_t']'$, such that the first-order approximation to the system of linear equations can be written as

$$\mathbf{A}\mathbb{E}_t[\mathbf{w}_{t+1}] = \mathbf{B}\mathbf{w}_t. \tag{E.5}$$

Notice that $\mathbf{A}$ and $\mathbf{B}$ are *square* matrices (i.e. the number of rows is equal to the number of columns). Consider the generalised Schur decomposition of $\mathbf{A}$ and $\mathbf{B}$ as follows:

$$\mathbf{a} = \mathbf{q}\mathbf{A}\mathbf{z}, \tag{E.6}$$

$$\mathbf{b} = \mathbf{q}\mathbf{B}\mathbf{z}, \tag{E.7}$$

such that $\mathbf{a}$ and $\mathbf{b}$ are upper-triangular matrices (i.e. all elements below the main diagonal are equal to zero), while $\mathbf{q}$ and $\mathbf{z}$ are both orthonormal matrices (i.e. $\mathbf{q}'\mathbf{q} = \mathbf{q}\mathbf{q}' = \mathbf{z}'\mathbf{z} = \mathbf{z}\mathbf{z}' = \mathcal{I}$, where $\mathcal{I}$ is an identity matrix). Let $\mathbf{v}_t = \mathbf{z}'\mathbf{w}_t$. Then it follows that

$$\mathbf{A}\mathbb{E}_t[\mathbf{w}_{t+1}] = \mathbf{B}\mathbf{w}_t \quad \Rightarrow \quad \underbrace{\mathbf{q}\mathbf{A}\mathbf{z}}_{\mathbf{a}}\underbrace{\mathbf{z}'\mathbb{E}_t[\mathbf{w}_{t+1}]}_{\mathbb{E}[\mathbf{v}_{t+1}]} = \underbrace{\mathbf{q}\mathbf{B}\mathbf{z}}_{\mathbf{a}}\underbrace{\mathbf{z}'\mathbf{w}_t}_{\mathbf{v}_t} \quad \Rightarrow \quad \mathbf{a}\mathbb{E}_t[\mathbf{v}_{t+1}] = \mathbf{b}\mathbf{v}_t. \tag{E.8}$$

The Schur transformation of the linear system of difference equations is useful is because $\mathbf{b}_{ii}/\mathbf{a}_{ii}$ measures the *generalised eigenvalue* of matrices $\mathbf{A}$ and $\mathbf{B}$, where subscript ii

indicates the i'th diagonal element of the matrix. Following the seminal contribution of Blanchard & Kahn (1980), generalised eigenvalues are used to determine whether or not a linear system of difference equations characterised by rational expectations is saddle-path stable. Klein (2000) further generalises the solution approach and states that if there are as many generalised eigenvalues whose absolute value is less than one as the number of state variables, then there is one unique time path for the entire system to converge to the deterministic steady state (i.e. saddle-path stability). But when there are less (more) generalised eigenvalues whose absolute value is less than one than the number of state variables, then the system is deemed unstable (indeterminate), such that there are none (infinitely many) time paths for the system to converge.

The next part eliminates equilibria that are inadmissible (i.e. non-convergent). Recall that the model contains 2 state variables. Suppose that

$$\mathbf{a} = \begin{bmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} \\ \mathbf{0} & \mathbf{a}_{22} \end{bmatrix}, \quad \mathbf{b} = \begin{bmatrix} \mathbf{b}_{11} & \mathbf{b}_{12} \\ \mathbf{0} & \mathbf{b}_{22} \end{bmatrix}, \quad \mathbf{z} = \begin{bmatrix} \mathbf{z}_{11} & \mathbf{z}_{12} \\ \mathbf{z}_{21} & \mathbf{z}_{22} \end{bmatrix}, \quad \mathbf{v}_t = \begin{bmatrix} \mathbf{v}_{1,t} \\ \mathbf{v}_{2,t} \end{bmatrix}, \tag{E.9}$$

where $\mathbf{a}_{11}$ and $\mathbf{b}_{11}$ are 2×2 matrices, whose diagonals do indeed generate generalised eigenvalues of $\mathbf{A}$ and $\mathbf{B}$ with absolute values that are less than one, whereas $\mathbf{a}_{22}$ and $\mathbf{b}_{22}$ are square matrices, whose diagonals generate generalised eigenvalues with absolute values greater than one. Then because $\mathbf{a}$ and $\mathbf{b}$ are upper-triangular, it follows that

$$\mathbf{a}_{22}\mathbb{E}_t[\mathbf{v}_{2,t+1}] = \mathbf{b}_{22}\mathbf{v}_{2,t}. \tag{E.10}$$

At this point, we know that $\mathbf{b}_{22}$ is invertible, since (i) each diagonal element of $\mathbf{b}_{22}$ is non-zero; and (ii) $\mathbf{b}_{22}$ is upper-triangular. Consequently,

$$\mathbf{v}_{2,t} = \mathbf{b}_{22}^{-1}\mathbf{a}_{22}\mathbb{E}_t[\mathbf{v}_{2,t+1}] \equiv \mathbf{0}, \tag{E.11}$$

since $\mathbf{b}_{22}^{-1}\mathbf{a}_{22}$ generates eigenvalues that are less than unity in modulus. This statement is unambiguously true, since (i) the inverse of a non-singular upper-triangular matrix is upper-triangular; (ii) the product of two upper-triangular matrices is also upper-triangular; and (iii) the eigenvalues of an upper-triangular matrix are the diagonal elements. As a consequence, the only way to ensure that the system of difference equations is non-explosive is to impose $\mathbf{v}_{2,t} = 0$, which rules out the non-convergent equilibria and implies that

$$\mathbf{a}\mathbb{E}_t[\mathbf{v}_{t+1}] = \mathbf{b}\mathbf{v}_t \quad \Rightarrow \quad \begin{bmatrix} \mathbf{a}_{11} & \mathbf{a}_{12} \\ \mathbf{0} & \mathbf{a}_{22} \end{bmatrix} \begin{bmatrix} \mathbb{E}_t[\mathbf{v}_{1,t+1}] \\ \mathbf{0} \end{bmatrix} = \begin{bmatrix} \mathbf{b}_{11} & \mathbf{b}_{12} \\ \mathbf{0} & \mathbf{b}_{22} \end{bmatrix} \begin{bmatrix} \mathbf{v}_{1,t} \\ \mathbf{0} \end{bmatrix}, \tag{E.12}$$

which means that

$$\mathbf{a}_{11}\mathbb{E}_t[\mathbf{v}_{1,t+1}] = \mathbf{b}_{11}\mathbf{v}_{1,t} \quad \Rightarrow \quad \mathbb{E}_t[\mathbf{v}_{1,t+1}] = \mathbf{a}_{11}^{-1}\mathbf{b}_{11}\mathbf{v}_{1,t}. \tag{E.13}$$

Using result E.11 it follows that

$$\begin{bmatrix} \mathbf{v}_{1,t} \\ \mathbf{0} \end{bmatrix} = \mathbf{v}_t = \mathbf{z}'\mathbf{w}_t = \begin{bmatrix} \mathbf{z}_{11} & \mathbf{z}_{12} \\ \mathbf{z}_{21} & \mathbf{z}_{22} \end{bmatrix}' \begin{bmatrix} \hat{\mathbf{x}}_t \\ \hat{\mathbf{y}}_t \end{bmatrix} = \begin{bmatrix} \mathbf{z}'_{11}\hat{\mathbf{x}}_t + \mathbf{z}'_{21}\hat{\mathbf{y}}_t \\ \mathbf{z}'_{12}\hat{\mathbf{x}}_t + \mathbf{z}'_{22}\hat{\mathbf{y}}_t \end{bmatrix}, \tag{E.14}$$

which gives us the terminal condition

$$\mathbf{z}'_{12}\hat{\mathbf{x}}_t + \mathbf{z}'_{22}\hat{\mathbf{y}}_t = \mathbf{0} \quad \Rightarrow \quad \hat{\mathbf{y}}_t = \underbrace{-\mathbf{z}'^{-1}_{22}\mathbf{z}_{12}}_{\mathscr{A}}\hat{\mathbf{x}}_t \equiv \mathscr{A}\hat{\mathbf{x}}_t, \tag{E.15}$$

where $\mathbf{z}'_{22}$ is invertible, since $\mathbf{z}'$ is orthonormal. Then using result E.15, we can show that

$$\mathbf{v}_{1,t} = \mathbf{z}'_{11}\hat{\mathbf{x}}_t + \mathbf{z}'_{21}\hat{\mathbf{y}}_t = \mathbf{z}'_{11}\hat{\mathbf{x}}_t \underbrace{-\mathbf{z}'_{21}\mathbf{z}'^{-1}_{22}\mathbf{z}_{12}\hat{\mathbf{x}}_t}_{\mathbf{z}'_{21}\hat{\mathbf{y}}_t} = (\mathbf{z}'_{11} - \mathbf{z}'_{21}\mathbf{z}'^{-1}_{22}\mathbf{z}_{12})\hat{\mathbf{x}}_t \equiv \mathbf{z}'^{-1}_{11}\hat{\mathbf{x}}_t. \tag{E.16}$$

where the last statement follows from the fact that $\mathbf{z}$ is orthonormal. See Schmidt-Grohé & Uribe (2017) footnote 6 on page 121 for algebraic details. Finally, substituting result E.16 into E.13 gives the law of motion for the state variables in conditional expectation

$$\mathbf{a}_{11}\mathbf{z}^{-1}_{11}\mathbb{E}_t[\hat{\mathbf{x}}_{t+1}] = \mathbf{b}_{11}\mathbf{z}^{-1}_{11}\hat{\mathbf{x}}_t \quad \Rightarrow \quad \mathbb{E}_t[\hat{\mathbf{x}}_{t+1}] = \underbrace{\mathbf{z}_{11}\mathbf{a}^{-1}_{11}\mathbf{b}_{11}\mathbf{z}^{-1}_{11}}_{\mathscr{B}}\hat{\mathbf{x}}_t = \mathscr{B}\hat{\mathbf{x}}_t. \tag{E.17}$$

The *transversality condition* thus holds, such that $\lim_{\iota\to\infty}\mathbb{E}_t[\mathbf{w}_{t+\iota}] = \mathbf{w}_0$, where $\iota = \{0, 1, 2, ...\}$ and $\mathbf{w}_0$ denotes the deterministic steady state of $\mathbf{w}_t$.

The impulse response function measure the deviation of an arbitrary variable from the deterministic steady state over time as implied by the system of difference equations when it is disturbed by an arbitrarily chosen value for a stochastic shock ε_t. The impulse response functions for the state variables are derived as follows:

$$\text{IRF}(\hat{\mathbf{x}}_{t+\iota}) = \mathbb{E}_t[\hat{\mathbf{x}}_{t+\iota}] - \mathbb{E}_{t-1}[\hat{\mathbf{x}}_{t+\iota}] = \mathscr{B}^\iota\mathbb{E}_t[\hat{\mathbf{x}}_t] - \mathscr{B}^\iota\mathbb{E}_{t-1}[\hat{\mathbf{x}}_t] \equiv \mathscr{B}^\iota\boldsymbol{\Sigma}\boldsymbol{\varepsilon}_t, \tag{E.18}$$

since $\hat{\mathbf{x}}_{t+\iota} = \mathscr{B}\hat{\mathbf{x}}_{t+\iota-1} + \boldsymbol{\Sigma}\boldsymbol{\varepsilon}_{t+\iota}$ and $\mathbb{E}_{t-1}[\boldsymbol{\varepsilon}_{t+\iota}] = \mathbf{0}$ for all $\iota = \{0, 1, 2, ...\}$. Similarly, the impulse response functions for the control variables are derived as follows:

$$\text{IRF}(\hat{\mathbf{y}}_{t+\iota}) = \mathbb{E}_t[\hat{\mathbf{y}}_{t+\iota}] - \mathbb{E}_{t-1}[\hat{\mathbf{y}}_{t+\iota}] = \mathscr{A}\left\{\mathbb{E}_t[\hat{\mathbf{x}}_{t+\iota}] - \mathbb{E}_{t-1}[\hat{\mathbf{x}}_{t+\iota}]\right\} \equiv \mathscr{A}\mathscr{B}^\iota\boldsymbol{\Sigma}\varepsilon_t, \tag{E.19}$$

since $\hat{\mathbf{y}}_t = \mathscr{A}\hat{\mathbf{x}}_t$, where $\iota = \{0, 1, 2, ...\}$.

F Solution Method: Anticipated Shocks

Suppose the shock to iceberg costs $\{\varepsilon_t\}_{t=1}^{T}$ for an integer $1 < T < \infty$ becomes known with certainty due to a credible announcement at date $t = 1$ by the relevant authorities. At date $t = 1$, the shock therefore comes as a "surprise", but from then onwards, all agents in this model acquire *perfect foresight*. Following Laffargue (1990), Boucekkine (1995), and

Juillard (1996), the PP-SS-CC model can be cast is the following compact form:

$$f(\mathbf{s}_{t+1}, \mathbf{s}_t, \mathbf{s}_{t-1}, \varepsilon_t) = 0, \tag{F.1}$$

where $\mathbf{s}_t = [\mu_t, s_t, c_t, \tau_t]$ is a 4×1 vector of stacked state and control variables. We assume that $\mathbf{s}_0$ (i.e. the *initial conditions*) and $\mathbf{s}_T$ (i.e. the *terminal conditions*) are given. The solution to the model is characterised by the time paths of all state and control variables $\mathbf{S} = [\mathbf{s}'_1, \mathbf{s}'_2, ..., \mathbf{s}'_T]$ that satisfy the above formulation at each time period in the domain:

$$F(\mathbf{S}) = 0, \tag{F.2}$$

where $F(\cdot)$ is a function parametrised by the deep parameters (β, ϕ, μ, γ, $\bar{s}$, $\bar{\tau}$, σ, ρ, θ), the initial conditions ($\mathbf{s}_0$), and the terminal conditions ($\mathbf{s}_T$).

Because $\mathbf{S}$ is *ex-ante* unknown by construction, the goal is to find its values iteratively until $F(\mathbf{S}) = 0$ is satisfied using an initial guess $\mathbf{S}^{(0)}$. Suppose $J(\mathbf{S}) = \partial F(\mathbf{S})/\partial \mathbf{S}$ denotes the $4T \times 4T$ matrix (i.e the *Jacobian*). Assuming that $\mathbf{S}^{(\iota-1)}$ is given for iterations $\iota = \{1, 2, ..., \bar{I}\}$, we take the first-order Taylor series expansion of $F(\mathbf{S}^{(\iota)}) = 0$ around a fixed point $\mathbf{S}^{(\iota-1)}$, which gives rise to the so-called *secant* equation:

$$F(\mathbf{S}^{(\iota)}) \simeq F(\mathbf{S}^{(\iota-1)}) + J(\mathbf{S}^{(\iota)})(\mathbf{S}^{(\iota)} - \mathbf{S}^{(\iota-1)}). \tag{F.3}$$

Since we are looking for $\mathbf{S}^{(\iota)}$, such that $F(\mathbf{S}^{(\iota)}) = 0$, we can impose this requirement and obtain the following *Newton-Raphson* sequential updating rule:

$$\mathbf{S}^{(\iota)} = \mathbf{S}^{(\iota-1)} - J(\mathbf{S}^{(\iota)})^{-1} F(\mathbf{S}^{(\iota-1)}). \tag{F.4}$$

In practice, the algorithm is deemed to have converged when $||F(\mathbf{S}^{\iota})|| < \epsilon$, where $\epsilon > 0$ denotes infinitesimal convergence criterion. The convergence of the *Newton-Raphson* algorithm is further improved by imposing *homotopy* in the sequential updating rule:

$$\begin{aligned} \mathbf{S}^{(\iota)} &= \delta \mathbf{S}^{(\iota-1)} + (1-\delta)\left[\mathbf{S}^{(\iota-1)} - J(\mathbf{S}^{(\iota)})^{-1} F(\mathbf{S}^{(\iota-1)})\right], \\ &= \mathbf{S}^{(\iota-1)} - (1-\delta) J(\mathbf{S}^{(\iota)})^{-1} F(\mathbf{S}^{(\iota-1)}). \end{aligned} \tag{F.5}$$

for some arbitrary value of $0 < \delta < 1$, usually in the neighbourhood of unity.

The $4T \times 4T$ Jacobian matrix $J(\mathbf{S})$ is subject to the *curse of dimensionality*. This means that the total number of elements increases quadratically with the length of the vector $\mathbf{s}_t$ and the number of time periods $T > 0$. However, the Jacobian matrix is *sparse*, since the number of non-zero elements increases linearly with the length of $\mathbf{s}_t$ and the size of $T > 0$. To see this, let $f(\mathbf{s}_{t+1}, \mathbf{s}_t, \mathbf{s}_{t-1}, \varepsilon_t) = f_t$ and note that the PP-SS-CC model contains only one lead $\mathbf{s}_{t+1}$ and one lag $\mathbf{s}_{t-1}$ at any time period, which implies that

$$J(\mathbf{S}) = \begin{bmatrix} \frac{\partial f_1}{\partial \mathbf{s}_1} & \frac{\partial f_1}{\partial \mathbf{s}_2} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \cdots & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} \\ \frac{\partial f_2}{\partial \mathbf{s}_1} & \frac{\partial f_2}{\partial \mathbf{s}_2} & \frac{\partial f_3}{\partial \mathbf{s}_3} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \cdots & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} \\ \mathbf{0}_{4\times4} & \frac{\partial f_3}{\partial \mathbf{s}_2} & \frac{\partial f_3}{\partial \mathbf{s}_3} & \frac{\partial f_3}{\partial \mathbf{s}_4} & \mathbf{0}_{4\times4} & \cdots & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \cdots & \frac{\partial f_{T-2}}{\partial \mathbf{s}_{T-3}} & \frac{\partial f_{T-2}}{\partial \mathbf{s}_{T-2}} & \frac{\partial f_{T-2}}{\partial \mathbf{s}_{T-1}} & \\ \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \cdots & \mathbf{0}_{4\times4} & \frac{\partial f_{T-1}}{\partial \mathbf{s}_{T-2}} & \frac{\partial f_{T-1}}{\partial \mathbf{s}_{T-1}} & \frac{\partial f_{T-1}}{\partial \mathbf{s}_{T}} \\ \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \cdots & \mathbf{0}_{4\times4} & \mathbf{0}_{4\times4} & \frac{\partial f_{T}}{\partial \mathbf{s}_{T-1}} & \frac{\partial f_{T}}{\partial \mathbf{s}_{T}} \end{bmatrix} \tag{F.6}$$

Traditionally, due to the curse of dimensionality, the Jacobian in its entirety is not inverted and not stored. Instead, $\mathbf{S}$ is solved for each iteration recursively by substituting out the Jacobian in the secant equation, which requires storing only its non-zero elements (see Laffargue (1990), Boucekkine (1995), and Juillard (1996)). But we calculate the inverse and store the Jacobian in its entirety by exploiting the sparse matrix algebra libraries that are now widely available. This proves to be both simpler and less computationally demanding.

G Empirical Methodology

Suppose $\mathbf{y}_t = [\text{TRF}_t, \text{IPR}_t, \text{MKP}_t, \text{CON}_t]'$, where notation for tariffs, import penetration ratio, markups, and consumption is standard. Such variable ordering is consistent with the seminal contribution by Blanchard & Perotti (2002), who identify the shock to government spending by placing the policy variable first in the Cholesky ordering. The idea is that the policy variable does not respond to the contemporaneous movements in the macroeconomy. A change in tariffs, however, contemporaneously affect import penetration ratio, which, in turn, can impact markups at the time of the shock. Finally, consumption contemporaneously reacts to all variables.

Now consider a log-linear structural vector autoregressive (SVAR) model for $\mathbf{y}_t$ as follows:

$$\mathbf{A}_0\mathbf{y}_t = \mathbf{A}_1\mathbf{y}_{t-1} + \boldsymbol{\varepsilon}_t, \tag{G.1}$$

where $\mathbf{A}_0$ and $\mathbf{A}_1$ are 4×4 matrices collecting the structural coefficients, and $\boldsymbol{\varepsilon}_t$ consists of orthogonal unit-variance structural errors. Without any loss of generality, the SVAR above includes only one lag, because in what follows we use the "companion form" matrix formulation to extend the lag structure.

Traditionally, SVAR is transformed into the reduced-form model as follows:

$$\mathbf{y}_t = \mathbf{A}_0^{-1}\mathbf{A}_1\mathbf{y}_{t-1} + \mathbf{A}_0^{-1}\boldsymbol{\varepsilon}_t = \mathbf{A}\mathbf{y}_{t-1} + \mathbf{u}_t, \tag{G.2}$$

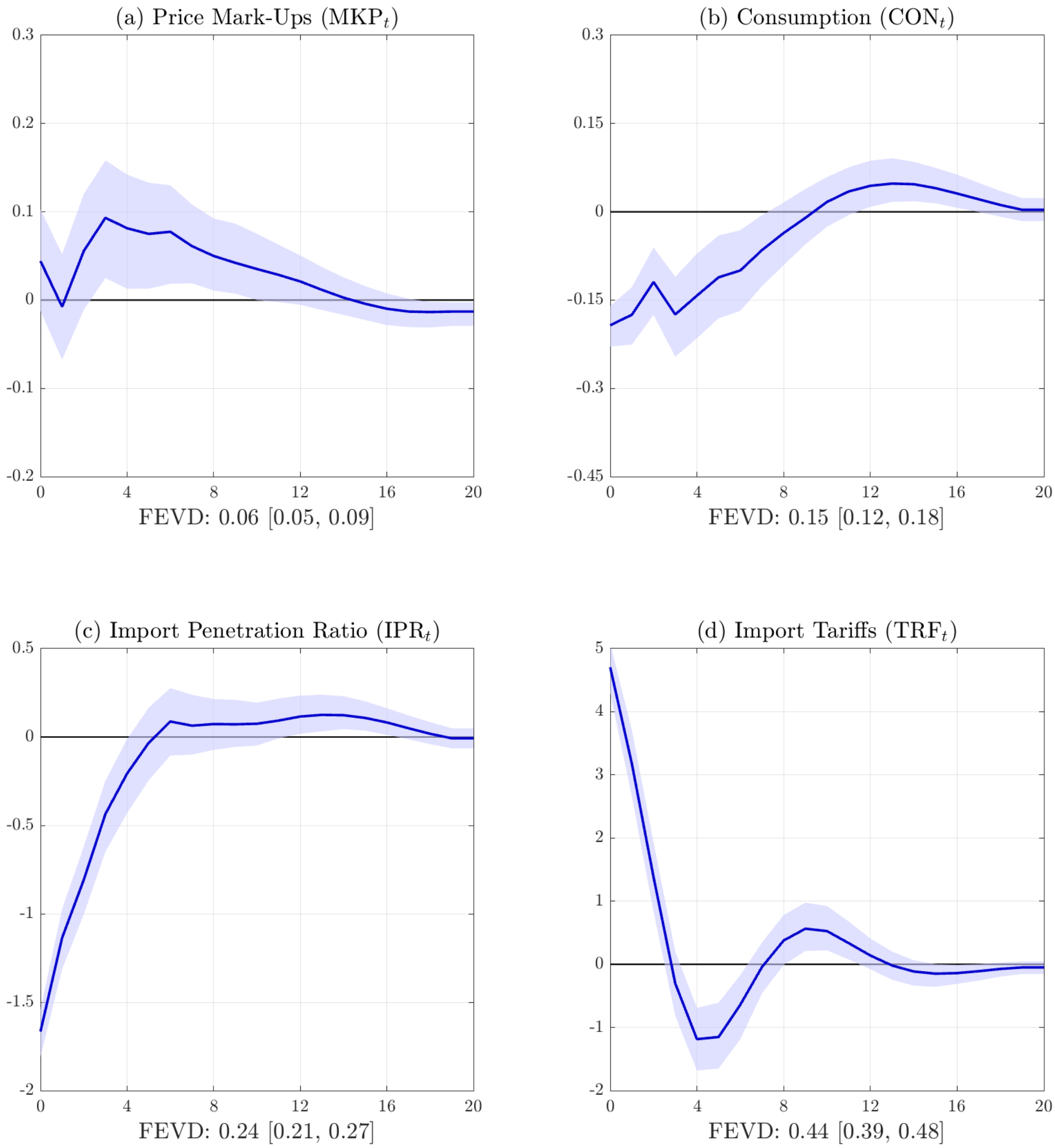
where we assume invertibility of the matrix $\mathbf{A}_0$. There is a large body of empirical literature discussing the estimation of reduced-form parameter matrix $\mathbf{A} \equiv \mathbf{A}_0^{-1}\mathbf{A}_1$, the variance-covariance matrix of the reduced-form errors $\mathbb{E}\left(\mathbf{u}_t\mathbf{u}_t'\right) = \mathbf{A}_0^{-1}\left(\mathbf{A}_0^{-1}\right)'$, and the identification of structural errors $\boldsymbol{\varepsilon}_t$. Having access only to the reduced form innovations $\mathbf{u}_t = \mathbf{A}_0^{-1}\boldsymbol{\varepsilon}_t$, the discussion revolves mainly around the restrictions imposed on the structural coefficients of the matrix $\mathbf{A}_0$ without which $\boldsymbol{\varepsilon}_t$ cannot be uncovered.[8] The traditional approach involves a recursive ordering of the variables (i.e. the "Cholesky" decomposition) along with orthogonality conditions (e.g. Sims (1980) pioneered this approach by placing zeroes inside $\mathbf{A}_0$; Blanchard & Watson (1986), Bernanke (1986) extended this approach). Others consider the so-called parametric long-run restrictions (e.g. Blanchard & Quah (1989)). But the most popular and less restrictive approach in more recent times involves choosing sign restrictions (instead of zeros) on the structural impulse responses (see Faust (1998), Canova & Nicolo (2002), Uhlig (2005), Mountford & Uhlig (2009), Rubio-Ramírez et al. (2010), Arias et al. (2018, 2019), Granziera et al. (2018)). A pure sign-restriction method does not aim to reduce the standard errors of the coefficients. Instead, it involves Bayesian estimation of the reduced-form SVAR alongside the impulse responses conditional on the priors that are consistent with the chosen sign restriction.

Unlike traditional structural VARs, where impulse responses are point identified, sign restrictions impose merely inequality restrictions, and as such deliver only set identified impulse responses. We use Bayesian approach to infer median impulse responses and their error bands. More precisely, we run unrestricted vector autoregressions to collect parameter and variance-covariance matrices. Assuming that the priors and posterior belong to the Normal-Wishart family, we randomly draw from the posterior distributions, characterised by the mean coefficient and covariance matrices. We move to extracting the orthogonal innovations using a Cholesky decomposition and constructing the associated impulse response function. As introduced by Uhlig (2005), we then minimise the penalty function with respect an orthogonal impulse vector, which penalises positive and rewards negative responses in linear proportion, although at a slope hundred times smaller on the negative than on the positive side. To ensure comparability, scaling of variables is done by taking the standard errors of the first differences of the variables.

H Annex

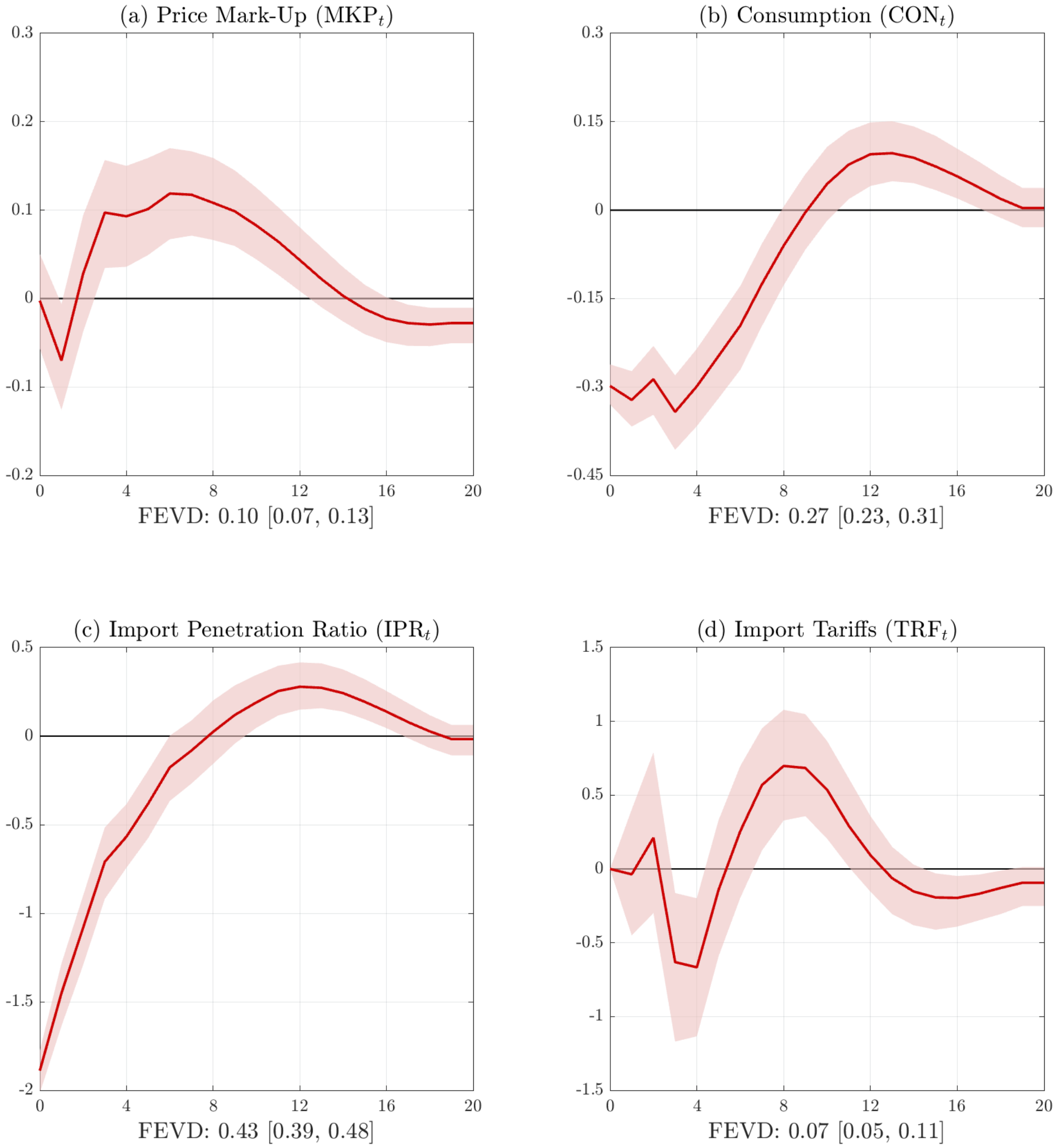
[8] This is because there are $N \times (N-1)/2$ number of unique elements in $\mathbb{E}\left(\mathbf{u}_t\mathbf{u}_t'\right) = \mathbf{A}_0^{-1}\left(\mathbf{A}_0^{-1}\right)'$, whereas $\mathbf{A}_0^{-1}$ contains $N \times N$ number of unique elements, leaving $N/2 \times (N+1)$ number of unidentified elements.

Figure 8: Transitional Dynamics with Unanticipated Trade Shocks (Two-Sided HP Filter)



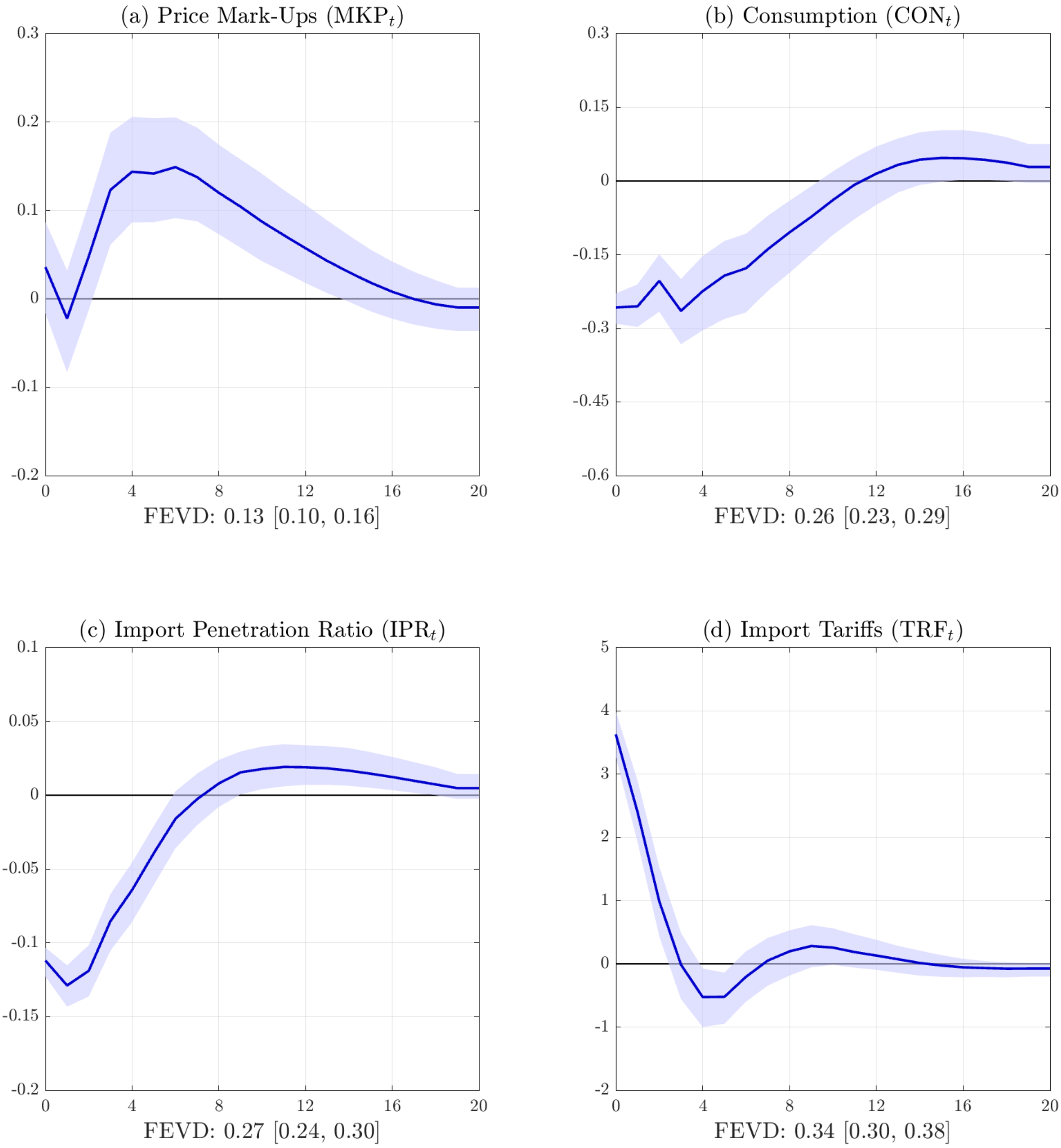
The figure displays impulse responses following an unanticipated shock to the U.S. import tariffs equal to the size of one standard deviation. The horizontal axes measure the time horizon $h = \{0, 1, 2, ...\}$ and the vertical axes indicate the log scale for the cyclical components of each variable. The solid lines are the point-wise posterior medians. The shaded areas are the 68 percent equal-tailed point-wise probability bands. Each figure is based on 1000 independent draws obtained using a Bayesian approach due to Uhlig (2005). The cyclical components of each variable are obtained using the two-sided Hodrick & Prescott (1997) filter. The SVAR model is estimated with a lag order of 4 quarters and includes a constant term in each equation. The Forecast Error Variance Decomposition (FEVD) displayed underneath each IRF measures the share of variation in that variable explained by unanticipated trade shocks with confidence bands displayed in square brackets.

Figure 9: Transitional Dynamics with Anticipated Trade Shocks (Two-Sided HP Filter)



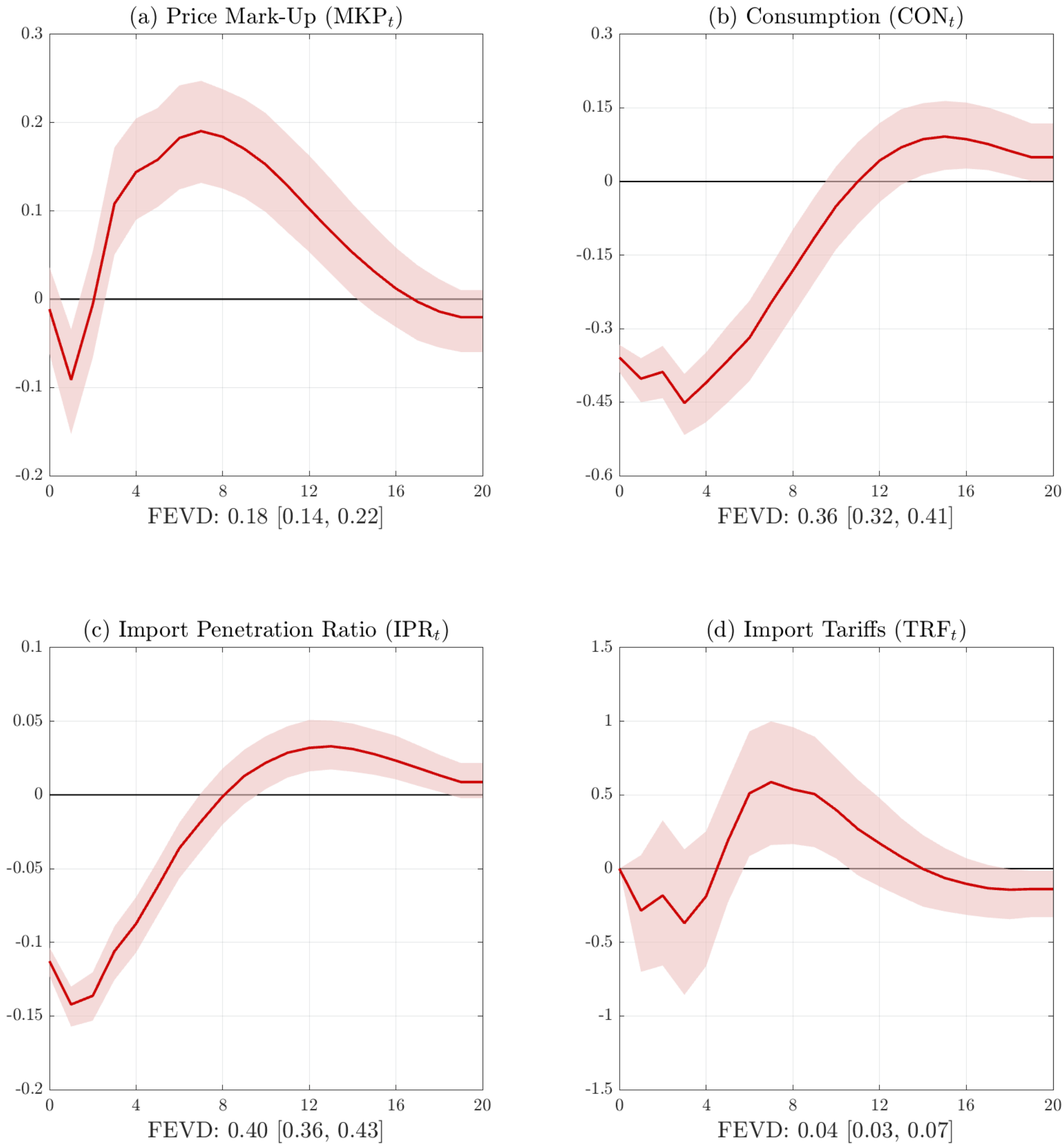
The figure displays impulse responses following an anticipated shock to the U.S. import tariffs equal to the size of one standard deviation. The horizontal axes measure the time horizon $h = \{0, 1, 2, ...\}$ and the vertical axes indicate the log scale for the cyclical components of each variable. The solid lines are the point-wise posterior medians. The shaded areas are the 68 percent equal-tailed point-wise probability bands. Each figure is based on 1000 independent draws obtained using a Bayesian approach due to Uhlig (2005). The cyclical components of each variable are obtained using the two-sided Hodrick & Prescott (1997) filter. The SVAR model is estimated with a lag order of 4 quarters and includes a constant term in each equation. The Forecast Error Variance Decomposition (FEVD) displayed underneath each IRF measures the share of variation in that variable explained by unanticipated trade shocks with confidence bands displayed in square brackets.

Figure 10: Transitional Dynamics with Unanticipated Trade Shocks (One-Sided HP Filter)



The figure displays impulse responses following an unanticipated shock to the U.S. import tariffs equal to the size of one standard deviation. The horizontal axes measure the time horizon $h = \{0, 1, 2, ...\}$ and the vertical axes indicate the log scale for the cyclical components of each variable. The solid lines are the point-wise posterior medians. The shaded areas are the 68 percent equal-tailed point-wise probability bands. Each figure is based on 1000 independent draws obtained using a Bayesian approach due to Uhlig (2005). The cyclical components of each variable are obtained using the one-sided HP filter due to Meyer-Gohde (2010). The SVAR model is estimated with a lag order of 4 quarters and includes a constant term in each equation. The Forecast Error Variance Decomposition (FEVD) displayed underneath each IRF measures the share of variation in that variable explained by unanticipated trade shocks with confidence bands displayed in square brackets.

Figure 11: Transitional Dynamics with Anticipated Trade Shocks (One-Sided HP Filter)



The figure displays impulse responses following an anticipated shock to the U.S. import tariffs equal to the size of one standard deviation. The horizontal axes measure the time horizon $h = \{0, 1, 2, ...\}$ and the vertical axes indicate the log scale for the cyclical components of each variable. The solid lines are the point-wise posterior medians. The shaded areas are the 68 percent equal-tailed point-wise probability bands. Each figure is based on 1000 independent draws obtained using a Bayesian approach due to Uhlig (2005). The cyclical components of each variable are obtained using the one-sided HP filter due to Meyer-Gohde (2010). The SVAR model is estimated with a lag order of 4 quarters and includes a constant term in each equation. The Forecast Error Variance Decomposition (FEVD) displayed underneath each IRF measures the share of variation in that variable explained by unanticipated trade shocks with confidence bands displayed in square brackets.

Table 3: Data Description

Variable	Description	Source
MKP_t	Markup: measured as the inverse of the labour share in the private business sector using data from the Bureau of Labor Statistics (BLS). Under the assumption of the Cobb-Douglas production function, this is measured as the value added divided by total labor compensation.	Nekarda & Ramey (2020)
CON_t	Consumption: personal consumption expenditures at constant prices (*Billions of Chained 2012 Dollars, Seasonally Adjusted Annual Rate, PCECC96*).	Federal Reserve Economic Data
TRF_t	Import tariffs: calculated from the nominal customs data (*Federal government current tax receipts, taxes on production and imports: Customs duties, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate, B235RC1Q027SBEA*) and nominal imports data (*Imports of Goods and Services, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate, IMPGS*) as a ratio between customs duties and imports less customs duties.	Federal Reserve Economic Data and own calculations
IPR_t	Import penetration ratio: ratio between real imports as a percentage of total real domestic demand, where domestic demand is GDP minus exports plus imports. Real imports of goods and services (*Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate, IMPGSC1*), real GDP (*Billions of Chained 2012 Dollars, Seasonally Adjusted Annual Rate, GDPC1*), and real exports of goods and services (*Billions of Chained 2012 Dollars,Quarterly, Seasonally Adjusted Annual Rate, EXPGSC1*).	Federal Reserve Economic Data and own calculations