Economica

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Economica (2021) **88**, 1054–1074
doi:10.1111/ecca.12380

Product Quality and International Price Dynamics over the Business Cycle

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Final version received 11 May 2021.

Two puzzling facts of international real business cycles are (1) weak or negative correlations between the terms of trade and output, and (2) a rise in relative consumption for countries where national goods become relatively more expensive. We show that these puzzles either vanish or become much weaker in recent data. We propose a new mechanism that generates endogenous international price movements that are consistent with both the 'old' and the 'new' facts. In this mechanism, firms operating in a monopolistically competitive environment adjust price and quality of their products in response to technological shocks. This model is consistent with the old facts if price levels are not adjusted for quality. Instead, if quality adjustments to price level are introduced, then the model's properties are in line with the new facts.

INTRODUCTION

Two common observations of the international real business cycle literature with regard to international price dynamics are (1) a negative correlation between the terms of trade[1] and output (Backus *et al*. 1994); and (2) a rise in relative consumption in a country where goods become relatively more expensive (Backus and Smith 1993). Columns (1) and (2) of Table 1 report these correlations for eleven of the largest economies in the Organisation for Economic Co-operation and Development (OECD) between 1971 and 1998.[2] Standard models of international real business cycles predict the exact opposite of these observations. The first goal of this paper is to provide an explanation for the failure of standard models to account for these facts.

Interestingly, a closer look at more recent data would suggest that a fundamental change has occurred in the dynamics of international prices. Columns (3) and (4) of Table 1 show the same correlations for the period 1999–2019, and their changes. Surprisingly, the correlation between output and the terms of trade is now strongly positive for most countries. The Backus–Smith puzzle is weaker for all but one of the eleven OECD economies in our sample. This poses a great challenge for any theory of international price dynamics. Not only should this theory explain the old puzzles, but it should also be able to provide a rationale for the dramatic change of these correlations in recent years. The second objective of this paper is to provide a possible explanation for the reversal or weakening of the aforementioned puzzles.

We present a simple yet powerful mechanism capable of generating international price correlations that are consistent with these facts. Our mechanism consists of giving firms a second dimension of production, namely quality. In standard models, price-taking firms choose to expand production in response to lower production costs as a result of a positive technology shock (firms like to 'make hay when the sun shines'). This is the only possible response for firms, so naturally an increase in the domestic supply of goods puts downward pressure on prices. In the model proposed, producers have the option to spend their productivity gains differently by improving the quality of their products. This affects goods prices through two channels: (1) a demand-side channel, whereby higher-quality

TABLE 1
INTERNATIONAL CORRELATIONS

	1971–98		1999–2019			
	(GDP,TOT)	$(c_{US}/c,\ RER)$	(GDP,TOT)		$(c_{US}/c,\ RER)$	
Country	(1)	(2)	(3)		(4)	
USA	−0.24	N/A	0.54	[+0.78]	N/A	N/A
Japan	−0.11	0.26	0.77	[+0.88]	0.33	[+0.07]
Germany	−0.07	−0.15	0.66	[+0.73]	0.09	[+0.24]
France	−0.06	−0.94	0.54	[+0.60]	−0.45	[+0.49]
UK	0.06	−0.46	0.08	[+0.02]	−0.32	[+0.14]
Italy	0.22	−0.10	0.77	[+0.55]	0.05	[+0.15]
Canada	−0.00	−0.09	−0.37	[−0.37]	0.24	[+0.33]
Spain	−0.05	−0.63	0.63	[+0.68]	0.27	[+0.90]
Australia	0.07	−0.22	0.30	[+0.23]	−0.41	[−0.19]
South Korea	−0.36	−0.64	0.19	[+0.55]	−0.60	[+0.04]
Netherlands	−0.05	−0.14	0.23	[+0.28]	0.10	[+0.24]

Notes
Change with respect to the 1971–98 period is shown in brackets. Source: OECD and FRED.

goods are more valued by consumers, and (2) a supply-side channel, since producing higher quality goods is generally costlier. This result is consistent with Verhoogen (2008): when higher firm-specific quality level requires higher firm-specific marginal costs, firms that implement costly technologies enter in order to produce high-quality goods in periods of relatively high aggregate demand. Therefore quality adjustments are procyclical. Both effects push prices of domestic goods up instead of down.

Quantity and quality changes push prices in opposite directions, whereas when firms could reduce prices only after technology improvements, we only had downward pressure on prices. It then remains a quantitative question whether the effect of quality improvements is strong enough to offset or even dominate the response in quantities. To test this, we calibrate the model to match a number of features of the US economy over the 1971–98 period. We argue that the signs and magnitudes of international price correlations generated by this model crucially depend on how price levels are measured. We find that international price fluctuations are much closer to the ones that we observe in the data for 1971–98 if we assume that statistical agencies ignore changes in quality in their price level calculations. On the other hand, adjusting price levels for shifts in quality affects the time series properties of the model in a way that is consistent with more recent data.

This change in the way in which price levels are determined by statistical agencies is in line with their methodological history. Quality adjustments to price indexes in the USA and elsewhere have improved over the years. One big push in this direction came partly in response to the 1996 Boskin Commission report (Boskin *et al.* 1996). This report led to an expanded use of hedonic methods and more frequent updating of the goods in the consumer's basket used to calculate the CPI (Johnson *et al.* 2006). Quality adjustments have also been increasingly important in price adjustments performed by the US Bureau of Economic Analysis (BEA) in the national accounts (Moulton and Wasshausen 2006). They are quite significant in categories of goods that are of great importance to trade, such as vehicles, consumer electronics and apparel.[3] The findings in Table 1 suggest the possibility that recently introduced quality adjustments to price indexes have reduced the discrepancies between theory and data. We run a simple panel data analysis using US

CPI subcategories as individuals to explore the potential role of quality adjustments in the dynamics of the CPI-U series. We find that quality is relevant for the behaviour of the volatility of CPI categories. We interpret all this as evidence of the importance of the mechanism presented in this paper.[4]

Following the seminal works of Backus *et al.* (1992, 1994), many studies have tried to explain the puzzle of strongly procyclical terms of trade as well as the Backus–Smith puzzle, though so far the results seem unconvincing. And the correlation reversal observed in the data is a fact that has not yet been addressed by the literature.

First, a number of papers address the issue by introducing new shocks that mitigate or even reverse the effects of productivity shocks on the terms of trade. This avenue was pioneered by Stockman and Tesar (1995), who add exogenous taste shocks. The effects of quality changes are similar to the effects of taste shocks. The advantage of the mechanism that we propose is that it retains most of the parsimony of the original model because it refrains from introducing new exogenous disturbances into the standard theory, as quality is determined endogenously. Backus and Crucini (2000) extend the basic international real business cycle model to include oil as a production input, and a third oil-producing country with exogenous shocks to its supply of oil. Raffo (2010) introduces investment-specific technological shocks and variable capacity utilization to a standard model with Greenwood–Hercowitz–Huffman (GHH) preferences. (See the Online Appendix for a version of our model with GHH preferences.) All of these papers improve the quantitative performance of models in terms of the aforementioned correlations, but at the expense of deterioration in other dimensions.

A second group of studies explores the effects of restricting the flow of capital to countries that receive a positive shock. The idea is that this would mitigate the expansion of production and the drop in domestic prices. Baxter and Crucini (1995) replace the complete markets structure of the standard model by a bond economy. They find that the incomplete markets model is not too different from the complete markets version unless there is high persistence of shocks and very few spillovers. In light of this and for simplicity, the model presented in this paper features a single asset that can be traded internationally. Heathcote and Perri (2002) find that a model with financial autarky does a better job at replicating the volatility of the terms of trade as well as cross-country correlations. However, counter to the data, it predicts procyclical net exports. They discuss that perfect risk-sharing generates strong positive cross-country consumption correlations, and efficiency implies that the optimal response to a productivity shock causes increasing investment and labour supply in the more productive country and reducing them in the rest. Therefore we opt for the single-asset scenario to prevent our model from reproducing some weak results already studied in previous literature. Corsetti *et al.* (2008) find that when trade elasticity is low, incomplete markets reconcile theory and data to a large degree, and the Backus–Smith puzzle largely goes away, but the strong, positive correlation between output and the terms of trade remains.

Finally, one study that does not fall in either group was carried out by Ghironi and Melitz (2005), who endogenize the non-tradeness of goods by introducing Melitz' heterogeneous firms structure to the production of intermediate goods. Their model provides an endogenous, micro-founded explanation for a Harrod–Balassa–Samuelson effect: More productive economies exhibit higher average prices relative to their trading partners. Terms of trade in this setting can be uncorrelated or even negatively correlated with output, but the Backus–Smith puzzle remains. The structure of production introduced in Section I is closest to this work: there is monopolistic competition in the market for intermediate goods, and firm technology is linear in labour. However, intermediate good firms in our model are homogeneous, and they have to make two decisions each period, one for price and one for quality. Section I outlines these differences in detail.

The rest of the paper is organized as follows. Section I presents the basic model of a dynamic, general equilibrium economy with quality selection in production. Section II explains how statistical agencies in our model measure business cycle statistics with and without quality adjustments, and then evaluates the quantitative predictions of the model. Section III explores US CPI data on the consequences of quality adjustments on CPIs. Section IV concludes.

I. An Economy with Quality Production

The economy consists of two countries, Home and Foreign, receiving different streams of technological shocks. Whenever necessary, we use an asterisk to indicate Foreign country variables rather than Home country variables. Population is normalized to a mass one of households that live and work in their own country. We assume the price of the final good to be the numeraire.

Households

Preferences of the representative agent in each country are characterized by a utility function of the form $U(c, 1-n)$, where c and n are consumption and the share of hours worked over the endowment of time, respectively. The function is concave in both arguments. Individuals can save in form of capital k or bonds b; capital is immobile across countries, while bonds allow international borrowing and lending so that trade need not be balanced every period. Let x denote irreversible investment in capital goods. Let w_t, $\mathrm{R_t}$ and $\mathrm{r_1}$ respectively denote wages, the rental price of capital at time t, and the price of bonds at time t that pay one unit of the final good the next period. Following Heathcote and Perri (2002), we assume that there is a small quadratic cost to holding bonds to make the model stationary. Households solve

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, 1-n_t) \tag{1}$$

subject, every period, to

$$c_t + x_t + r_t b_t + \frac{\phi_b}{2} b_{t-1}^2 \leq w_t n_t + R_t k_{t-1} + b_{t-1},$$
$$k_t = (1-\delta)k_{t-1} + \psi(x_t/k_{t-1})k_{t-1}.$$

Following Backus and Crucini (2000), physical capital formation is subject to adjustment costs captured by ψ, a function such that $\psi > 0$, $\psi' > 0$ and $\psi'' < 0$. In particular, we use $\psi(x/k) = (x/k)^{\eta}$, where $\eta \in (0, 1)$.

Final good firm

The final goods sector is competitive. Final goods technology uses both domestic and imported inputs, both of which are available in a large number of varieties. Final output depends on the quantity as well as the quality of each of the intermediate goods used in production, and it is sold domestically. The final good firm takes prices and qualities of intermediates as given, and chooses the amount of each input that it needs for production. Therefore the production function is

$$Y_t = \left(\alpha \sum_{i=1}^{I_t} (q_{i,t} d_{i,t})^{\nu} + (1-\alpha) \sum_{i=1}^{I_t^*} (q_{i^*,t} m_{i,t})^{\nu} \right)^{1/\nu},$$

where I_t stands for the number of domestic firms/varieties and I_t^* for the number of foreign firms/varieties, $d_{i,t}$ is the total quantity produced domestically and consumed domestically, $m_{i^*,t}$ is the total quantity produced abroad and consumed domestically, while q_i and q_{i^*} capture quality at at home and abroad, respectively. More broadly, q may be interpreted as a characteristic of the good that makes it more or less desirable. Producers can invest in increasing 'desirability' of their goods by raising the quality of their products as well as by spending on advertising that affects how consumers perceive the benefits they derive from consumption of this good. $\nu \in (0, 1)$ determines the elasticity of substitution between varieties, which is $1/(1-\nu)$. And $\alpha \in (0.5, 1)$ captures home bias in consumption. The problem of the final good firm is

$$\max_{x_{i,t},\, m_{i,t}} \left\{ Y_t - \left(\sum_{i=1}^{I_t} p_{i,t} d_{i,t} + \sum_{i=1}^{I_t^*} \underset{i^*,t}{p}\, m_{i,t} \right) \right\},$$

where $\tilde{p}_{i^*,t}$ are foreign export prices. This determines the demand for each variety as

(2) $$d_{i,t} = Y_t \left(\alpha \frac{q_{i,t}^{\nu}}{p_{i,t}} \right)^{1/(1-\nu)},$$

(3) $$m_{i,t} = Y_t \left((1-\alpha) \frac{q_{i^*,t}^{\nu}}{\underset{i^*,t}{p}} \right)^{1/(1-\nu)}.$$

The demand of each production input increases with domestic absorption Y_t, decreases with the price, and increases with the quality of the input. In a model without quality, if a final good producer takes aggregate final good production as given, then the demand of intermediates depends exclusively on prices: if prices go up, then demand must automatically go down. In this model, however, the demand of a good also depends on its quality. If quality goes up enough, then demand for an intermediate good may increase even after an increase in its price.

Intermediate good firms

Intermediate good firms operate in a monopolistically competitive environment, so in terms of market structure, this model is closest to Ghironi and Melitz (2005), with three important differences. First, to keep things simple, firms in this setting are homogeneous (they all have the same level of productivity and receive the same productivity shock). Second, firms choose not only a price for their products but also an associated quality. More broadly, q may be interpreted as a characteristic of the good other than price that makes it more or less desirable. Hence producers may invest in increasing 'desirability' of their goods by raising the perceived quality of their products or, for instance, by improving the quality of the materials. So producers can actually decide the level of quality every period, climbing up and down the quality ladder. Note, for example, the car company Skoda, which offered a basic model of its Fabia without air-conditioning or electric windows during 2008, although they have the technology to introduce these extras. Introducing them would not require R&D but it would raise the cost of production. And third, we explicitly introduce capital by requiring that firms rent F units of capital every period to operate.

The only (variable) input of production in this sector is labour. Workers in each firm can be assigned to either production tasks or quality-generating tasks. Demand for labour devoted to manufacturing of good i is labelled $l_{i,y}$, while demand for labour devoted to generating a certain level of good quality is labelled $l_{i,q}$. Quality is determined purely by the amount of labour put into quality-augmenting activities, $q_i = l_{i,q}$. By construction, labour input in the two activities (production and increase of quality) are positively correlated. Labour inputs are procyclical in the model. Regarding labour markets, this result is sustained by Shimer (2012): job creation is highly procyclical. The procyclicality of quality improvements is in line with Broda and Weinstein (2010). They find that net creation is strongly procyclical, with more products being introduced in expansions and in product categories that are booming. The production technology is given by

$$y_{it} = \frac{z_t l_{i,yt}}{q_{it}^{\rho}} = z_t l_{i,yt} l_{i,qt}^{-\rho}, \quad \rho \in (0, 1),$$

where z_t is a productivity draw common to every firm at time t. The constant ρ captures how q affects production costs: holding z constant, if $\rho > 0$, then higher-quality goods require more production workers per unit of output. Taking factor prices as given, intermediate firms maximize profits every period t:

$$\max \pi_{i,t} = \max_{l_{i,yt},\, l_{i,qt},\, p_{it},\, \tilde{p}_{it}} \{d_{it} p_{it} + m_{it}^{*} \tilde{p}_{it} - l_{i,yt} w_t - l_{i,q} w_t - F R_t\},$$

subject to the optimal demand equations (2) and (3), and the condition that production must be able to meet demand:

$$d_{it} + m_{it}^{*} \le z_t l_{i,yt} l_{i,qt}^{-\rho}.$$

One can easily show that for a maximum it is sufficient to have $\nu < 1/(2 - \rho)$. There are no barriers of entry for new firms in this sector, so the equilibrium number of firms is given by the zero profit condition. From the maximization problem, optimal quality and prices are given by

(4) $$\bar{q}_t = \left[(1-\rho) z_t^{\nu/(1-\nu)} W_t \left(\frac{\nu}{w_t} \right)^{1/(1-\nu)} \right]^{(1-\nu)/(1-(2-\rho)\nu)},$$

(5) $$\bar{p}_t = \bar{\tilde{p}}_t = \frac{1}{\nu} \frac{\bar{q}_t^{\rho}}{z_t} w_t,$$

where

$$W_t = \alpha^{1/(1-\nu)} Y_t + (1-\alpha^*)^{1/(1-\nu)} Y_t^*.$$

Note that prices are dependent on quality. There is a fixed mark-up over the unit cost of $1/\nu$. Note also that the condition $\nu < 1/(2-\rho)$ ensures that the outer exponential in the expression for quality is positive. So we can expect to observe that quality increases with positive technology shocks. Finally, the solution to this problem implies a constant relationship between l_y and l_q. This is very convenient in calibrating the model:

(6) $$l_q = (1-\rho) l_y.$$

The model has no closed-form solution and requires a numerical analysis. We have explored simpler versions of the setup: shutting down capital variation (i.e. capital is fixed per firm and period), fixing the number of firms and using complete markets. However, the reduced version does not provide us with a closed-form solution either, and it hinders the matching of the data.

Equilibrium

Let $s_t = (z_t, z_t^*)$ denote the state of the economy at time t. This economy is said to be in equilibrium if every period, given a state of the economy, there is a sequence of international interest rates r_t, and for each country, sequences of wages w_t, rental prices R_t, number of firms I_t, capital stocks k_t, household decisions $\{c_t, n_t, x_t, b_t\}$, final good firm decisions $\{d_t, m_t\}$, and intermediate good firm decisions $\{p_t, \tilde{p}_t, q_t, l_{y,t}, l_{q,t}\}$, such that we have the following. Given wages, prices, the interest rate, the number of firms, the current stock of capital and savings, and a transition rule $s_{t+1} = g(s_t)$, the household's decision variables solve the household problem (1). Given qualities, intermediate good prices and the number of intermediate good firms, the final firm's decisions are equations (2) and (3), which solve the intermediate good firms problem. Given the state of the economy and wages, qualities and prices are given by equations (4) and (5). Goods markets clear, that is, $c_t + x_t = Y_t$ and $d_t + m_t^* = (z_{y,t}/q_t^{\rho}) l_{y,t}$. Labour markets clear, that is, $n_t = I_t(l_{y,t} + l_{q,t})$. Capital markets clear, that is, $k_{t-1} = I_t F$. Financial markets clear, that is, $b_t = -b_t^*$. Firms make zero profits, that is, $\Pi_t = \pi_{i,t} = 0$ for all i. And no-Ponzi-scheme conditions hold.

II. Numerical Analysis

Measurement and adjustment for quality

Before proceeding to calibrate the model to the data, think about the variables in the model and their observability to agencies that compute the statistics that we use in the calibration. Assume that statistical agencies do not adjust for quality so that steady-state prices are taken to be the base year prices. In this scenario, real gross domestic product (GDP) is measured as

$$GDP_t = I_t p_{ss}(d_t + m_t^*),$$

while observed domestic absorption (i.e. the total demand of all final goods and services used in the country, either originated from domestic production (GDP) or imported from abroad) is given by

$$\widehat{Y_t} = GDP_t - (I_t p_{ss} m_t^* - I_t^* p_{ss}^* m_t).$$

Y_t is allocated to consumption and investment. We assume that the share of $\widehat{Y_t}$ that is consumed is exactly the same as the share of Y_t that is consumed, hence observed consumption is

$$\widehat{c_t} \equiv \frac{c_t}{c_t + x_t}\widehat{Y_t} = \frac{\widehat{Y_t}}{Y_t} c_t.$$

Similarly, observed investment is

$$\widehat{x_t} \equiv \frac{\widehat{Y_t}}{Y_t} x_t.$$

Terms of trade are defined as the ratio of import price deflators to export price deflators. Since in equilibrium all goods from the same country have the same price, the terms of trade (TOT) can be defined simply as[5]

$$tot_t \equiv \frac{I_t^* p_t^* m_t / I_t^* p_{ss}^* m_t}{I_t p_t m_t^* / I_t p_{ss} m_t^*} = \frac{p_t^* p_{ss}}{p_t p_{ss}^*}.$$

Calculating the consumption real exchange rate requires the construction of a consumption price index for each country. Let M_t be the period t share of imported goods in consumption. Then

$$P_t \equiv (1 - M_t)\frac{p_t}{p_{ss}} + M_t \frac{p_t^*}{p_{ss}^*}.$$

Finally, we define the real exchange rate (RER) as the ratio of these price indexes:

$$rer_t \equiv \frac{P_t^*}{P_t}.$$

Now suppose that the statistical agency observes quality and that it can adjust prices to reflect changes in this dimension of each good. We assume that the statistical agency makes the following correction:

$$\breve{p}_t = \left(\frac{q_t}{q_{ss}}\right)^{\rho} p_{ss}. \tag{7}$$

This is the ideal correction given the expression for optimal prices (5). It guarantees that in the steady state, both adjusted and non-adjusted variables are the same. The agency then replaces p_{ss} with $\breve{p}_t$ in all the expressions above.

Calibration

We use the standard utility function

$$U(c, 1-n) = \frac{\left[c^{\mu}(1-n)^{1-\mu}\right]^{\theta}}{\theta}.$$

Our economy is calibrated to match features of the US economy over the 1971–98 period as follows. We set the value of the discount factor β to 0.99 to match an annualized interest rate of about 4%, and set the capital depreciation rate δ to 0.025 to match an annualized depreciation rate of 10%. Following the literature, the coefficient of risk aversion θ is set to -1. Following Mandelman *et al.* (2011), we assume a cost of holding bonds (ϕ_b) equal to 0.001. We estimate α, the home bias in consumption, as 1 minus the average of the level of openness to trade ratio for the period 1971–98, which is 0.82.[6] μ is set to obtain a share of hours worked equal to 0.34. The capital adjustment cost parameter η is set so that the standard deviation of investment is about three times that of output. The value of the trade elasticity ν is $0.\dot{7}$, to get an elasticity of substitution of 4.5. This is the median value for the estimates in Redding and Weinstein (2016); the mean is 4.4. Redding and Weinstein (2016) develop an extensive analysis to reconcile micro and macro models with actual data for the measurement of price changes, economic welfare and demand parameters (the elasticity of substitution among them). The value that we take comes from their estimates for a constant elasticity of substitution demand function, as in our setup. The reason why this parameter strongly affects the level of investment is that under monopolistic competition with free entry, a low degree of substitutability between intermediate goods implies a high mark-up over marginal costs, which creates incentives for many firms to enter the market. Since capital is a fixed cost that is independent of the firm, the level of investment will crucially depend on the number of firms that enter the market each period. The parameter F is set so that the correlation between output and investment is close to 0.94.

The parameters calibrated so far are pretty common to most of the papers in the literature, and their values do not differ significantly from those in other studies. This is not the case for ρ, which captures how changes in quality affect the costs of production. Equation (6) shows that this parameter determines the fixed relationship between the number of workers in production tasks and the number of workers in quality tasks. To calibrate this parameter, we first determine a plausible range. BLS data for 2009 reveal that between 2.3% and 6.5% of the workforce in the USA may be classified as quality tasks employees, depending on how conservative the measure is. Our model considers two types of workers: those devoted to quality and those devoted to production tasks. Therefore to obtain ρ from the data, we also consider two general groups: quality workers and the rest. (See the Appendix below for details.) These results suggest a ρ between 0.93 and 0.98 for 2009. We take $\rho = 0.96$ as the baseline value and perform a sensitivity analysis for other values in the identified range. The main implications of the model are not affected by moving ρ within these limits: lower values of ρ imply that quality enhancements are cheaper, therefore the firm responds by making quality even more strongly procyclical. If, on the other hand, one takes ρ arbitrarily close to its maximum possible value of 1, then this is still not enough to affect the sign of the correlations of interest.

Productivity process The shock process has the usual form

$$s_t = As_{t-1} + \varepsilon_t,$$

where ε_t is a vector of normally distributed shocks, independent of past values. The cross-country correlation of shocks is set to 0.55 after the estimates in Islamaj (2014). He estimates the cross-country average correlations of technology shocks for the USA with up to 42 countries, including 25 advanced and 17 emerging economies, for the period between 1983 and 2010.[7] The variance of shocks is set to 0.00852 as in Backus *et al.* (1994). The values in the transition matrix of technology shocks (A) take the persistence from empirical estimations in Heathcote and Perri (2002) and keep spillovers to zero. We also check the outcomes for spillovers as those in Heathcote and Perri (2002). The complete parametrization of the model is given in Table 2.

Simulation

Simulation results are presented in Table 3. These are averages over 1000 simulations of 500 periods after discarding the first 100 periods. Let us first evaluate the fit of the model with no adjustments for quality to the data for the 1971–98 period. The model produces terms of trade (TOT) volatility far below that of actual data. It reaches only 20% and 13% of actual standard deviation in not-adjusted and adjusted scenarios, respectively. This excessive smoothness is partly a consequence of excessive risk-sharing.[8] Raffo (2008) suggests that excessive smoothness in international trade variables can be alleviated by introducing Greenwood–Hercowitz–Huffman (GHH) preferences, a possibility that we explore in the Online Appendix. The model matches domestic correlations remarkably well: output, consumption and investment are strongly positively correlated with each other, while net exports and TOT are countercyclical.[9] The cross-country correlation of investment is too strong in the model compared to the data. The Backus–Smith puzzle vanishes: both sign and magnitude of the correlation between relative consumption and the real exchange rate are in line with the data. Finally, the output–consumption anomaly is not such in our simulations: cross-country correlation for output is larger than that for consumption. Therefore the model does appear to successfully address both of the ‘old’ puzzles, while maintaining a level of accuracy in the data matching the statistical moments of the cycle similar to the previous literature.

Column (4) of Table 3 contains the results from an adjustment to price-level calculations for changes in quality in the way described in equation (7). What changes

TABLE 2
BENCHMARK PARAMETER VALUES

	Value	Target description	Target
Household parameters			
θ	−1	From the literature	–
β	0.99	r_{ss}	1% (4% p.a.)
μ	0.36	n_{ss}	0.34
δ	0.025	x_{ss}/k_{ss}	2.5%
η	0.84	$sd(\hat{x})/sd(GDP)$	2.9
ϕ_b	0.001	Bond holding costs	
Firm parameters			
ν	$0.\dot{7}$	$\hat{x}_{ss}/GDP_{ss}$	23%
α	0.82	1971–98 estimates	
ρ	0.96	l_q/l_y	4%
F	0.19	$\mathrm{corr}(GDP, \hat{x})$	0.94
Shock process			
$\varepsilon = \varepsilon^*$	0.00852^2	From the literature	
$\mathrm{corr}(\varepsilon, \varepsilon^*)$	0.55	From the literature	
Productivity transition matrix	$A = \begin{bmatrix} 0.97 & 0.0 \\ 0.0 & 0.97 \end{bmatrix}$	From the literature	–

Notes
Calibrated to 1971–98 US data.

predicted by the model will result from this shift in the way we measure prices? Consider first the two correlations that are the main objective of this paper. The correlation between TOT and GDP increases from −0.38 to +0.52. This is a remarkable change, as remarkable as the +0.70 increase observed in the data. The correlation between relative consumption and the real exchange rate increases by even more, from −0.77 to +0.94. The direction of the change is in line with the data, but the magnitude of the change is much too strong. We believe that the discrepancies in the magnitudes of these changes might be explained by a composition effect. Adjustments for quality are not performed for all categories of goods in the actual Consumer Price Index (CPI). Some of the categories of goods that are affected by these adjustments are vehicles, computers, other consumer electronics, apparel and appliances. These categories of goods represent a large fraction of international trade, but are not as important to the consumption basket of the average consumer. Therefore quality adjustments to these categories will affect import and export deflators much more than they affect the CPI. As a consequence, we should expect to see a stronger effect on TOT than on the real exchange rate. However, the model does not take into account this composition effect. Finally, the model reproduces the reversal in the correlation between TOT and output present in actual data.

There are discrepancies in some other aspects of the changes in the data and in the model. The model suggests that we should observe an increase in the volatility of output and consumption, and an international decoupling in the form of weaker cross-country correlations of GDP and investment. In fact, the opposite has been observed for GDP, consumption and TOT volatilities, and the decoupling has not occurred for the two mentioned variables. We understand that these phenomena may easily be caused by factors that are external to our model. We could exogenously introduce a 'Great Moderation' in the form of lower volatility of the exogenous shocks, and an increase in globalization in the form of higher interdependence of exogenous shocks, as well as a

TABLE 3
SIMULATION RESULTS

	Data[a]		Model	
	1971–98	1999–2019	Non-adjusted	Adjusted
	(1)	(2)	(3)	(4)
Standard deviations[b]				
Output	1.00	0.81	1.00	1.17
Hours	1.22	1.45	0.31	0.29
Consumption	0.84	0.67	0.71	0.75
Investment	2.81	2.87	3.20	3.23
Net exports	0.34	0.39	0.64	0.25
Terms of trade	1.78	1.17	0.37	0.15
Correlation with domestic output				
Hours	0.86	0.92	0.88	0.95
Consumption	0.93	0.91	0.96	0.98
Investment	0.94	0.95	0.96	0.98
Net exports	−0.41	−0.60	−0.43	−0.50
Terms of trade	−0.26	0.44	−0.38	0.52
Cross-country correlations				
Output	0.58	0.77	0.55	0.39
Hours	0.42	0.86	−0.17	−0.17
Consumption	0.36	0.74	0.46	0.25
Investment	0.30	0.80	0.68	0.63
Relative consumption – RER	−0.71	−0.13	−0.77	0.94

Notes
[a]Source: OECD and FRED.
[b]Relative to the standard deviation of output for the period 1971–98.

reduction of the home bias parameter, when we compare the model with recent data. If, by doing so, we calibrate to match the volatility and cross-country correlation of output and the share of imports in GDP for the 1999–2019 period, then the sign turns in the correlations of interest are robust to the changes observed in the data, and their magnitudes are not greatly affected. However, we prefer to show the results from a homogeneous calibration for both adjusted and non-adjusted versions of the model to identify what and how much of the changes may be explained by quality-adjustment considerations. Since some production has shifted towards cheaper places such as China, we were concerned about capturing the changes in world production allocation through the variations in GDP–TOT correlations. If this were the case, then we would expect a relative increase in import prices and a relative decline in export prices due to changes in composition. To disregard this explanation, we checked the correlation between real GNP and TOT for the two periods, and the results are consistent with those of GDP correlations. For the USA, we find −0.22 for 1971–98 and +0.60 for 1999–2019. The correlation between GNP and TOT changes in the same direction and by almost the same magnitude of that of GDP–TOT.

Finally, our model produces a low but negative cross-country correlation of labour inputs.[10] This is a common problem of these kind of models (see, for instance, Backus *et al.* 1995; Kollmann 1996) that has been addressed in very different ways over time. For instance, Kehoe and Perri (2002) use endogenous incomplete markets with imperfect

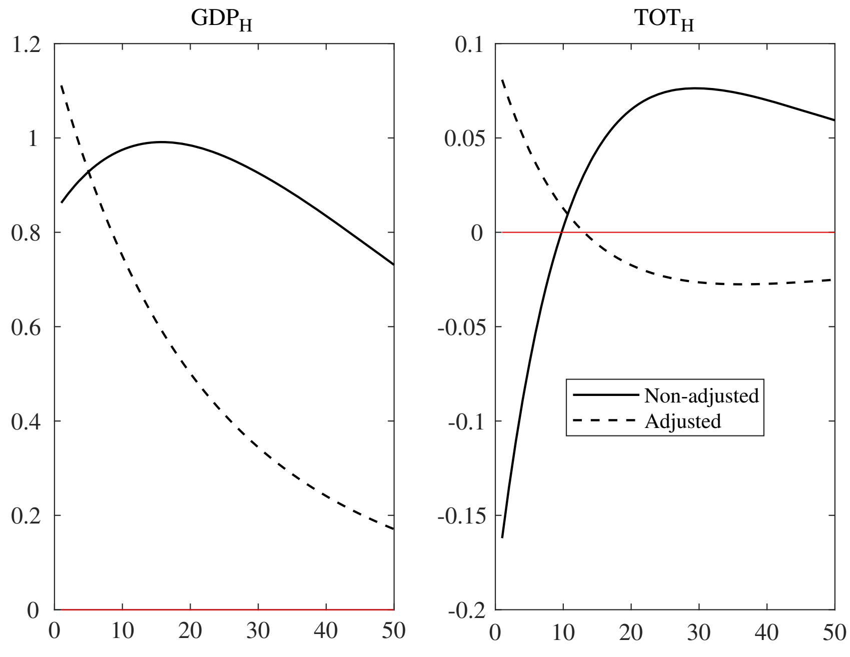

FIGURE 1. Impulse responses of output and terms of trade.

enforceability of loan repayment, and Dmitriev and Roberts (2012) rely on GHH preferences and internal habit formation. However, both of them suffer from the output–consumption anomaly that our simulations overcome. In the Online Appendix, we explore GHH preferences and also overcome the negative cross-country correlation, but the model performs worse in many dimensions. For example, the GHH version overcomes TOT excessive smoothness for the not-quality-adjusted scenario, but produces close-to-zero standard deviation for the quality-adjusted one. It also misses the change of sign in TOT correlations.[11]

To appreciate the mechanism driving our results, we plot impulse response functions in Figures 1 and 2. As the country receives a positive technology shock, quality goes up. This leads to an increase in the price of goods and a decline of quality-adjusted prices. Hence TOT (in the right-hand panel of Figure 1) moves in opposite directions depending on whether or not we apply quality adjustments. Output (in the left-hand panel) increases in both cases, though its response is stronger when prices are adjusted for quality. Taken together, this illustrates the negative correlation between output and net exports that is observed in the data before the 1990s, and the reversal of this correlation once quality adjustments are introduced to price-level calculations.

The top-left panel in Figure 2 shows the effects of the shock on the aggregate price level. Since domestic good prices increase relative to foreign good prices and consumers are biased towards domestic goods, the price level increases as well. Of course, the opposite happens when prices are adjusted for changes in quality. Therefore the real exchange rate (bottom-left panel) declines in the first case, but it increases in the second. Consumption (top-right panel) increases in both cases, though the response is slightly larger when quality adjustments take place. Similarly, relative consumption (bottom-

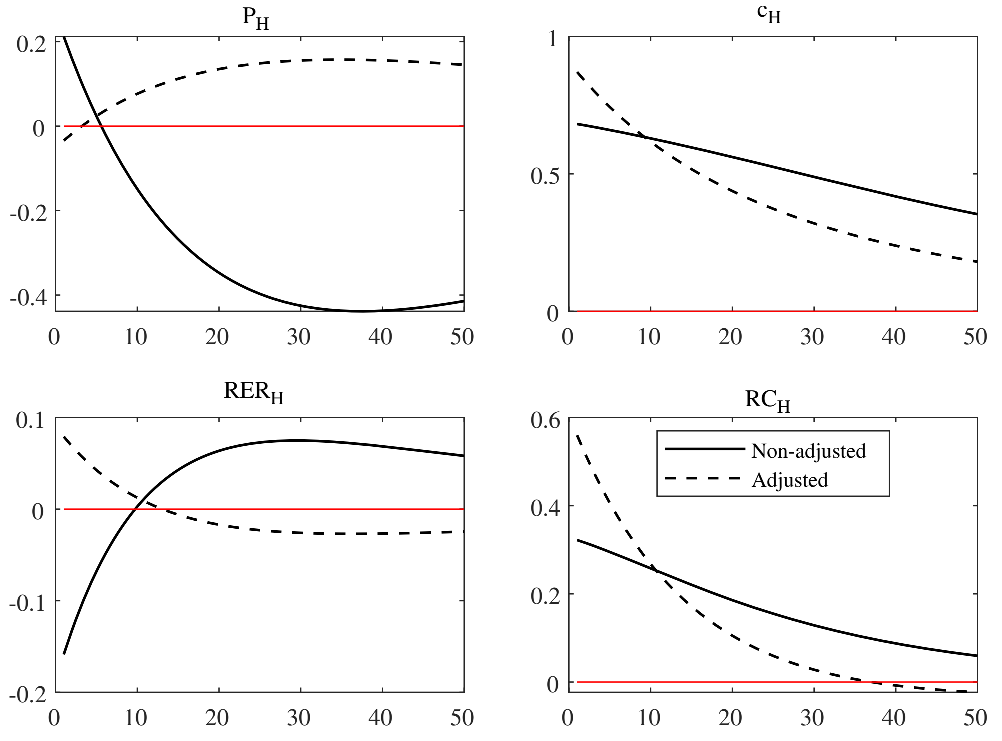

FIGURE 2. Impulse responses of relative consumption and the real exchange rate.

right panel) increases in both cases. Taken together, this illustrates the negative correlation between relative consumption and the real exchange rate that is observed in the data before the 1990s, and the reversal of this correlation after the introduction of quality adjustments.

III. EMPIRICAL EVIDENCE

This section explores the consequences on the price index behaviour of late 1990s main changes in US CPI-U computations. The Online Appendix offers a revision of the scarce literature addressing the impact of quality-adjustment methodology introduction on international relative CPI movements. The Appendix in this paper provides more details on the data that we use.

Relevance of quality adjustments on CPI behaviour

Over time, US CPI has suffered from many changes and full revisions. The most extensive and recent one was applied from 1998 and further developed in the following years.[12] It addressed crucial improvements regarding the frequency of basket of consumption updating: the now almost continuous item replacement procedure (products disappear and are replaced with new versions, and new products emerge, every month), which accounts for quality changes; the substitution of the Laspeyres formula with the geometric mean index formula (except for: shelter; gas, electricity and water services; medical care services) from January 1999 (see BLS 2020); and the expansion of the use of hedonic regression in quality adjustment, together with other quality-adjustment methods. The use of the geometric mean index formula mitigates lower-level substitution bias and reflects shifts in consumer spending within item categories as relative price change. Therefore it allows CPI-U to capture consumer purchase shifting to cheaper (and potentially different in quality) substitute items in contractionary periods. A consumer who was buying a specific item and, facing an increase in its price, turns to a cheaper close substitute product, is now buying an item that provides her less utility and therefore embeds, for her, less quality. Statistical agencies turning to geometric mean formulas for narrow categories want to capture this behaviour and to approximate CPI to a cost-of-living index (COLI) (see Dalton *et al.* 1998; IMF 2020). Twenty-two of the OECD countries and almost every EU member introduced the geometric mean formula (see Evans 2012; OECD 2018, 2020).

We explore whether the introduction of relatively recent quality-adjustment methods in US CPI-U has caused any significant change in the behaviour of the aggregate or disaggregate indexes. To do so, we construct an unbalanced monthly panel data with 109 CPI series, including *CPI-U all items* and some of their subcategories from 1950 to 2020, 20 of which are affected by quality adjustments. We use a dummy variable Q taking value 1 from the month in which the quality-adjustment method is introduced onwards, and 0 before that. When a category has no new quality consideration, the entire series has value 0 for Q. We also consider the tradability condition of the goods in every subcategory.[13]

Exploiting the panel, we regress different volatility measures on the introduction of quality adjustments, tradability and changes in the aggregate unemployment rate. Although the unemployment rate is common to all series, we introduce it to control for the economic cycle, avoiding reliance on any aggregate that may be affected by how CPI is computed, for example, real GDP. We use a Hodrick–Prescott (HP) filter on the natural logs of CPI series and unemployment rate. Then we compute two volatility variables for HP-filtered CPI series: the 6-month overlapping rolling window standard deviation ($sd6_{i,t}$) and the annual (non-overlapping 12-month) standard deviation ($sdyear_{i,s}$). We run a Levin–Lin–Chu unit-root test on our volatility variables and find that they are stationary at any level of confidence.[14] The models that we estimate are

$$sd6_{i,t} = a + \sum_{n=1}^{5} \beta_n sd6_{i,t-n} + \gamma Q_{i,t} + \delta sd6U_t + \phi c_i + \mu_{i,t}, \tag{8}$$

$$sdyear_{i,s} = a + \beta sdyear_{i,s-1} + \gamma Q_{i,s} + \delta sdyear U_s + \phi c_i + \mu_{i,s}, \tag{9}$$

where the standard errors μ are robust to heteroscedasticity and serial correlation, and we include fixed effects. Subscript s refers to the end-of-year value of the variable. Recall that we are computing the 12-month standard deviations, year by year, to use them as a dependent variable in the regression. Subscript t indicates the month. β are the coefficients for the lags of the dependent variables. Due to the construction of $sd6$, five lags are significant in the first model. γ is the coefficient for quality adjustment, δ for the standard deviation of national unemployment rate, and ϕ for the CPI series dummy (the fixed effect). Finally, we explore whether quality has any effect on the change in the

TABLE 4
PANEL DATA RESULTS

		sd6		sdyear	diffsd
	(1)	(2)	(3)	(4)	(5)
y_{t-1}	1.3753***	0.8925***	1.3752***	0.4709***	0.3894***
	(0.0171)	(0.0078)	(0.0172)	(0.0306)	(0.0039)
y_{t-2}	−0.6568***		−0.6570***		
	(0.0253)		(0.0254)		
y_{t-3}	0.0748***		0.0746***		
	(0.0216)		(0.0217)		
y_{t-4}	0.0435**		0.0436**		
	(0.0193)		(0.0194)		
y_{t-5}	0.0624***		0.0622***		
	(0.0113)		(0.0114)		
Q	0.00025***	0.00029***	0.00013**	0.00149***	2.67e-06
	(0.00004)	(0.000058)	(0.00005)	(0.00047)	(0.00011)
$sd6U$	0.0017***	0.00199***	0.0018***		
	(0.0004)	(0.00058)	(0.0005)		
$sdyearU$				0.0349***	
				(0.0084)	
$diffU$					0.0098***
					(0.0009)
R-squared	0.9224	0.8934	0.9216	0.6533	0.1542
Adj. R-squared	0.9222	0.8931	0.9214	0.6446	0.1525
Prob. >F	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	55,471	55,907	52,835	4518	55,798
Categories	109	109	105	109	109

Notes
Standard deviations are in parentheses. y_s refers to s-period lags of the dependent variable, which is a 6-month rolling window of the standard deviation of CPI-U categories for models (1)–(3), a 12-month standard deviation for model (4), and a first difference of the 6-month rolling window of the standard deviation for model (5). Model (3) uses narrow CPI subcategories only, discarding CPI all items and main subcategory aggregates. *, **, *** denote statistically significant at 10%, 5%, 1%, respectively.

variability of CPI. To do so, we regress the difference

$$diff6_{i,t} = c + \beta diff6_{i,t-1} + \gamma Q_{i,t} + \delta diff6U_t,$$

where $diff6_{i,t} = sd6_{i,t} - sd6_{i,t-1}$. Quality is not significant in this case. Table 4 summarizes the results. Q is significant at 1% for models (1)–(4), but it is not significant in model (5). Therefore the introduction of new quality-adjustment considerations in CPI computations in the late 1990s and early 2000s seems to be relevant for the cyclicality of CPI as an aggregate and for its subcategories. Instead, quality does not affect the speed of increase or decrease of the volatility.

Let us set an example to understand γ. Focus on column (2) of Table 4, and imagine that the volatility of a CPI-U subcategory last period was 0.0094038.[15] In this case, the period t standard deviation will be 0.00029 higher for a subcategory with $Q = 1$. In this example, it represents a 3% higher standard deviation for the CPI series. The analysis allows us to observe how dynamics change, but does not shed light on the direction of change of CPI values over the cycle. The results in Table 4 may indicate that when quality and price changes are disentangled, prices can respond more to economic fluctuations. Hence they do not reject our theoretical model story.

One concern that the reader may have is the possible coincidence in time of globalization upsurge and quality-adjustment methods in CPI. If this were the case, then we could erroneously conclude the relevance of the quality changes consideration, while part of the hidden effects could come, instead, from trade openness. The literature locates most relevant regulatory changes that favour openness between 1970 and 1995 (see, for instance, Krugman 1995; Sachs and Warner 1995). Ben-David and Papell (1997) develop a detailed cross-country time series analysis testing for structural breaks in imports and exports over GDP ratios. They find 1972 and 1973 as breaking points for US imports and exports over GDP ratios. All of the 47 analysed countries suffered the break in 1986 at the latest, and there is quite a lot of variety in the break date. A more recent paper, Husein and Pier (2019), looks for structural breaks for US exports and imports endogenously, and finds them around 2007. Finally, we run a simple analysis for annual import and export data from 1960 to 2019, and systematically reject the hypothesis of a structural break in their trends around years close to 1998, where major quality-adjustment changes were introduced in CPI.[16] To explore the effects of globalization on CPI volatility, we run regressions for both volatility measures and for the first difference between them on the trade dummy variable for our panel of categories. Trade results are not significant at any level of confidence in all cases.[17]

In our opinion, the empirical evidence provided in this section and summarized in Table 4 supports quality adjustments at cyclical frequency as one potential explanation for over-time changes in correlations that involve price indexes.

IV. Conclusions

Over the course of a few years, many of the goods that we consume have experienced dramatic changes in quality. Most of these have been innovations that occurred slowly but steadily. To the best of our knowledge, this is a fact that has been largely ignored by the international real business cycle literature. From our point of view, it is an important reason for the discrepancies that exist between theoretical model predictions and actual data estimates. Interestingly, these discrepancies have dwindled in recent years.

How can we arrive at a theory that explains both the reasons for these puzzles as well as their gradual banishment? We have argued that in order to achieve both of these objectives, one needs two elements: first, a modification of the standard model of international real business cycles that takes changes in quality into account; and second, a change in price measurement techniques that reflects improvements in quality-adjustment practices of statistical agencies. The results presented in this study show that taking changes in quality into account has the potential to explain some of the puzzles related to the co-movement of international prices and quantities. The model introduces a mechanism capable of endogenously arriving at this result, without the need to introduce new shocks, thus preserving most of the simplicity of the original model and avoiding many of the pitfalls typically brought about by the introduction of exogenous disturbances. Furthermore, it shows that taking into account recent changes in the methodology of price-level calculations has the potential to explain the diminishing importance of the puzzles.

It could be argued that prices in previous models could simply be understood as being 'quality-adjusted', and therefore price drops following productivity gains already reflected changes in quality. The advantage of the framework in this paper is that by explicitly modelling both pricing and quality decisions, it is possible to answer the question of whether quality improvements are quantitatively important enough to explain the aforementioned puzzles. Furthermore, our framework acknowledges that price drops and quality enhancements are not necessarily two sides of the same coin. In many cases, the decision to improve quality comes at the expense of higher production costs, such as hiring better engineers or using better materials. Profit-maximizing firms often face this trade-off, and a purely symmetrical model in which price drops and quality improvements are interchangeable completely ignores it.

Using a monthly panel data for US CPI subcategories, we find evidence of the significance of the introduction of quality adjustment for changes in CPI volatility, thus supporting our story. While the idea that investments in quality are important to business cycle properties is highly intuitive, it would be desirable to find additional support in the data for our mechanism. Paradoxically, it is precisely the lack of good data on quality that creates the biases in price indexes that give relevance to this idea in the first place. Finding industry-level data to test the cyclical properties of quality suggested in this paper would be an important complement to this research project and an avenue for research to be pursued in the future.

This model also has interesting implications for the estimation of shocks. Given that changes in quality resemble demand shocks, an econometrician could potentially mistake changes in quality driven by technological shocks with demand shocks that are independent from the former. A closer evaluation of this possibility is another interesting potential extension of this model.

APPENDIX

DETERMINE A SUITABLE

The Standard Occupational Classification (SOC) 2000 of the Bureau of Labor Statistics, provides a detailed classification of employees based on their working tasks (see BLS website http://www.bls.gov/oes/2009/may/oes_nat.htm#11-0000). It considers 821 detailed occupations, and lists the tasks for every category. Data are collected annually, but the classification changes over time. SOC 2000 finishes in 2009. However, the changes from the immediately previous year, 1999, are not dramatic and we can homogenize them to compare 2009 and 1999 (we cannot claim the same for 1998 data).

After revising the definitions for every occupation, we construct two measures of quality tasks employees. We select occupations that imply the design, creation, invention and customization for specific clients or group of clients, and research (and similar tasks) on products and services, as well as the direct control of quality and its improvement. We also include those occupations involved in the enhancement of the interest of the public on goods and services (i.e. marketing activities).

The *broad measure* includes 53 categories that are listed in the Online Appendix. All of them together represent 6.57% of total employment in 2009 and 5.74% in 1999.

The *conservative measure* is more restrictive. It includes 25 categories and requires the appearance of the words creation, design, conversion, product safety, conservation, new uses, discovery, quality, marketing or advertising in the definition. Moreover, we are cautious with a broad category labelled *Industrial Engineers*, which specifies that they: ‘Design, develop, test, and evaluate integrated systems for managing industrial production processes including human work factors, quality control, inventory control, logistics and material flow, cost analysis, and production coordination.’ Therefore they are actually involved in the enhancement and control of quality, and in some design. However, the latter are not the only tasks that they perform. We decided to include only a quarter of industrial engineers in our conservative measure. The other 24 categories are listed in the Online Appendix. This measure implies 2.33% and 2.12% of the workforce devoted to quality tasks in 2009 and 1999, respectively.

From equation (6), we derive

$$\rho = 1 - \frac{l_q}{l_y}.$$

In the model, we consider only two types of labour, so we must do the same in the data. Therefore, due to labour market clearing,

$$\rho = 1 - \frac{l_q I}{n - l_q I}.$$

The ratio divides total workforce in quality tasks by total employment minus total workforce in quality tasks. This implies a ρ of 0.93 and 0.94 for 2009 and 1999, respectively, by using the broad measure; and $\rho = 0.98$ for both years by using the conservative measure.

Supplementary data

Supplementary data associated with this paper can be found in the Online Appendix.

ACKNOWLEDGMENTS

We thank Juan Carlos Conesa, Kristian Estevez, Vahagn Jerbashian, Tim Kehoe and Johannes Pfeifer for useful discussions during the development of this work. We also thank Jonathan Church, from the BLS Information and Analysis Section, for his help with US CPI data.

Marta Arespa gratefully acknowledges financial support from the Spanish Ministry of Science, Innovation and Universities through the grant RTI2018-093543-B-I00, MCIU/AEI/ FEDER, UE.

NOTES

1. We adhere to standards of the international real business cycle literature and define terms of trade as the price of imports divided by the price of exports.
2. Terms of trade are computed as the ratio of the price deflator for imports and the price deflator for exports, while price deflators are calculated as the ratio of imports (exports) in current prices and their corresponding value in real terms. See the Online Appendix for details on the data.
3. For a short and comprehensive introduction (with examples) to hedonic price construction and its relevancy in the CPI, see the related FAQs on the Bureau of Labor Statistics (BLS) website—see https://www.bls.gov/cpi/quality-adjustment/questions-and-answers.htm.
4. The BLS kindly responded to our questions to say that they have not computed hedonic prices in retrospect to homogenize the series. It would be, indeed, impossible to go back to every period and compute the progression of quality, feature by feature, of every good in the basket of consumption. Moreover, at the time, this basket was not updated as often as has been recommended since the Boskin Commission report.
5. Notice that in actual data, price deflators involved in the measure of terms of trade are affected by the same quality adjustment considerations as CPI-U, and these adjustments were introduced simultaneously in the different price indexes computed by the US Government (see BEA (2020) and BLS FAQs at https://www.bls.gov/mxp/questions-and-answers.htm, especially items 6, 7 and 9).
6. We keep this value for the quality-adjusted framework for comparability reasons. Although the home bias for the period 1999–2019 actually reduced to 0.734, our simulation results do not vary significantly with the change.
7. The results of Islamaj (2014) range between 0.53 and 0.68, depending on the decade of analysis and the group of countries (advanced or emerging) observed. We disregard, in the range indicated, the lower values found for the correlation with emerging countries in the 1980s and 1990s, due to the small number of countries included in the sample (due to data availability). The correlation of technology shocks in the USA with the rest of the world is 0.54 in the 2000s, 0.55 in the 1990s, and 0.58 in the 1980s. These numbers are even higher when you focus on advanced countries alone. In our simulations, the use of lower levels of correlation—close to those in Backus *et al.* (1994) or Heathcote and Perri (2002)—produce very low cross-country correlations for consumption in the quality-adjusted version.

8. Backus *et al*. (1994) already reached 26% of actual volatility with their low-elasticity model, and 16.4% with their benchmark model.
9. The countercyclicality of TOT is a result that is difficult to find in the theoretical literature. For instance, both Backus *et al*. (1994) and Heathcote and Perri (2002) get a positive correlation for TOT.
10. The introduction of symmetric spillovers such as those in Heathcote and Perri (2002) worsens the negative cross-country correlation for hours and makes the model miss the change of sign in the correlation of TOT with output. The latter data mismatching appears when spillovers from the rest of the world (Foreign) towards Home are introduced, while the sign turns positive again when we allow for Home spillovers towards Foreign, and it is a robust result for a wide range of spillover sizes.
11. Low elasticities of substitution in our setup help the model to produce cross-country correlations for labour input quite in line with data, and reduce the correlation between relative consumption and real exchange rate (RER) in the quality-adjusted scenario. However, it does it at the expense of a too low imports–GDP ratio in the steady state, which causes the volatility of net exports and TOT to stay close to 0 for the not-quality-adjusted and quality-adjusted scenarios, respectively.
12. See CPI historical changes at https://www.bls.gov/cpi/additional-resources/historical-changes.htm.
13. See the Online Appendix for details.
14. This test requires a strongly balanced panel data. As a consequence, we run the test for every CPI category for the entire available time period, and between 2010 and 2015 for the entire panel.
15. This is the true value for $sdyear_{TV,2000}$.
16. We use Stata to test for unknown structural breaks in the logs of total exports and total imports for the USA, and the logs of exports and imports over GDP. The tests report 1973, 1988 and 2008 as breaks.
17. The Online Appendix also explores the role of quality adjustments in trend changes for CPI subcategories. We conclude that they are not significant for the CPI trend.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

A Data for international correlation facts
B Determine suitable
C GHH preferences
D Empirical evidence for the role of quality
E Tables
F Figures