# News Shocks and Terms of Trade: A Quantitative Investigation*


*Kyriacos Lambrias*†

*Université Toulouse 1 - Capitole, TSE and GREMAQ, France*


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**Abstract**

In this paper we investigate the effects of "news shocks" to technology on the terms of trade. To do so, we augment a standard, frictionless model of the international business cycle with news shocks and check the changes in the model's prediction with regard to persistence and volatility of model-generated data. Our results show that news can increase persistence of the terms of trade, but leave variability rather unchanged. We provide intuitive explanations for these results and we pose a potential trade-of in news-driven open-economy models: news can increase the persistence of the relative price series, but if anything their variability decreases.



**Keywords:** Terms of Trade, News-shocks, International Business Cycles.

**JEL Classification:** E, F.



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†email: kyriacos.lambrias@univ-tlse1.fr. fax: +33 (0)5 61 22 55 63. Address: Toulouse School of Economics, Université Toulouse 1 - Capitole, Manufacture des Tabacs, 21, Allé de Brienne, 31000 Toulouse, France.

# 1 Introduction

"A central puzzle in international real business cycle literature is that fluctuations in real exchange rates are volatile and persistent" (Chari, Kehoe and McGrattan 2002). In general, both New Keynesian (see e.g. Chari, Kehoe and McGrattan 2002) as well as Neoclassical (see e.g Backus, Kehoe and Kydland 1994) type of models have difficulty matching these features of relative prices. Recent work has shed more light in what can be an important source for the aforementioned "irregularities" like non-tradeable services in the production of tradeables (Corsetti et al 2007), pricing-to-market (Betts and Deveroux 2000), habits and learning (Johri and Lahiri 2008), agent heterogeneity and private information (Kocherlakota and Pistaferi 2007), different productivity processes (Heathcote and Perri 2002, Rabanal et al 2008) and investment-specific shocks (Raffo 2010, Mandelman 2011). The common workhorse of these works is a two country, open-economy DSGE model augmented by an exogenous, stochastic process for (mainly) technology driven by unexpected innovations. However, Beaudry and Portier (2006) have shown that technology improvements are to a large extent foreseeable and diffuse only slowly over time; implying a change in agents expectations before the technology index actually improves. The authors demonstrate that this very change in expectations can be an important source of fluctuations, possibly more than the actual change itself. Following the pioneering work of Beaudry and Portier (2006) the effects of these so called "news shocks" have been investigated quite extensively both in closed economy (Jamonvich and Rebello 2006, Blanchard, L'Huillier, and Lorenzoni 2009) and open-economy set-ups (Beaudry, Dupaigne and Portier 2009, Jamonvich and Rebelo 2008, Cova et al 2008). The emphasis of these papers is on macroeconomic aggregates, mainly cyclical co-movements in these aggregates, at the national and the international level. In this paper, we take a different approach. We investigate the extent at which changes in expectations, as captured by "news shocks", can help us better understand movements in *relative prices*; and in particular the behaviour of the terms of trade. News shocks are a pure wealth effect, as agents discover about higher future wealth due to the forthcoming improvement in productivity and thereby their wage income. The latter, together with the forward-looking nature of prices in a world where agents are fully-rational and take into account all available information in their consumption and investment decisions; makes the terms of trade responsive to changes in expectations even if fundamentals have not changed. The terms of trade, the relative price of imports in terms of exports, reflect the relative use of home and foreign goods for investment and consumption purposes. Consumption-smoothing implies an immediate adjustment of agents' consumption plans faced with new information about higher wealth (Beaudry and Portier 2006), and this adjustment is reflected both in prices and quantities. In this paper we try to understand the direction of the effect in the terms of trade, as well as its implication on the series' empirical regularities.

More precisely, we investigate the quantitative and qualitative changes of a standard, frictionless model of the international business cycle in relation to the terms of trade persistence and volatility when changes in technology are forecastable. As our workhorse, we use the model of Backus, Kehoe and Kydland (1994), henceforth BKK. This is a well understood, flex-price complete-market model whose successes and failures are well known; thus making comparison easy. Based solely on the first-order autocorrelation coefficient, the model matches the persistence of the terms of trade well. The authors attribute the latter to the persistence of the exogenous driving force of the model, the TFP process. Nevertheless, we show that the model fails the persistence in the terms of trade once we consider autocorrelations of higher order, and less so for half-lives of impulse responses and the highest-roots of lag polynomials. With that in hand, we show that augmenting the model with news shocks can increase persistence and close the gap between the model and the data. Nevertheless, this relation is not monotonic in so far that longer foresight does not imply more persistence. Fève et al (2009) and Leeper et al (2011) have shown that news shocks add moving-average components in the specification of economic aggregates, which explains from a statistical viewpoint that news can indeed increase persistence of time-series. Our work is related to theirs for we also provide intuition as to why this might be the case for the terms of trade. As far as volatility of the terms of trade is concerned, the benchmark model generates substantially less than what is observed in the data. We show that augmenting the model with news does not help much on that front, in so far that the variability of relative price hardly changes with news, and if anything is decreased.

The key intuition to the above findings is the consumption-investment behaviour of forward looking agents. In a news-driven environment, movements in relative prices reflect changes in relative demands of the intermediate goods. In this context, investment plays a particularly important role (similarly to Raffo 2010). As agents discover about the increase in the future marginal productivity of capital, they postpone investment and increase consumption. However, the response of investment is much higher (in absolute terms) than that of consumption; and together with the home-bias in the production of final goods the world demand of the home-intermediate good falls. This demand-effect causes a terms of trade depreciation; even though there has not been any actual change in the relative efficiency in the production process of final goods in the two countries.

The following section describes briefly our benchmark, the BKK model, section 3 presents and discusses the results. The final section provides some final remarks and the way forward coming out of this exercise.

# 2 The BKK model

## 2.1 Description

In this section we briefly describe the BKK model. There are two countries in the world, named one and two, inhabited by a large number of identical agents. Their preferences are symmetric and characterised by utility functions of the form:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{(C_{it}^{\tau}(1-N_{it})^{1-\tau})^{\gamma}}{\gamma} \quad \imath = 1,2 \tag{1}$$

where $C_{it}$ and $N_{it}$ are consumption and hours worked in each country $i$.

There is full-specialisation of production and each country produces an intermediary good, namely country one produces intermediary good $a$ and country two the intermediary good $b$. Neither capital nor labour are mobile across countries but intermediate goods can be freely and costlessly exchanged around the world. Output, $Y_{it}$ is produced using a standard Cobb-Douglas production function $Y_{it} = K_{it}^{\alpha}(Z_{it}N_{it})^{1-\alpha}$, $i = 1, 2$ where $K_{it}$ and $Z_{it}$ denote capital and technology in each country. The latter give rise to the following world's resource constraints:

$$\begin{aligned} Y_{1t} &= a_{1t} + a_{2t} \\ Y_{2t} &= b_{1t} + b_{2t} \end{aligned} \tag{2}$$

where $a_{it}$ and $b_{it}$ denote the use of good $a$ and $b$ in each country $i$. Therefore, $Y_{it}$ is measured in units of the local intermediate good.

Intermediate goods are thereafter used in each country to produce final goods using a CES aggregator of the form $G_{1t} = \{\omega a_{1t}^{\frac{\theta-1}{\theta}} + (1-\omega)b_{1t}^{\frac{\theta-1}{\theta}}\}^{\frac{\theta}{\theta-1}}$ for country 1 and $G_{2t} = \{(1-\omega)a_{1t}^{\frac{\theta-1}{\theta}} + \omega b_{1t}^{\frac{\theta-1}{\theta}}\}^{\frac{\theta}{\theta-1}}$ for country two. We introduce home-bias in each country by letting $\omega > 0.5$, and $\theta > 0$ is the elasticity of substitution between the two goods. For values of $\theta$ close to zero intermediate goods are compliments, $\theta = 1$ corresponds to the Cobb-Douglas case and for $\theta \to \infty$ goods are perfect substitutes. Final goods are used only locally for consumption and investment purposes:

$$C_{it} + I_{it} = G_{it} \tag{3}$$

Capital stocks evolve according to[1]:

$$K_{it+1} = (1-\delta)K_{it} + I_{it} \tag{4}$$

Finally, we close the model by specifying the technology process which constitutes

[1]Note that we abstract from the time-to-build structure that the original paper proposes.

the exogenous variable to our system and the sole driving force of fluctuations:

$$\begin{pmatrix} Z_{1t} \\ Z_{2t} \end{pmatrix} = \begin{pmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{pmatrix} \begin{pmatrix} Z_{1t-1} \\ Z_{2t-1} \end{pmatrix} + \begin{pmatrix} \epsilon_{1t-q} \\ \epsilon_{2t-q} \end{pmatrix}, \quad q \geq 0 \tag{5}$$

For $q = 0$ the model matches exactly the one in the original BKK paper. Allowing for the innovations to the technology process to be forecastable, that is $q > 0$, constitutes the main contribution of this paper. Finally, in equilibrium we have that:

$$\begin{aligned} C_{1t} + I_{1t} &= q^1_{at} a_{1t} + q^1_{bt} b_{1t} \\ Q_t(C_{2t} + I_{2t}) &= q^2_{at} a_{2t} + q^2_{bt} b_{2t} \end{aligned} \tag{6}$$

where $q^i_{at}$ and $q^i_{bt}$ are the prices of the two goods in each country, expressed in units of the country-one final good and $Q_t$ is the relative price of the country-two final good with respect to the country-one final good (the numeraire), i.e. the real exchange rate. Obviously, with free-movement of intermediate goods the law of one price holds: $q^1_{at} = q^2_{at}$ and $q^1_{bt} = q^2_{bt}$ $\forall t$. We thus define the *terms of trade* as the marginal rate of transformation between the two intermediate goods in country 1 evaluated at equilibrium quantities; which (in equilibrium) equals their relative price[2]:

$$p_t = \frac{q^1_{bt}}{q^1_{at}} = \frac{\frac{dG_{1t}}{db_{1t}}}{\frac{dG_{1t}}{da_{1t}}} \tag{7}$$

The real exchange rate is defined as the ratio of marginal utilities of consumption in each country, evaluated at equilibrium final-goods consumption[3]:

$$RER_t = \frac{MU_{C2}}{MU_{C1}} \tag{8}$$

where $MU_{C_i}$ stands for marginal utility of consumption in country $i = 1, 2$.

[2]Notice that this is not the standard definition of terms of trade, as it constitutes the relative price of imports (the foreign good) in terms of exports (the local good). However, this is consistent to the standard way the real exchange rate is defined in macroeconomic models.

[3]In solving the model, imposing this condition is redundant.

Table 1: Parametrisation

| | | |
|---|---|---|
| Preferences | | |
| | $\beta = 0.99$ | Discount factor |
| | $\tau = 0.34$ | Consumption share |
| | $\gamma = -1$ | Risk Aversion |
| Technology | | |
| | $\alpha = 0.36$ | Capital share |
| | $\delta = 0.025$ | Depreciation rate |
| | $\theta = 1.5$ | Elasticity of substitution |
| | Import share: 0.15 | |
| Shocks | | |
| | $var(\epsilon_{1t}) = var(\epsilon_{2t}) = 0.00852^2$ | |
| | $corr(\epsilon_{1t}, \epsilon_{2t}) = 0.258$ | |

Calibration to approximate US steady-state values.

## 2.2 Solution, steady state and calibration

As in the original paper, we take country one to be US and country two to be "the rest of the world". In terms of calibration, we choose the exact same parametres as in BKK, thus we refer to the original paper for justification of these choices. The table below gives a list of benchmark values, some of which we alter at a later section for tests of robustness. As a solution method, given the values of the model's parametres we solve the social planner's problem that weights equally the utility of consumers in the two countries. We define the steady-state as the situation where all variables grow at constant, zero rates and where $\epsilon_{it} = 0 \, \forall i, t$. Thereafter, we approximate the model by taking a first-order log-linear approximation around the steady-state and we solve it numerically in Dynare.

This finalises the exposition to the benchmark model which is to be used as a workhorse for the quantitative exercise, the results of which we present in the following section.

# 3 Results

## 3.1 Impulse-Response Functions and Intuition

Below we present the response of the terms of trade to one-standard deviation innovation in the technology index of country one ($Z_{1t}$) for different values of $q$. Following Beaudry, Dupaigne and Portier (2009) we name the period between the announcement and actual change as the "interim period". First, we observe that the terms of trade responds to news on impact as expected to be the case by the forward-looking nature of prices. Rational agents adjust their behaviour in light of new information, thus prices move to clear the market (see more detail below). Second, we observe that the highest impact-response occurs when the impulse comes as a surprise, i.e. an *actual* change in technology occurs, rather than when an announcement is made. Third, the impact response falls with $q$, that is the further in the future the actual change in technology will occur, the lower the response on impact. Fourth, the responses follow a hump-shaped behaviour which implies endogenous propagation mechanisms, since the technology index - the sole exogenous driving force of the system - decays as an $AR(1)$ process. Finally, we observe that following the peak, each response decays at a different speed. We turn to each of these topics below.

An actual, unexpected, temporary change in the technology index causes a general expansion: consumption increases because people are wealthier, employment and investment increase because of the temporarily higher marginal product of labour and capital. Thus, output necessarily increases. The terms of trade depreciate to reflect the scarcity of the foreign good, which is now the least efficient to produce. Nevertheless, the terms of trade increase on impact even when an actual change in technology has not occurred as forward-looking agents adjust their behaviour to new information. To make things more transparent we show below the equation of the (log-linearised) terms of trade $\widehat{p}_t$, derived by log-linearising equation (7):

$$\widehat{p}_t \simeq \frac{1}{\theta}(\widehat{a}_{1t} - \widehat{b}_{1t}) \tag{9}$$

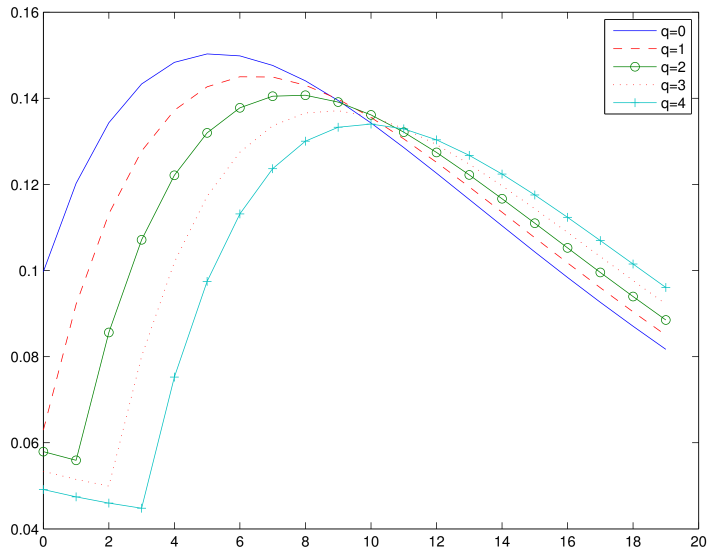


Figure 1: IRFs of the terms of trade to one standard deviation technology shocks to country one, at different values of $q$. Percentage deviations from steady state.

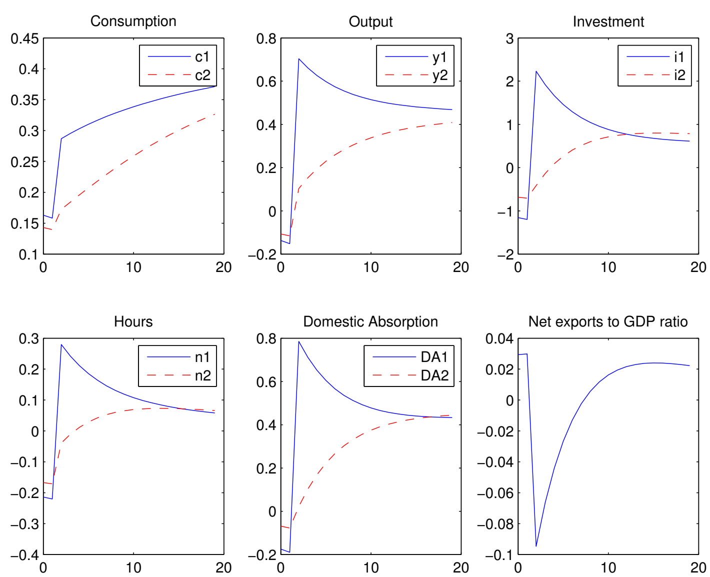


Figure 2: World recession generated by one standard-deviation expected technology shock in country one, $q = 2$. Percentage deviations from steady-state. Solid-lines: Country one. Dashed-lines: country two.

The terms of trade move to clear the market of intermediate goods, as they are used in the production process of final goods in both countries. Where faced with actual, unexpected technology improvements the terms of trade depreciate to reflect the scarcity of the foreign good; they depreciate in response to positive news about the future to reflect the fall in the *relative demand* of the home good. News gen-

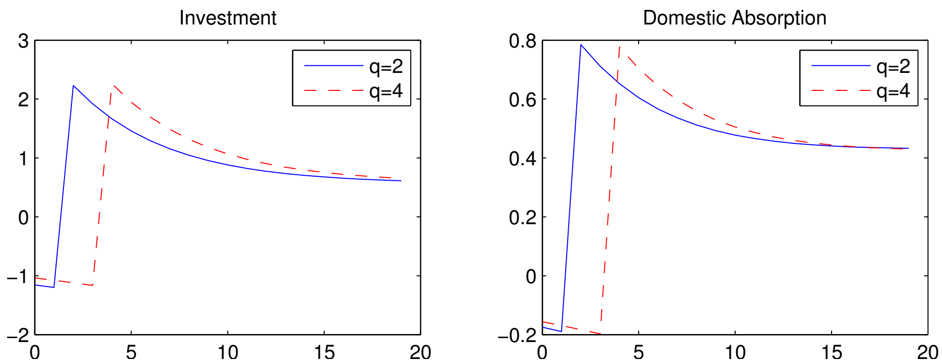


Figure 3: IRFs of Investment and Domestic Absorption in country one at different lengths of the interim period. Percentage deviations from steady state. Solid-lines: two quarters. Dashed-lines: four quarters

erate a pure wealth effect and act as a world demand shock (Beaudry, Dupaigne and Portier 2009). As people learn about higher productivity in the future, which implies higher wealth, the desire for consumption smoothing induces an immediate increase in consumption. Agents also consume more leisure, thus employment falls. Investment is also lower as agents allocate capital to the future when its marginal productivity is going to be higher. Thereby, output necessarily falls and, as it is known (Beaudry, Dupaigne Portier 2009, Jaimonvich and Rebello 2008), abstracting from the increase in consumption good news about the future create a general recession (see figure 6 in the Appendix). The fall in investment in country one is so big that in equilibrium the overall demand for final goods in that country is now lower than before the announcement. As Raffo (2010) explains, domestic absorption, defined as $G_{it} = C_{it} + I_{it}$, $i = 1, 2$, falls on aggregate (see figure 3). Due to the home bias in the production of the final goods the intermediate good $a$ is now less valuable than good $b$. In Figure 6 we also plot the responses of country two. Note that output and investment fall in country two as well, thus lowering somehow the demand of good $b$, however the drop in these aggregates is lower than in country one since the wealth effect in the country that is going to benefit the least from the technological change is much lower. Residents of country 2 benefit from a temporary increase in country's one technology only via spillovers. Overall, the relative world demand for country one intermediate good falls by more as shown by the response of domestic absorption in each country during the interim period. Market clearing requires the terms of trade to depreciate in view of the fact that good $a$ is now less valuable for world residents.

A similar argument explains why the impact-response of $p_t$ is lower for a higher lag between the announcement and the actual technology improvement. First, the wealth effect at present is less strong the more into the future income is to increase because agents discount future. The present value of income is lower for higher values of $q$. Most importantly, investment is also less responsive with higher values of $q$, as shown in figure 3. The longer the interim period, the lower the fall (in absolute value) of domestic absorption, thereby the lower the fall in relative demand of the country one intermediate good and the lower the decrease in its relative price. Nevertheless, relative demand for the home intermediate good still falls causing a depreciation in the terms of trade. Further, since the required adjustment of prices is now necessarily lower; the variability in the terms of trade can be expected to fall with the length of the interim period. We discuss issues of persistence and variability in later sections of the paper. First, we test the intuition outlined so far by performing two types of tests: by allowing for a long interim period and by assuming that agents are very risk averse. We turn to each of these cases below.

#### 3.1.1 Long interim periods

In the first case, we allow that agents learn about the forthcoming one-standard-deviation technology improvement twenty periods in advance, such that $q = 20$. The response of the terms of trade is shown in figure 4 whereas other variables of interest in figures 11 to 13 in the Appendix. We observe that the responses of the main variables of interest are not vastly different from above (figure 11). That is, all variables respond on impact to the news, consumption in both countries increases as agents smooth future gains of productivity, whereas hours and investment fall for the reasons explained above. Nevertheless, we do observe some differences in magnitudes that confirm our intuition. As agents value less heavily future than present periods, the wealth effects stemming from the news-shock are pretty low. Indeed, in figure 12 we see that the response of consumption, investment and other variables is lower (in absolute value) than those shown before; that is responses do fall with the length of the interim period.

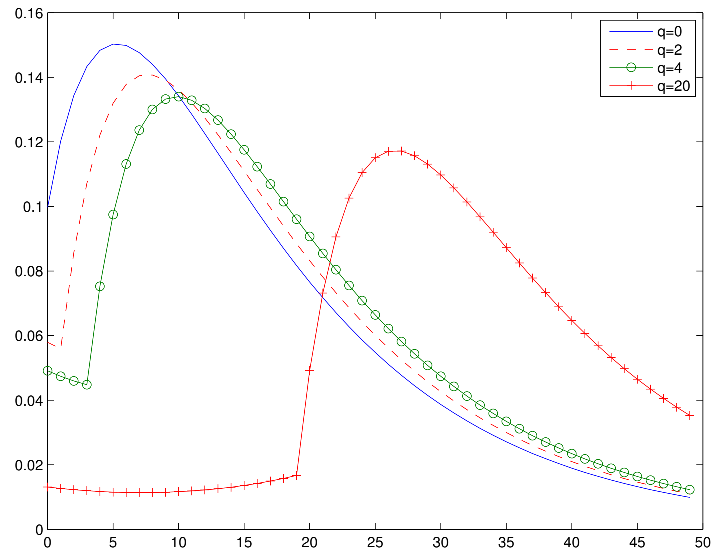


Figure 4: IRFs of the terms of trade to one standard deviation technology shock to country one when the interim period is long, $q = 20$. Percentage deviations from steady state.

How do the terms of trade behave along the path? In figure 4 we see that the terms of trade respond positively on impact, the response is lower than all the other values of $q$ studied above and following the actual increase in the technology index the response of the terms of trade is hump-shaped. This behaviour confirms the basics of the intuition already outlined in the previous section. A lower impact-response reflects the fact that the wealth effect is less strong and the fall in relative demands is not as pronounced. This is evident from the lower response of domestic absorption and investment as depicted in figure 12 in the appendix. The desire to smooth the benefits from future income increase over the interim period is also evident in the consumption path; which is very stable throughout this period. With a lower income effect, a smooth consumption path and a lower response of investment; domestic absorption responds falls less, the difference in relative demands is less pronounced and eventually the necessary movement in relative prices to clear the world market for intermediate goods is lower. Once again, the fall in relative demand causes the terms of trade to depreciate on impact , albeit slightly, and remain below its steady-state value throughout the interim period.

A longer interim period allows for more interesting conclusions to be derived. We see that most of the necessary price adjustment occurs on impact, since the variation in the terms of trade is very small during the interim period. This is consistent with complete, frictionless markets assumed in this economy. Nevertheless, closer inspection of the response during this period reveals that the terms of trade follows a small-scaled inverse hump-shaped behaviour. That is, after the initial depreciation, the terms of trade appreciates - it follows a decreasing path up to period eight - and then starts depreciating again up to the period when the actual increase in technology occurs; when it jumps.

Moreover, the behaviour of relative prices during the news-period, in conjunction to the response thereafter, means that we cannot say with certainty that the overall persistence of the variable increases with news. This might be the case for short interim periods, where the effect of the response during news accounts for less relative to the overall response, but whether this remains to be the case at higher lags is not clear. Indeed, for q=20 the autocorrelation coefficients of order 1 to 4 are $0.994, 0.972, 0.958, 0.932$ which when compared to other models (see section Persistence below) do not necessarily imply higher persistence.

A high value of $q$ allows also to grasp more intuition on economic behaviour about the transition paths the economy undergoes before it reverts back to the initial steady-state. First, once news are revealed, consumption increases instantly whereas capital decreases. For a period, the economy is on an explosive path and consumers eat their capital since by assumption (final) consumption and capital goods are homogeneous. Note that this explains the lower response of investment when $q$ is high as well. As agents find it optimal to eat their capital during the interim period, and as they like consumption smoothing, they want to eat approximately equal levels of capital all along. For this consumption plan to be feasible, investment cannot decrease by much as the economy needs more capital stock for *consumption purposes* than it does when the technology improvement is more imminent. Heuristically, it takes more capital to feed the agents for twenty periods than for two.

In figure 12 we observe that throughout the interim period consumption decreases, albeit slightly, until it eventually jumps once the technology improvement is realised. The explanation for the above is that, as we have seen, optimality instructs the de-cumulation of capital before the materialisation of the shock. Note also that investment drops at a higher pace and magnitude than consumption does (figure 12). With lower output and capital, there are less goods to consume; which decrease even further as we move along the interim period since no production takes place (output is also falling). Following the impact response, and up to the period of the actual improvement in technology (here its period 19 since the IRFs start from zero), both of these aggregates fall, with capital falling at higher speed; an effect again of consumption smoothing as agents do not like big variations in their consumption path. Finally, on period twenty, consumption and capital jump to new values higher than before the shock; and the economy finds itself on a transition path where both variables increase. This is not the final path as both variables cannot continue increasing forever. With a transitory shock, as assumed in this case, they have to eventually decrease so that the economy goes back to the initial steady-state. Indeed, following a long expansionary period, the economy enters a path where both consumption and capital fall (see figure 13, variables start falling after a bit less than 100 periods following the news-shock) until the economy is stabilised to the same steady-state it was before the shock. Note that the latter path is one of the initial stable paths of the saddle-path stable system.

Overall, this section confirms the basics of our intuition above: what guides the response of variables and the response of the terms of trade is the fact that a lower income effect, coupled with the desire to smooth consumption and investment, decrease the response of domestic absorption as the length of the interim period increases. The differences in world relative demands for the intermediate goods are smaller and their relative price needs to move less to clear the world markets of intermediate goods. A longer interim period also reveals more clearly the transition paths of consumption and capital.

### 3.1.2 Extreme Risk Aversion

In this section, we calibrate the risk aversion parameter to a very high value, in particular we set $\gamma = -100$. The agents of the world are extremely risk averse and dislike any potential variability of their consumption paths, much more than in the benchmark case where $\gamma = -1$

IRFs of this economy are given in figures 5 and 6 for the terms of trade and 14 and 15 in the Appendix for other variables. Once again, the responses of the variables of interest are very similar to the initial case in terms of shape; but we do observe some differences in terms of magnitudes. Nevertheless, these differences are rather small. The response of the terms of trade is slightly higher than in the initial case, for all values of $q$ (see figure 6). Consequently, the terms of trade is more volatile in this case with its theoretical standard deviation standing at 0.011 compared to 0.009 before[4]. Also, following the materialisation of the shock, the terms of trade falls at a lower speed in cases where the parameter for the relative risk aversion is high. This is the case irrespective of whether shocks are pure surprises or are known to occur two periods in advance. The latter can imply more persistence in relative prices. Indeed, for $q = 2$, the first and second order autocorrelation coefficients are 0.992 and 0.981 respectively, whereas these numbers stand at 0.991 and 0.978 with the benchmark parametrisation of the curvature of the utility function[5].

In terms of the other variables, the most notable differences are to be found in the response of consumption in country one. The impact response of consumption in country two is now higher than in country one, contrary to the benchmark case (figure 14)[6]. Consistently with the benchmark case though, investment, hours worked and domestic absorption drop by more in country one than in country two. Second, the shape of the response of consumption in country one is different for a low value of relative risk aversion than for a high one. In particular, whereas in the benchmark case following the realisation of the shock consumption continues to increase, for $\gamma = -100$

[4]Theoretical moments, non-filtered data. However, this is no longer the case if we look at standard deviations relative to output. This statistic is 0.079 for $\gamma = -100$ and 0.144 for $\gamma = -1$.

[5]Theoretical moments, non-filtered data.

[6]This is the case for values of $\gamma < -5$ or $-6$.

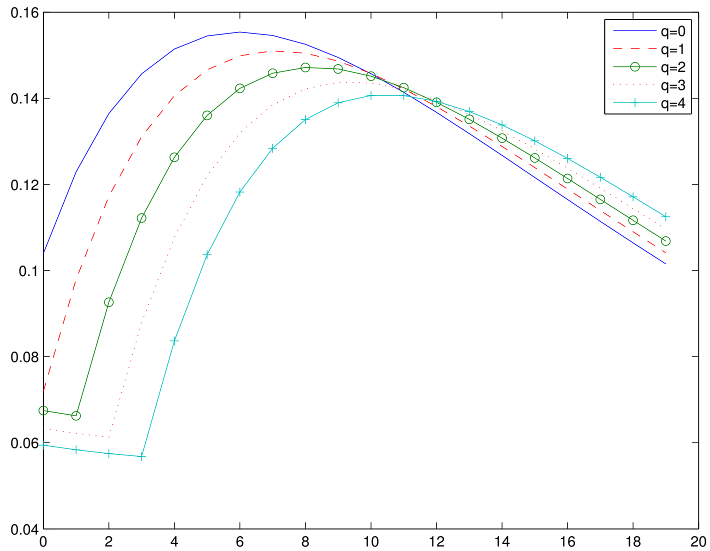


Figure 5: IRFs of the terms of trade to one standard deviation technology shocks to country one when risk aversion is high, $\gamma = -100$, at different values of $q$. Percentage deviations from steady state.

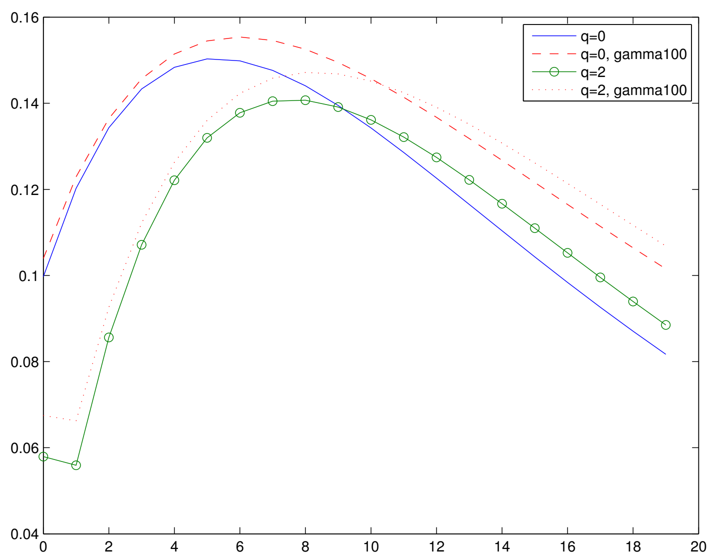


Figure 6: IRFs of the terms of trade to one standard deviation technology shocks to country one for different values of relative risk aversion and $q$. Percentage deviations from steady state.

it peaks on that date reaching 0.4% higher its steady-state value. Thereafter it starts decreasing as an $AR(1)$ process following a similar trajectory as all the other variables. This is clearly seen in figure 15 where we plot the responses of various variables for different values of the coefficient of relative risk aversion, for the case of $q = 2$. Strangely, consumption is more volatile when the risk aversion is high than low, with standard deviation at 0.094 and 0.060 for $\gamma = -100$ and $\gamma = -1$ respectively. If we look at standard deviations relative to output, the ranking changes with this statistic being equal to 0.700 for a high value of $\gamma$ and 0.933 for a low one.

The responses of these variables help us once again understand the response of the terms of trade. In the benchmark case, the demand for good $b$ was relatively higher because of the big drop in investment in country-one following the announcement. In the present case, we do not only have this effect but also there is more demand for the foreign intermediate-good coming from the "consumption-side": with the country-two consumption increasing by more than in country-one following the announcement, the world demand for the country-two intermediate good is even higher than before. Thus, good b is relatively more valuable following a news-shock in country-one under conditions of extreme risk-aversion; more than in the benchmark case which implies more depreciation in the terms of trade.

Moreover, similarly to the benchmark case the response of the terms of trade is again lower the longer the interim period. This is for the same reasons provided above since even for high values of $\gamma$ the fall in investment and domestic absorption is less pronounced the longer the interim period (figure 16). Nevertheless, this difference is much smaller in the current case, as can be seen in figure 16. To give some numbers, the difference in the impact response of domestic absorption in country-one between $q = 2$ and $q = 4$ is $-0.008$ for $\gamma = -100$ whereas it is $-0.019$ for $\gamma = -1$. When agents are very risk averse, they smooth consumption and savings (investment), thus the responses of all these variables vary less with $q$ compared to the benchmark case. In the previous sections we pose that the longer the interim period, the lower are the responses of economic aggregates during news; an effect of consumption smoothing and the consequent desire to spread the wealth effect throughout. The current test in environments of high risk aversion confirms the latter and additionally it shows the strength of consumption smoothing: the more risk-averse agents are, the less they like variability in consumption and other variables and hence their responses are very similar irrespective of the length of the interim period and consequently the strength of the wealth effect.

Finally, in figure 15 we also observe that for $\gamma = -100$ the response of investment, hours, domestic-absorption and net exports is always lower (in absolute value) the period the technology improvement occurs than it is in the benchmark case; and remains so for subsequent periods.

Overall, in this section we have outlined the intuition governing economic behaviour in news-driven open-economies. We have stressed the wealth effects generated by announcements and the importance of consumption smoothing and investment in driving world relative demand of intermediate goods. We have shown that the latter govern the responses of the terms of trade and other variables of interest during the interim period. In a nutshell, terms of trade respond positively on impact to clear the market as agents adjust to new information. Also, the responses are less pronounced the longer the interim period because of two related reasons: first, the wealth effect is less strong, meaning that consumption and investment respond less; as do prices. Second, since agents wish to smooth the benefits of higher future income, the longer in the future this increase is to occur, the lower the current change in consumption plans as agents want to maintain a relatively stable consumption path.

After getting some intuition about the effects of news shocks on relative prices, we move on the the last two points of the first paragraph of this section which refer to persistence of the terms of trade implied by this model. As explained, this hump-shaped behaviour is a powerful source of the model's endogenous persistence, that can be however attributed to “real shocks” in general rather than news-shocks (Steinsson 2007). Moreover, the empirical literature on news, mostly the VAR literature, has shown that from a technical point of view news shocks can increase the persistence and volatility of forward-looking variables (Féve et al 2009, Leeper et al 2011). Issues of persistence and volatility are analysed in detail in the following sections.

## 3.2 Persistence

We now move on to the main part of our paper, the analysis of persistence and volatility in relative prices in news-driven cycles. We choose to focus on terms of trade, rather than the real exchange rate, because it is easier to define. Specifically,

Table 2: Persistence of Terms of Trade - Coefficients of Autocorrelation

| | Coefficients of Autocorrelation | | | | |
|---|---|---|---|---|---|
| Data | 1 | 2 | 3 | 4 | 5 |
| TT - full sample | 0.986 | 0.967 | 0.948 | 0.932 | 0.913 |
| TT - BKK sample | 0.990 | 0.970 | 0.952 | 0.934 | 0.916 |
| Models | | | | | |
| q=0 | 0.984 | 0.960 | 0.929 | 0.893 | 0.855 |
| q=1 | 0.991 | 0.971 | 0.944 | 0.911 | 0.875 |
| q=2 | 0.991 | 0.978 | 0.955 | 0.926 | 0.892 |
| q=3 | 0.992 | 0.978 | 0.961 | 0.936 | 0.904 |
| q=4 | 0.992 | 0.978 | 0.961 | 0.940 | 0.913 |

Full sample: 1950:1 - 2010:4
BKK sample: 1950:1 - 1990:2

we can measure terms of trade in the data as we do in the model. See the Appendix for the exact definition of the terms of trade in the data. We compare model-generated data under different lengths for the interim-period, against actual data. A problem in exercises of this type is that there is not a universally accepted measure of persistence. The most widely used measure are the coefficients of autocorrelation; especially of order one. We spend most on our analysis on persistence on the latter, but emphasise also the role of autocorrelation at higher order. Thereafter, we analyse two other measures less widely used: half-lives of impulse-responses and the largest roots of lag polynomials.

The coefficients of autocorrelation are given in Table 2. The first-order autocorrelation coefficient is close to 0.99 for all models, implying that a stationary by construction economy can generate highly persistent relative prices. As it was the case in the original paper, the benchmark model with technological innovations coming as pure surprises - calibrated for US data - matches closely the first-order autocorrelation coefficient. This is the authors' sole measure of persistence, based on which they conclude the model's success with regard to this statistic. However, we observe that the original model ($q = 0$) performs rather poorly when it comes to higher orders of autocorrelation. In Figure 2 we see that the autocorrelation function of the terms of trade when $q = 0$ deviates substantially from the one implied by the data, whereas it does so at a lesser extend in news-driven environments. Moreover, the longer the interim period, the higher the autocorrelation coefficients of all orders, with the marginal difference being at its highest between $q = 0$ and $q = 1$. This is especially evident in figure 3, where we plot autocorrelation coefficients up to the 12th order. The increase in "overall persistence", i.e. as implied by the first, as well as higher orders of autocorrelation increases with news even though the marginal increase is admittedly small. Nevertheless, it seems that even though models with $q = 3, 4$ match well persistence of the 4th and 5th order, they generate maybe too much persistence at lower orders. Finally, figure 2 shows clearly that models fail to keep up with the data as the order of autocorrelation is increased.

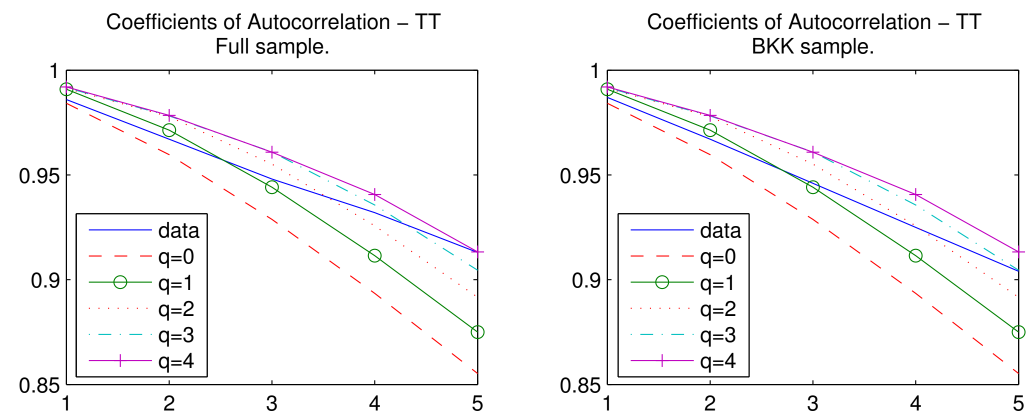


Figure 7: The autocorrelation function of the terms of trade for different values of $q$. Non-filtered data.

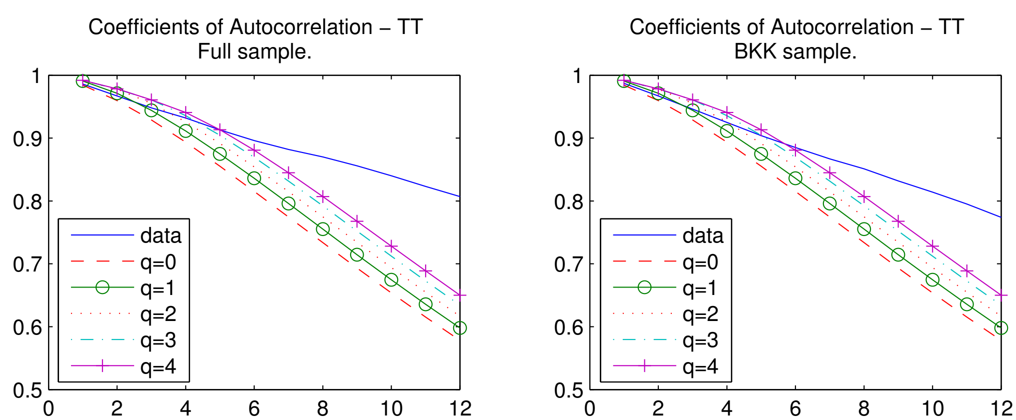


Figure 8: The autocorrelation function of the terms of trade, up to order 12, for different values of $q$. Non-filtered data.

The above results are not surprising. As Leeper et al (2011) have shown, perfect-foresight adds a moving-average (MA) component in the process of economic variables, with recent news being more heavily discounted than past ones since they provide information about changes that lie in the more distant future. More foresight implies more MA components, thus somehow mechanically the persistence of the process increases. For example, Fève et al (2009) show that a purely forward-looking variable:

$y_t = \alpha y_{t+1} + \epsilon_{t-q}, \;\; \alpha < 1, q \geq 0$

admits a solution of the form:

$y_t = \sum_{i=0}^{q} \alpha^{q-i} \epsilon_{t-i}$

Obviously, a higher value of $q$, equivalently more foresight, means more persistence. Since $\alpha < 1$, recent news receive less weight (Fève et al 2009, Leeper et al 2011). Statistically, where economic aggregates behave as AR(p) processes with unexpected shocks, they behave as ARMA(p,s) with news. The complexity of this model does not allow to solve the expression for the terms of trade analytically to demonstrate these issues, but we can use the coefficients of the model's policy function to get something similar.

For example, consider an economy where shocks are pure surprises (equation 10) and when $q = 2$ (equation 11).

$$\begin{aligned}\Phi(L)p_t = {} & \widehat{u}_{1t} - \widehat{u}_{2t} \\ & + 1.182\,(\widehat{u}_{1t-1} - \widehat{u}_{2t-1}) - 1.182\,(\widehat{u}_{1t-2} - \widehat{u}_{2t-2})\end{aligned} \tag{10}$$

$$\begin{aligned}\Phi(L)p_t = {} & \widehat{u}_{1t} - \widehat{u}_{2t} + 1.0858\,(\widehat{u}_{1t-1} - \widehat{u}_{2t-1}) \\ & + 1.625\,(\widehat{u}_{1t-2} - \widehat{u}_{2t-2}) + 1.375\,(\widehat{u}_{1t-3} - \widehat{u}_{2t-3}) \\ & - 1.375\,(\widehat{u}_{1t-4} - \widehat{u}_{2t-4})\end{aligned} \tag{11}$$

where $\widehat{u}_{1t} - \widehat{u}_{2t} = \frac{1}{0.0013}(u_{1t} - u_{2t})$ in the first equation and $\widehat{u}_{1t} - \widehat{u}_{2t} = \frac{1}{0.0008}(u_{1t} - u_{2t})$

in the second, with $u_{it}$ being the model's structural innovations. As it can be seen, the autoregressive coefficients of the two processes are the same but equation (12) includes more moving-average components, implying an increase in persistence. Similarly to Leeper et al (2011), news arriving in more recent periods appear to be less important. In equation (12), the coefficient on $\widehat{u}_{1t-1} - \widehat{u}_{2t-1}$ is lower (in absolute value) than all the others. However, this relation seems not to be monotonic as the coefficient on two lags is higher than the one of three and four.

The main outcome of this section is that news-driven economies generate higher persistence in terms of trade. The intuition is as follows: News shocks generate wealth effects, which cause an immediate response of consumption and investment. However, because rational agents smooth consumption the potential increase in wealth is spread throughout the interim period. The longer the interim-period, the further into the future this wealth increase is to be realised and the more people smooth consumption and investment during that period; i.e. they change consumption "little by little" thus increasing persistence. This makes the real exchange rate more persistent, as relative consumption processes become more persistent with $q$ (see figure 4). The terms of trade, on the other hand, mirror the relative use of the two intermediate goods in final-goods production. Therefore, the process for the relative use of the intermediate goods follows closely that of consumption, meaning that news-shocks can increase the persistence of the terms of trade as well. When analysing the impulse response functions of the terms of trade following an expected shock in productivity, we stressed the importance of investment which, due to its relatively higher variability, is a more important determinant of the change in the world relative demand for the intermediate good and consequently its price. Figure 5 shows that agents also smooth the response of investment, for reasons explained above, which in turn implies more persistence in the terms of trade.

## 3.3 Other measures of persistence

The coefficients of autocorrelation are the most common measure of persistence. In this section, we use other measures less widely used in the literature; half-lives of

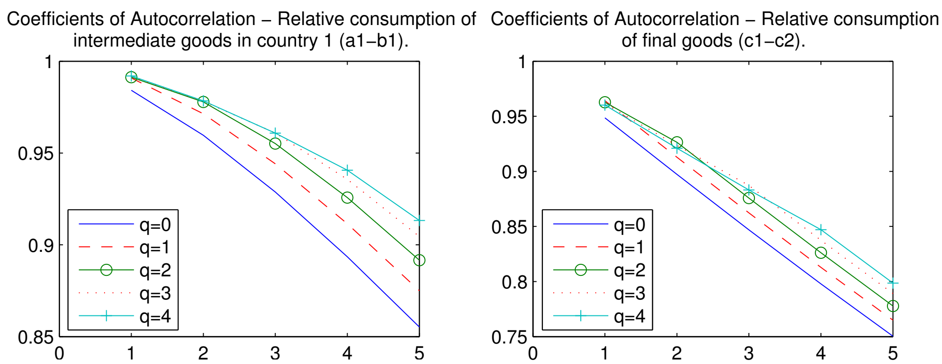


Figure 9: The autocorrelation function of relative consumption.

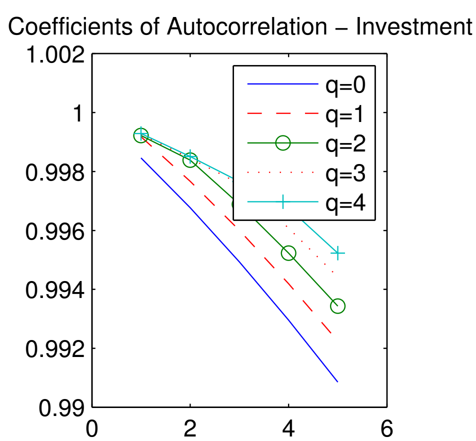


Figure 10: The autocorrelation function of investment

impulse responses and the largest root of the lag polynomial for the terms of trade.

Half-life is the largest time $T$ "such that $IR(T-1) \geq 0.5 \times impulse$ and $IR(T) < 0.5 \times impulse$" (Steinson 2007, p. 3), where $IR(T)$ denotes the impulse response of the terms of trade at time $T$. Thus, half-life measures the time needed for a response to fall below half the size of the impulse.

Figure 9 plots the reduced-form impulse responses of terms of trade data, constructed as explained in the Appendix. First, we observe that the IRF of the terms of trade follows a hump-shape behaviour, which implies some propagation mechanisms in the true data generating process. Remember that this is not a response from an identified VAR, thus the shock represents a mixture of all shocks in the economy. Steinsson (2007) uses this empirical regularity to motivate that "real shocks" are the primal source of real exchange rate movements, because contrary to monetary shocks, they imply hump-shape responses. Interestingly, data generated from our model with only temporary technology shocks in the two countries exhibit a hump-shape response to one-unit reduced-form shock (see figure 19).

We observe that the implied IRFs in the data to one-unit reduced form innovation, as well as the corresponding half-life, depend heavily on the filtering procedure. Figure 8 in the Appendix plots the series together with two alternative filtering methods. We observe that an HP-filter with the conventional filtering parameter $\lambda = 1600$ takes away a lot of its persistence, as it can be "visually" measured by the impulse responses. The response dies out much faster than the one in the raw data, as well as the response of the data for which we simply removed a linear trend. This is evident in the implied half-lives: where the half-life in the raw-data minus a linear trend is as high as 33 periods, it is only four(!)[7] once we apply the filter. Issues and flaws of the HP-filter are discussed in King and Rebello (1993).

Turning to the theoretical models, we observe that news shocks do add persistence to the terms of trade, as measured by the half-life of impulse responses. Table 2 shows the results. The half-life of the impulse in the model with technology shocks

[7] However, we do not achieve stationarity in the log-terms of trade by simply removing a linear trend (ADF tests).

Table 3: Persistence of Terms of Trade - Half-lives

| | Half-lives | |
|---|---|---|
| Data | | 95% Confidence Intervals |
| Raw | 241 | |
| HP-filtered | 4 | |
| Minus a Linear Trend | 33 | |
| Models | Half-life | 95% Confidence Intervals |
| q=0 | 15 | |
| q=1 | 141 | |
| q=2 | 67 | |
| q=3 | 38 | |
| q=4 | 54 | |

Artificial data were generated by simulating each model 200 times, 200 periods each. Thereafter, we took the average over the simulated series, and dropped the first 100 observations.
Half-Lives refer to responses generated from one-unit shock, derived from AR processes with four lags, using the backward-forward approach. Confidence intervals were computed by 1000 Monte-Carlo simulations.
Data sample: 1950:1 - 2010:4
HP-Filtered data refers to the cyclical component of the data extracted using HP-filter with $\lambda = 1600$.
Minus a Linear Trend refers to the cyclical component of the data extracted after removing a linear trend.
Model-generated data are not filtered.

coming as pure surprises is 15 periods, with all other models having longer half-lives. Nevertheless, this relation is not monotonic as, according to our estimations, an interim period of one quarter generates the most persistent response with a half-life of 141 periods. This result is surprising since, as Fève et al (2009) have shown, more foresight adds more persistence in a monotonic fashion by implying MA processes of higher order. The reason behind this result is something we currently work on. Which model is closer to the half-life in the data depends on which measure of the data is the right one to look at. Raw data instruct a very persistent process for the log of the terms of trade, at 241 quarters, making the model with news arriving one period before the actual change the most appropriate one; but still rather far from reality. The benchmark model is the one that stands closest to the half-life estimated from HP-filtered data, since it generates the least persistent series for the terms of trade, whereas taking the medium way - that is simply removing a linear-trend from the data - instructs that an interim period of three quarters is the one that best fits the data.

As a final measure of persistence, we document the largest roots of lag polynomials

Table 4: Persistence of Terms of Trade - Largest Root

| | $AR(4)$ | | $AR(8)$ | |
|---|---|---|---|---|
| Data | | | | |
| Raw | 0.9954 | | 0.9963 | |
| HP-filtered | 0.8046 | | 0.8844 | |
| Minus a Linear | 0.9642 | | 0.9641 | |
| Models | Mean of simulated data | Median of simulated data | Mean of simulated data | Median of simulated data |
| q=0 | 0.8840 | 0.9580 | 0.9256 | 0.9679 |
| q=1 | 0.9891 | 0.9864 | 0.9761 | 0.9810 |
| q=2 | 0.9669 | 0.9504 | 0.9830 | 0.9038 |
| q=3 | 0.9397 | 0.9423 | 0.9394 | 0.9335 |
| q=4 | 0.9654 | 0.9511 | 0.9424 | 0.9422 |

We simulated the model 200 times, 200 periods each.
We took the average or median over the simulated data to end up with a single time-series for each variable.
Before running the AR models, we drop the first 100 observations.

using different versions of the benchmark model as data generating processes. We use four and eight lags in our estimations. Results are presented in table 4. Looking at data that have been averaged over simulations, outcomes are largely in accordance with those of half-lives just analysed. That is, all models generate more persistent processes for the terms of trade when compared to the benchmark one; with the relation between persistence and length of the interim period not being necessarily monotonic. Again, the series generated with $q = 1$ seems to be the most persistent - except for one case when we estimate an $AR(8)$ model. These results are sensitive on whether we take the average or the median over the simulated series, where in the latter case gains in terms of persistence when we add forecastability in TFP are rather minimal.

## 3.4 Volatility

So far we have concentrated our analysis on persistence. However, the inability of models to generate enough variability in relative prices has also troubled researchers (Backus, Kehoe and Kydland 1994, Chari, Kehoe and McGrattan 2002, Heathcote

Table 5: Volatility of the terms of trade - Standard Deviations (percent)

| | $sd(TT)$ | $sd(y1)$ | $\frac{sd(TT)}{sd(y1)}$ |
|---|---|---|---|
| Data - BKK sample | 14.06 | 40.56 | 34.66 |
| Data - Full sample | 14.65 | 57.30 | 25.57 |
| Lags of news | | | |
| q=0 | 0.7874 | 2.3485 | 33.528 |
| | (0.2235) | (0.8867) | (16.195) |
| q=1 | 0.7708 | 2.3782 | 32.412 |
| | (0.2342) | (0.9087) | (17.968) |
| q=2 | 0.7202 | 2.2994 | 31.323 |
| | (0.2280) | (0.8578) | (15.646) |
| q=3 | 0.7128 | 2.4362 | 29.260 |
| | (0.2227) | (0.8347) | (14.476) |
| q=4 | 0.6925 | 2.4135 | 28.693 |
| | (0.2295) | (0.8764) | (13.888) |

Full sample: 1950:1 - 2010:4. BKK sample: 1950:1-1990:2.
Numbers in brackets represent standard deviations.
Data derived from 200 simulations, 100 periods each.

and Perri 2002, Rabanal et al 2008). In this section we analyse how the outcomes of our benchmark model change on this front when allowing for news-shocks in the technology processes.

Overall, our results indicate that news shocks do not change much the conclusions derived from the benchmark model on the variability in terms of trade (Table 5). If anything, we observe that volatility drops as the interim period increases; which is also obvious in the IRFs of the terms of trade for different values of $q$ in figures 1 and 4 above. The intuition is simple and comes as a consequence of all complete-market models of the international business cycle, as well explained by Chari, Kehoe and McGrattan (2002) and Heathcote and Perri (2002) among others. In brief, in a world of perfect international risk sharing, the relative price of goods across countries are tied down by the processes of consumption[8]. With complete markets, both at the domestic and at the international level, agents smooth consumption in space (between countries) and time (between periods). The arrival of good news about the future is not going to change dramatically peoples' consumption patterns and

[8] A very good analysis of the relative consumption - real exchange rate relation is given in the classic Backus and Smith (1993).

the use of intermediate goods. In other words, the demand shifts sparked by news are not likely to be large in magnitude because of forward-looking agents' desire to smooth the wealth effect. For this reason, movements in the terms of trade during the interim period are largely driven by the response of investment, as in our economy intermediate goods are used to produce a single, homogeneous final good that can be used for both consumption and investment purposes. Nevertheless, it is known that in news-driven environments investment is not very responsive when compared to actual shocks[9]. Investment falls in light of news about higher productivity in the future, but falls by less the more in the distant future this change will occur because of discounting[10]. For this reason, the demand for the home-intermediate good falls, but falls by less the longer the intermediate period is. Therefore, the adjustment in relative prices is less pronounced and the implied variability in the terms of trade is lower.

To better understand the intuition outlined above, it is useful to look at the log-linearised expression for the terms of trade and its reaction in light of expected and unexpected shocks. Following Raffo (2008), one can show that the terms of trade can be expressed as a function of relative output, and excess home-supply relative to domestic absorption:

$$\hat{p} \simeq \frac{1-2\bar{is}}{\bar{is}} \left( \frac{1}{2\theta(1-\bar{is})}(\hat{y_{1t}} - D\hat{A}_{1t}) + (\hat{y_{1t}} - \hat{y_{2t}}) \right) \tag{12}$$

where $\bar{is}$ is the steady-state import-share, calibrated at 0.15.

In order to express the terms of trade as a function of future variables we first find an expression for the real exchange rate and then use the fact that the two measures of relative price are equal up to a constant. As it is known, in complete market models the real exchange rate equals to the ratio of marginal utilities of consumption across

[9] Counter-intuitively, and in contrast to empirical evidence (positive correlation of economic aggregates within and across countries, see BDP), investment falls following positive news about the future. The importance for the variability of relative price, nevertheless, is not to be found in the direction of the response but rather in its magnitude.

[10] Investment falls because people want to postpone it for the period when the marginal product of capital will be higher. This strategy obviously increases their income. However, the more in the future productivity will change, the less profitable this strategy is. Nevertheless, some investment is postponed no matter the length of the interim period (see figure 12).

the two countries. That is:

$$\begin{aligned} q &= \frac{MU_{c_2}}{MU_{c_1}} \\ \Rightarrow \hat{q}_t &\simeq (1-\gamma\tau)\,(\hat{C}_{1t} - \hat{C}_{2t}) \end{aligned} \tag{13}$$

For simplicity, we have ignored the effects of relative labour supply. Equivalently, we can assume that utility is separable in consumption and leisure, and in that case the expression for the real exchange rate will be exactly as above with $\tau = 1$. The fact that the real exchange rate is tightly linked to the process of consumption makes it easier to get an expression in terms of future variables using the Euler equation. Doing so, provides the following expression for the terms of trade:

$$\begin{aligned} \hat{p}_t \simeq\; & AE_t\{(1-\delta)(1-\gamma\tau)\bar{C}^{-(1-\gamma\tau)}(\hat{C}_{1t+1} - \hat{C}_{2t+1}) \\ & + B\frac{1-2\bar{is}}{\bar{is}}\left(\frac{1}{2\theta(1-\bar{is})}(\hat{y_{1t}} - D\hat{A}_{1t}) + (\hat{y_{1t}} - \hat{y_{2t}})\right) \\ & - C(\omega(1-\bar{is})M\hat{P}_{K_{1t+1}} - (1-\omega)(\bar{is})M\hat{P}_{K_{2t+1}}\} \end{aligned} \tag{14}$$

where A, B and C are positive coefficients, $\bar{C}$ is consumption at the steady-state, $\omega$ is the degree of home-bias and $\bar{is}$ is the steady-state import-share. The above shows clearly how the terms of trade responds to shocks. In the case of unexpected shocks, it increases because the output in the country where productivity is temporarilly higher is increased. In particular, it is increased above the level of domestic absorption and above the level of foreign output. This results in a strong depreciation in the country's terms of trade. In response to expected shocks, the terms of trade responds to the direct effect, coming from the future increase in country's one marginal product of capital (the third term in equation 15) and to indirect effects coming from changes in future relative consumptions and output. Notably, the direct effect pushes towards a current terms of trade appreciation and so does a strongly higher domestic absorption relative to output in country one during the interim period. The latter is instructive

Table 6: Volatility of relative consumption - Standard deviations (percent)

| | $sd(\widehat{a_1} - \widehat{b_1})$ | $sd(\widehat{C_1} - \widehat{C_2})$ | $\frac{sd(\widehat{a_1} - \widehat{b_1})}{sd(y1)}$ | $\frac{sd(\widehat{C_1} - \widehat{C_2})}{sd(y1)}$ |
|---|---|---|---|---|
| Lags of news | | | | |
| q=0 | | | | |
| q=1 | 1.1562 | 0.5176 | 48.618 | 21.767 |
| | (0.3512) | (0.1312) | (26.952) | (11.124) |
| q=2 | 1.0804 | 0.4896 | 46.984 | 21.292 |
| | (0.3420) | (0.1288) | (23.469) | ( 9.740) |
| q=3 | 1.0693 | 0.4859 | 43.891 | 19.947 |
| | (0.3340) | (0.1267) | (21.715) | (9.090) |
| q=4 | 1.0388 | 0.4779 | 43.040 | 19.800 |
| | (0.3442) | (0.1299) | (20.832) | (8.673 ) |

Numbers in brackets represent standard deviations.
Data derived from 200 simulations, 100 periods each.

of the strong wealth effects generated by news-shocks. The fact that the two effects move in opposite directions explains why the aggregate response of the terms of trade ends up being lower in light of news-shocks compared to pure surprises. Finally, the fact that relative consumption increases by more in response to unexpected shocks compared to expected ones is also instructive of the differences in magnitude of these responses.

Overall, our results suggest that the inability of complete-market, neoclassical models to replicate the observed variability of the terms of trade is not likely to be resolved by allowing technology improvements to be perfectly predictable. If anything, the latter seems to be worsening these models' performance. Note that restricting the asset structure alone is not a panacea to issues of variability in the terms of trade, as the allocations under complete and incomplete markets are likely to be very similar and in some cases identical (Cole and Obstfeld 1991, Baxter and Cruccini 1995). Nevertheless, augmenting incomplete markets models with other frictions has been helpful towards this direction (Corsetti et al 2008).

# 4 Conclusion

In this exercise we have augmented a standard, frictionless model of the international business cycle with news shocks. In a world where technology disturbances are forecastable, movements in relative prices reflect changes in relative demands. We have emphasised the role of wealth effects generated by news shocks in explaining both the direction and the magnitude of terms of trade movements. Moreover, our simple analysis has shown that news can add persistence to the terms of trade, especially when looking at autocorrelation coefficients of order higher than one, half-lives of impulse responses and roots of lag-polynomials.In terms of volatility, whether technology improvements come as pure surprises or are expected does not alter the results match, and all models fail substantially to match the observed variability in the terms of trade. Indeed, the fact that the fall in relative demand is lower for longer interim periods implies - if anything - a lower variance in the terms of trade; making one of the most puzzling features of international data even more difficult to address.

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# 5 Appendix

Following BKK, we define the empirical US terms of trade series as "the ratio of the implicit price deflator for imports to the implicit price deflator for exports, with deflators computed as the ratios of currrent-price imports and exports to base-year-price imports and exports". Our source is the same as the authors, that is the OECD's Quarterly National Accounts database.

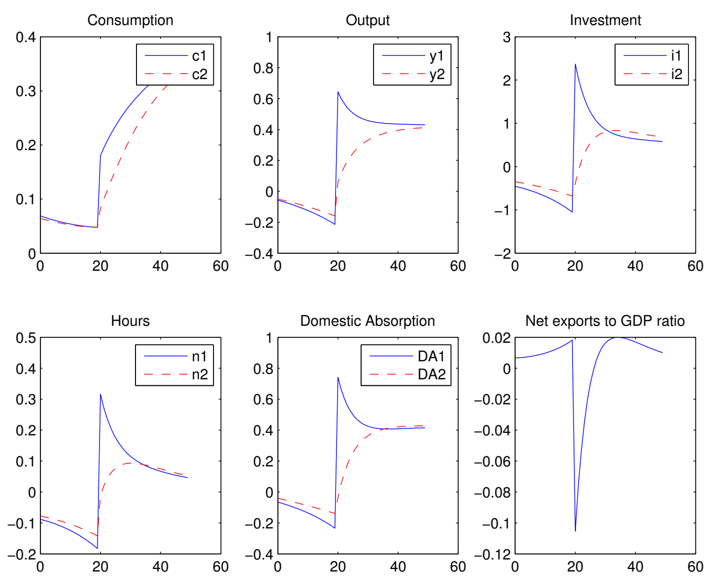


Figure 11: World recession generated by one standard-deviation expected technology shock in country one, long interim period, $q = 20$. Percentage deviations from steady-state. Solid-lines: Country one. Dashed-lines: country two.

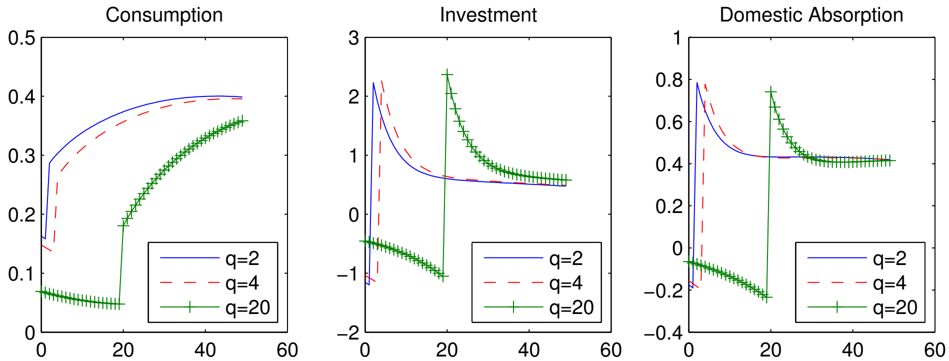


Figure 12: IRFs of Consumption, Investment and Domestic Absorption in country one at different lengths of the interim period. Percentage deviations from steady state. Solid-lines: two quarters. Dashed-lines: four quarters. Crosses: twenty quarters

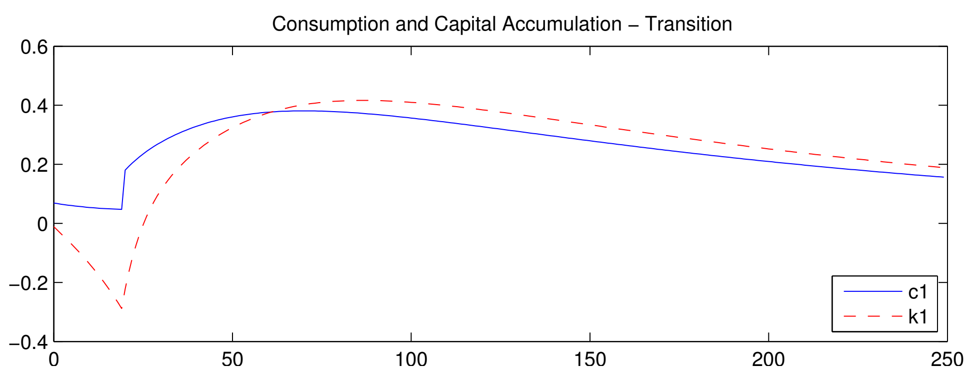


Figure 13: The transition of Consumption and Capital in country one for long interim period. Percentage deviations from steady state.

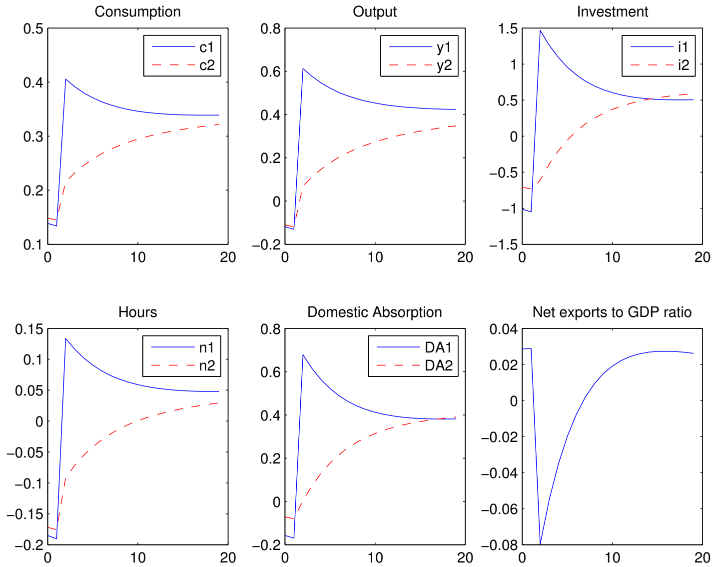


Figure 14: IRFs of variables to one standard-deviation expected technology shock in country one, high risk-aversion, $\gamma = -100$, $q = 2$. Percentage deviations from steady-state. Solid-lines: Country one. Dashed-lines: country two.

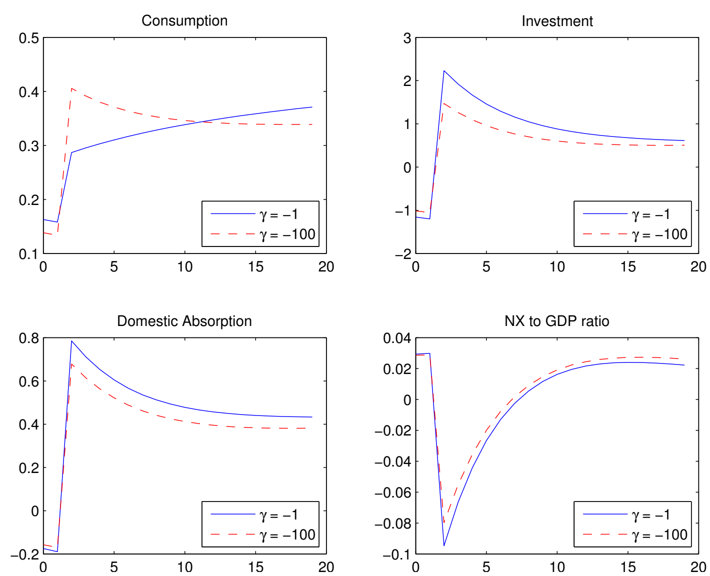


Figure 15: IRFs of country-one variables to one standard-deviation expected technology shock in country one, for different values of relative risk aversion, $q = 2$. Percentage deviations from steady-state. Solid-lines: $\gamma = -1$. Dashed-lines: $\gamma = -100$.

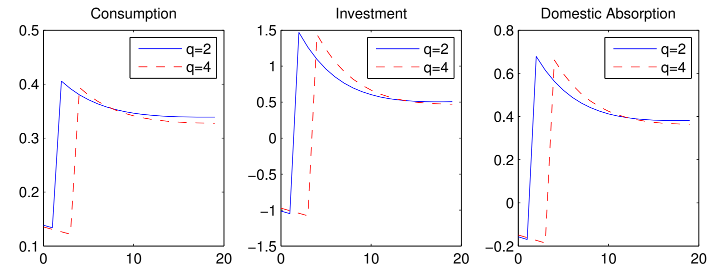


Figure 16: IRFs of country-one variables to one standard-deviation expected technology shock in country one, for different values of $q$. Percentage deviations from steady-state.


Figure 17: The terms of trade for US, logs, under different filtering procedures

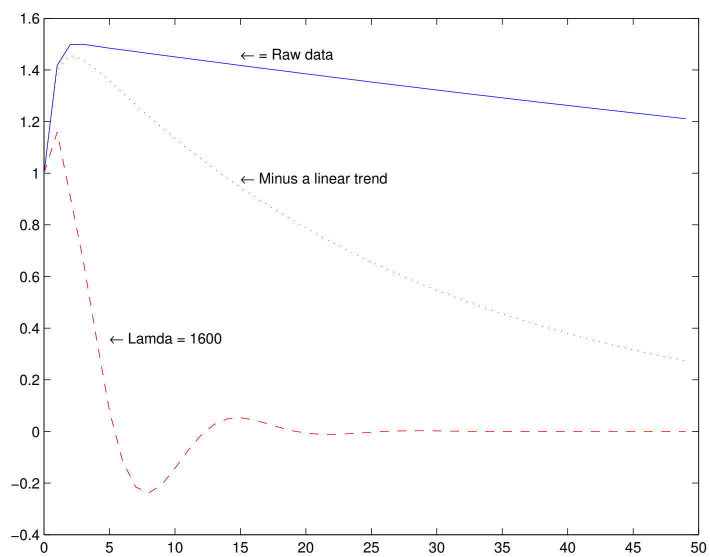


Figure 18: IRFs to one-unit reduced-form innovation, estimated from an AR with four lags.

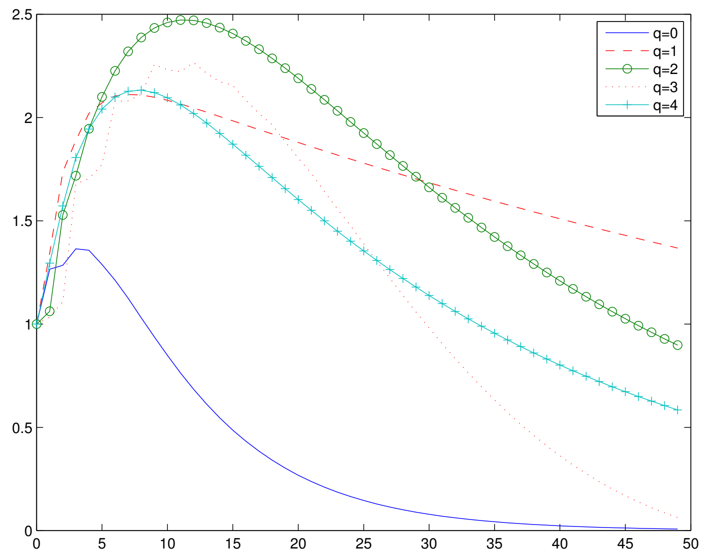


Figure 19: IRFs to one-unit reduced-form innovation, estimated from an AR with four lags. Model-generated data.