Productivity, external balance and exchange rates: evidence on the transmission mechanism among G7 countries*

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Abstract

In this paper we investigate the international transmission of productivity shocks in a sample of five G7 countries. For each country, using long-run restrictions, we identify shocks that increase permanently domestic labor productivity in manufacturing (our measure of tradables) relative to an aggregate of the other the G7 countries. We find that, according to standard theory, these shocks raise relative consumption, deteriorate net exports, and raise the relative price of nontradables — in full accord with the Harrod-Balassa-Samuelson hypothesis. Moreover, the deterioration of the external account is fairly persistent, especially for the US. The response of the real exchange rate and (our proxy for) the terms of trade differs across countries: both prices appreciate in the largest and least open economies in our sample; they depreciate in the smaller and more open economies. These findings question the conventional view that supply shocks worsen the terms of trade of a country on impact — providing an empirical contribution to the current debate on the correction of global imbalances. Productivity growth in the US manufacturing sector do not necessarily deteriorate the US terms of trade, nor improve the US trade deficit, at least in the short and medium run.

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1 Introduction

A widespread view of the transmission mechanism embedded in standard open-macro models holds that a productivity increase in the traded goods sector of a country should simultaneously worsen that country's terms of trade — i.e. the international relative price of domestic tradables — and raise the domestic price of nontradables, according to the Harrod-Balassa-Samuelson (henceforth HBS) hypothesis. A great deal of theoretical and quantitative models built by academics and researchers in policy institutions subscribe to this view of the international transmission, with far reaching implications at both theoretical and policy levels. According to it, international spillovers of productivity shocks are positive: foreign consumers benefits from an increase in the traded goods production in the domestic country via reduced import prices. For this very reason, technical progress improves world welfare even in the absence of technological spillovers — i.e. when it remains confined to a single country. An important implications is that terms of trade movements purportedly reduce the consumption risk of asymmetric productivity shocks: even if international asset markets do not provide complete insurance, relative price movements systematically reduce the wedge between domestic and foreign wealth induced by fluctuations in relative productivity.[1] Positive spillovers also tend to reduce the scope for welfare gains through the design of optimal stabilization policy and international policy coordination.

However, according to standard general equilibrium open economy models, the macroeconomic effects and the international transmission of technology shocks may actually differ across economies, depending on their degree of openness, their trade elasticities, market dynamics as well as the degree of shock persistence. Gains in productivity are not necessarily associated with an impact deterioration in the international relative prices of a country's output and consumption.

As the international transmission mechanism is at the core of theoretical modelling and policymaking alike, it is somewhat surprising to find limited empirical work on these issues. Addressing this gap in the literature, this paper analyzes the international transmission of productivity shocks using a subset of the G7 countries, including Germany, Italy, Japan, the UK and US.[2] The countries in our sample have different size and degree of openness: it turns out that heterogeneity in these dimensions has relevant implications for our analysis. For each country, we run structural VARs, identifying productivity shocks in manufacturing – our measure of the tradable goods sector – using long-run restrictions as in Galí [1999], Francis and Ramey [2003] and Christiano, Eichenbaum and Vigfusson [2004]. We study the dynamic effects of these shocks on the domestic economy, and their transmission to other countries. Whereas previous

[1] To emphasize this point, Cole and Obstfeld (1991) point out that, with unitary elasticity of substitution between domestic and foreign goods and no home bias, international consumption risk sharing can be achieved without any international trade in assets.

[2] We could not include France and Canada in our analysis because of the results of unit root tests on relevant variables — see section 4.

studies mostly focused on the link between productivity and real exchange rates, motivated by the HBS hypothesis, we place significant emphasis on the joint dynamics of the international relative prices, including the price of tradables, net trade and the international transmission.

Overall, our baseline VAR results square well with the conventional view of the international transmission in many dimensions: in all countries positive productivity shocks raise domestic manufacturing output and aggregate consumption relative to foreign countries, leading to a persistent worsening of the trade balance; the price of domestic tradables in terms of nontradables— proxied in most cases by the PPI relative to the services CPI — falls, in support of the HBS hypothesis. While the textbook version of this hypothesis is often phrased in reference to a real appreciation of the exchange rate, we emphasize that such version is not correct when countries are specialized in the production of different tradable goods. In this case, whether or not the appreciation of nontradables also transpires into an appreciation of the real exchange rate depends on the sign and relative strength of the terms of trade movement.

We find that the real exchange rate's response to productivity shocks is heterogenous across countries, and differentiated by size and degree of openness of the economy. In the case of the US and Japan — the two largest and least open economies in our sample — productivity gains lead to a short-run appreciation in all our measures of international relative prices. The price responses instead are not significant for Germany, at least in our baseline specification. In the case of the UK and Italy — the smaller and more open economies in our sample — we detect permanent depreciations. Observe that the response of CPI-based real exchange rate has the same sign as the response of the PPI-based and export-deflator-based real exchange rates. So, while we find evidence of a domestic HBS effect in all countries, our results nonetheless suggest that the real exchange rate appears to be driven by a country's terms of trade — as proxied by our export-deflator-based exchange rates.

We verify the robustness of our results by modelling those variables for which unit-root tests give contrasting results, in levels rather than first difference. For the US and Japan, our results are unchanged under this alternative specification. However, we detect short-run real exchange rate appreciation for Germany — in line with the other large countries' result — and for the UK, while the response of the real exchange rate becomes insignificant for Italy. We also verify that our results are reasonably stable over different subsamples.

Our overall findings for the US, Japan and (to a lesser extent) Germany clearly question a popular view of the core transmission mechanism embedded in many DSGE models of the international economy. First, our results suggest that price movements may magnify the consumption risk of productivity fluctuations, as countries with larger tradable supplies will also enjoy favorable terms of trade movements. Second, our evidence implies that the sign of the international spillovers from domestic productivity shocks be potentially negative, at least in the short run, with widespread policy implications.

Namely, this paper provides a contribution to the recent debate on the adjustment process associated with an hypothetical reversal of the US current account. In a series of papers, Obstfeld and Rogoff [2004, 2005] argue that a correction of the US external balance would entail a large real depreciation of the dollar. Yet, productivity differentials in the tradable sector between the US and the rest of the world would somewhat smooth out the adjustment: a higher supply of tradable would improve the US net exports, via a fall in the terms of trade, while containing the overall rate of real depreciation via the HBS effect.

Our empirical results question and qualify this view in at least two respects. First, we find evidence that the impact response of the terms of trade may be just the opposite of what is postulated by Obstfeld and Rogoff [2004]: our measures of the US international price of tradables appreciate with domestic productivity gains in the domestic tradable sector.[3] Second, we find that, for a prolonged period of time, productivity gains do not lead to a surplus. Once the dynamic response of absorption to productivity gains in the traded good sector is taken into account, the effect on the US net trade is a deficit. By the same token, contrary to the claim that productivity growth in the rest of the world would unconditionally hamper the US external correction, unless it is concentrated in the nontraded good sector,[4] our VAR results suggest a more conventional view about the beneficial implications of world growth driven by technical progress. Productivity growth in the most industrial countries, especially in Japan and Europe, is in fact likely to raise global demand for US products, at least in the medium run, even when productivity gains are concentrated in their manufacturing sector. A trade deficit in the other G7 countries would correspond to a less negative trade balance in the US.

The paper is organized as follows. Section 2 will review the international transmission mechanism in standard theoretical and quantitative models, identifying alternative views and empirical predictions. Section 3 describe the data and the empirical methodology. Section 4 presents and discusses in detail our main results. Section 5 concludes.

2 Productivity, international prices and the current account: theoretical perspectives

The conventional view of the international effects of country-specific productivity growth is that a higher supply of domestic tradable goods is absorbed by international markets at a lower price, to the benefit of consumers worldwide. This view, common in both trade and international macro literature, has been recently challenged by a number of theoretical, empirical and quantitative contributions.[5] In this section, we discuss the main results from this recent debate

[3] This result holds also when in our US VAR model, we specify the terms of trade as the relative price of exports in terms of overall imports.

[4] "We dispel some common misconception about what kind of shifts are needed to help close the US current account imbalances. Faster growth abroad helps only if it is relatively concentrated in nontradable goods; faster productivity growth in foreign tradable goods is more likely to exacerbate the US adjustment problem." (Obstfeld and Rogoff, [2004], abstract).

[5] An incomplete list includes Acemoglu and Ventura [2003], Corsetti, Dedola and Leduc [2004], Corsetti, Martin and Pesenti [2005, Debarae and Lee [2004], Ghironi and Melitz [2006].

on the transmission of productivity shocks. We first consider open economy and trade models where both the set of products and the pattern of comparative advantage is exogenous specified; then we discuss models allowing for endogenous product variety, whereas adjustment can occur at both the intensive margin (altering the scale of production of a given set of goods) and the extensive margin (via the introduction of new goods varieties).

2.1 The conventional view of the international transmission mechanism

Consider standard general equilibrium models including both tradables and non-tradables production (e.g., Obstfeld and Rogoff [2000]). In addition to raising the relative price of non-tradables — according to the HBS effect — productivity gains in the domestic tradable sector are posited to deteriorate a country's terms of trade. Hence the overall response of the real exchange rate will depend on the relative magnitude of two relative price movements opposing each other: worsening terms of trade tend to depreciate the real exchange rate; the HBS effect tends to appreciate it. Depending on price elasticities, reflecting preferences and market structure, either outcome is possible.

The structure of asset markets matters. When models are developed under the assumption of complete markets, important restrictions are imposed on equilibrium relative price movements. As is well known, efficient risk sharing implies that the ratio of marginal utility of consumption across countries is proportional to the bilateral real exchange rate between these countries. This means that an increase in domestic consumption relative to foreign is systematically associated with domestic real depreciation. With complete markets, contingent income transfers eliminate wealth effects from asymmetric shocks: other things equal, domestic productivity shocks raise domestic consumption relative to foreign only if its relative price — the real exchange rate — is depreciating. Because of income transfers, cross-country movements in domestic demand in response to positive shocks cannot generate an international scarcity of Home tradable goods, and an increase in their international price. It follows that models with a high degree of international consumption risk sharing support the 'conventional view' of the international transmission mechanism, described above. The same is true also for models assuming incomplete markets, yet implying allocations that are close to the first best. This is the main lesson from influential contributions which have contrasted complete-market and incomplete-market models, showing important examples where the models are remarkably close to each other as regards the equilibrium allocations and the transmission mechanism (see Baxter and Crucini [1995] and Chari, Kehoe, McGrattan [2003]).

When markets are incomplete, however, equilibrium wealth effects of productivity gains can be associated with substantial asymmetric effects in domestic demand relative to foreign demand. The transmission mechanism in the presence of strong wealth effects can be different from the conventional view. With large movements in relative domestic absorption, the terms of trade response can change sign relative to the complete market allocation; by the same token, a rise in relative consumption is not necessarily associated with real exchange rate depreciation, but can be accompanied by real appreciation — consistent with a large body of evidence after Backus and Smith [1993], Kollman [1995] and Ravn [2000]. This considerations suggests that, to move beyond the conventional view of the international transmission mechanism, it is appropriate to focus on incomplete market models, whereas the equilibrium allocation is not characterized by a high degree of international consumption risk sharing.

2.2 Moving beyond the conventional view of the international transmission mechanism

2.2.1 Dynamic response of the terms of trade to persistent shocks

The possibility of strong equilibrium wealth effects from productivity shocks makes it clear that the international transmission mechanism predicted by standard general equilibrium open economy models is richer than what envisaged by the conventional view. A first way to see this is to consider the macroeconomic dynamics in response to shocks which are permanent and/or anticipated ('news shocks'). The transmission mechanism is as follows. With incomplete markets, domestic absorption increases markedly in the short run. A strong response in domestic absorption opens a trade deficit, but also makes the world supply of domestic tradables scarce — possibly leading to an equilibrium appreciation of the terms of trade. The response of the terms of trade however changes sign over time, as new capital is installed and becomes productive, and/or productivity reaches new, higher levels; likewise in the long-run the trade balance improves.

This model of the international transmission is reminiscent of a key prediction of the Mundell-Fleming model: with flexible exchange rate, any increase of domestic demand would appreciate the currency in real terms (in this model there is no distinction between terms of trade and real exchange rate) and 'crowd out' net exports. In the Mundell-Fleming tradition, however, demand shocks are unrelated to productivity, and driven by exogenous policy measures (fiscal policy) and/or exogenous expectations raising consumption or investment. In dynamic general equilibrium models, instead, productivity shocks affect relative prices and wealth, thus shaping consumption and investment demand in the short run. The crucial question is under what conditions the response of domestic absorption is strong enough to require a real appreciation in the short run.

In related work (Corsetti, Dedola and Leduc [2004]), we analyze the above transmission mechanism in a standard DSGE model with traded and nontraded goods, where agents can borrow and lend in international markets. The model indeed generates temporary terms of trade appreciation in response to highly persistent productivity shocks to tradables under the following conditions. First, the economy has a sufficiently high degree of home bias in absorption — calibrated in line with the US economy — so that the response in spending to a shock raising wealth falls to a large extent on domestically produced goods (the economy is relatively closed to trade). Second, the long-run price elasticity of domestic tradables is relatively high — close to the (mainly panel) estimates by trade economists. This is because, the higher the price elasticity is, the smaller the long-run fall in the international price of domestic goods required to accommodate an increase in their supply. Hence, other things equal, the increase in quantities supplied to the market does not lead to a marked deterioration in the value of domestic output — containing the adverse terms of trade effect on relative domestic wealth. So, provided that consumption risk is not efficiently shared, under the above two conditions, otherwise standard DSGE open economy models with tradable and nontradables yield a dynamic response of the terms of trade to productivity innovations — appreciation in the short run, depreciation in the long run — in contrast with the conventional view of international transmission. Despite the long-run depreciation, intertemporal trade allows domestic agents to capture a large portion of the benefits in the short run. In other words, spillovers are negative in the short run, when the upsurge in domestic absorption driven by expectations of future productivity gains appreciate the terms of trade, reducing the overall net benefits to foreign consumers.

2.2.2 The role of price elasticities

Another difficulty with conventional views of the transmission mechanism via a terms-of trade-deterioration stems from the general equilibrium implications of the relatively low price elasticity of imports picked up by a variety of aggregate, time-series estimates (e.g., see Hooper et al. [1995]). If this price elasticity is sufficiently below unity, combined with home bias in absorption, wealth effects from terms of trade movements can be so strong that productivity gains raise the international price of a country's tradable output. Intuitively, since domestic consumers and firms are the largest buyers of domestic goods, an increase in the global demand for these goods is possible only if domestic private income and absorption rise enough. For this reason, in equilibrium domestic supply rises and the terms of trade appreciate — as a fall in the latter would mean a fall in the wealth of domestic agents relative to foreign agents, causing a shortfall in the global demand for domestic goods.

Different from the case described before, the dynamic response of the terms of trade does not change sign over time — i.e. there is no long-run depreciation — if the elasticity remains sufficiently low in the long-run. Despite the fact that in both cases the terms of trade appreciate and domestic absorption booms in the short run, opening a trade deficit, welfare implications may be different. With a low elasticity, strong wealth effects imply that a country can capture most of the domestic gains in productivity in both the short and the long run, independently of the possibility of intertemporal trade. Welfare spillovers are unambiguously negative. With a high elasticity, instead, terms of trade movements tend to create positive spillovers in the long run.

2.3 Adjustment at the extensive margin

Further doubts on the conventional view of international transmission of technology shocks are raised by the recent macroeconomic literature on firm dynamics and endogenous goods variety, which allows for both an intensive margin (i.e., altering the scale of production of a given set of goods) and an extensive margin (i.e., via the introduction of new goods).[6] Namely, the international business cycle model by Ghironi and Melitz [2006] predicts that the terms of trade appreciate in response to an increase in productivity. In this model, however, productivity shocks reduce symmetrically both the marginal costs of producing goods, and the sunk cost of setting up new firms. Corsetti, Martin and Pesenti [2005] relax this assumption, showing that the terms of trade response to productivity differ radically depending on which costs is affected: the terms of trade appreciate following a drop in entry costs, but depreciate if technology innovations make good manufacturing cheaper. Cross-country evidence consistent with these effects is provided by Acemoglu and Ventura [2003] as well as by Debaere and Lee [2004].

Moreover, the intensity as well as the direction of international price movements crucially depend on the degree of international consumption risk sharing, as well as the elasticity of labor supply. If both the degree of risk sharing and the labor supply elasticity are high enough, terms of trade do not appreciate at all (see Corsetti, Martin and Pesenti [2005]).

Observe that, when the supply of goods varieties is endogenous, international spillovers depend not only on the movements of the terms of trade (an appreciation hurts foreign consumers), but also on the welfare implications of a changing array of goods available to consumers (an increase in varieties benefits foreign consumers). International welfare effects are more difficult to assess: if the consumers' love for goods variety is high enough, international spillovers of productivity shocks may be positive even when the terms of trade move against the Foreign country.

3 Estimating the effects of a permanent technology shock to manufacturing

In this section, we present our strategy for identifying the effects of permanent shocks to technology in the manufacturing sector for the US, Japan, Germany, the UK, and Italy vis-à-vis an aggregate of the other G7 countries and three other OECD countries (Australia, Sweden and Ireland) for which we were able to obtain quarterly data on hourly labor productivity. We focus on time series evidence and use VAR methods, extending work by Galí [1999], Francis and Ramey [2003] and Christiano, Eichenbaum and Vigfusson [2004] — where technology shocks are identified via long-run restrictions — to an open-economy context. Namely, we adopt the identifying assumption that the only type of shock which

[6] A theoretical attempt to build a model encompassing a discussion of both elasticities and creation of new goods is provided by Ruhl [2003].

affects the long-run level of average labor productivity in manufacturing is a permanent shock to technology. A number of recent papers have investigated the effects of technology shocks identified using long-run restrictions in a closed-economy framework. This literature uses the basic insight from the stochastic growth model, that only technology shocks should have a permanent effect on labor productivity, to identify economy-wide technology shocks in the data.[7]

As discussed below, we use reduced-form time series methods in conjunction with our identifying assumption to estimate the effects of a permanent shock to technology. As argued by Christiano et al. [2004], an advantage of this approach is that we do not need to resort to the set of assumptions usually required to construct measures of technology shocks based on Solow residuals, including corrections for labor hoarding, capital utilization, and time-varying markups. On the other hand, we are fully aware that there exist models in which our identifying assumption may not be verified. An obvious instance is the case of endogenous growth models where all shocks affect productivity in the long run. Another instance is that of an otherwise standard two-sector model, when there are permanent shocks in both the manufacturing and the other (nontradable goods) sector. These caveats notwithstanding, we proceed as in the literature, and examine the effects of technology shocks to the manufacturing sector (our proxy for traded goods), identified with long run restrictions, on the real exchange rate, the terms of trade, net exports and relative consumption and output. To be as sure as possible that we have actually identified technology shocks, we carry out several checks. For example, we include in our benchmark specification the relative price of manufactured goods in terms of consumer services, as a proxy for the relative price of domestic tradables in terms of nontradables: this price should fall in response to a technology shock which is specific to the tradable sector.[8] Leaving to the data appendix a detailed description of data sources, hereafter we describe our approach.

Over the period 1973 to 2004, we estimate several specifications of the following structural VAR model

$$\begin{bmatrix} \Delta x_{j,t} \\ \Delta y_{j,t} \end{bmatrix} = \begin{bmatrix} C^{xz}(L) & C^{xm}(L) \\ C^{yz}(L) & C^{ym}(L) \end{bmatrix} \begin{bmatrix} \varepsilon^{z}_{jt} \\ \varepsilon^{m}_{jt} \end{bmatrix}. \tag{1}$$

[7] See Shapiro and Watson [1988] and King, Plosser, Stock and Watson [1991], among others. Some open-economy papers, following Blanchard and Quah [1989], use long-run restrictions derived in the context of the traditional aggregate demand and aggregate supply framework. For instance, Clarida and Galí [1994] identify supply shocks by assuming that demand and monetary shocks do not have long-run effects on relative output levels across countries. While monetary shocks satisfy this assumption in most models, fiscal or preference shocks do not, since they can have long-run effects on output (and hours) in the stochastic growth model. A survey of the closed economy literature using long-run restrictions is Galí and Rabanal [2005].

[8] In Corsetti, Dedola and Leduc [2004] we obtained very similar results for the US using (annual) TFP data. As argued by Chang and Hong [2002], the use of TFP provides a further check on the identification strategy, as it amounts to controlling for long-run effects on labor productivity brought about by changes in the long-run capital labor ratio by other permanent shocks, e.g. capital tax-rate shocks (see Uhlig [2003]). Unfortunately, we could not extend the analysis in Corsetti et al [2004] to the other countries because of lack of data on sectoral TFP.

Here $x_{j,t}$ denotes the variable that is assumed to respond in the long run exclusively to permanent technology shocks: in all our specifications, this variable is the (log of the) quarterly labor productivity in manufacturing, measured in deviation from quarterly labor productivity in manufacturing in the "rest of the world" (hereafter ROW). All ROW's variables are specific to country j and built as an aggregate of a large sample of the other G7 countries (excluding country j) weighted according to their respective (time-varying) GDP shares at PPP values.[9] This set of countries comprises six of the G7 countries (thus including Canada and France), plus Australia, Ireland and Sweden.[10] The vector $y_{j,t}$ is 5x1 and always includes (the log of) a country-specific index of manufacturing production and aggregate consumption relative to the same variable for the ROW, the country's ratio of nominal net export over GDP and (the log of) the relative domestic producer price index over the domestic consumer price index of services in country j. The last variable in $y_{j,t}$ is a measure of international relative prices vis-à-vis ROW:

$$RER_i = \frac{P_i}{SP_i^*}.$$

where the price indexes P_i and P_i^* are alternatively (the log) of the CPI, PPI and export-deflator, with SP_i^* also built as PPP GDP-weighted aggregates of the countries included in ROW.[11]

Finally, $C(L)$ is a polynomial in the lag operator of order $p = 4$ in all countries; ε_{jt}^{z} denotes the technology shock to manufacturing specific to country j, and ε_{jt}^{m} the other structural, non-technology shocks. Although not necessary for identification, implicit in our benchmark specification is the assumption that all the variables other than productivity also have a unit root. Lacking any strong theoretical a-priori on the stationarity of the variables included in the VARs, we resorted to standard unit root tests. In our sample, the assumption of nonstationarity is not consistently rejected by the data but for the Japanese net exports — we report these tests' results in the data appendix.[12] However, following the suggestions in Christiano, Eichenbaum and Vigfusson [2004], whenever there is some evidence against a unit root, we also estimate specifications of the VARs

[9] We use GDP shares as trade weights were not available for all countries going back to 1970.

[10] These 10 countries add up to roughly half of world GDP at PPP values, so they represent a substantial sample of the global economy. Moreover, trade flows among them also amount to over a half of their respective total trade, on average. For instance, the US trade share with the other 9 countries in our sample is around 60 percent of US total trade.

[11] This is meant to capture the following well-known decomposition of the CPI-based real exchange rate between a first component due to the relative price of tradables *across countries*, and a second component due to the relative price of tradables in terms of nontardables *within countries*:

$$RER = \frac{P}{SP^*} = \frac{P_T}{SP_T^*}\left(\frac{P_T^*}{P_N^*}\right)\left(\frac{P_N}{P_T}\right)$$

[12] We run both the Phillips and Perron [1988] and Elliot, Rothenberg, Stock [1996] GLS-modified Dickey-Fuller tests, allowing the level of variables to have alternatively a constant term or also a deterministic trend.

with the corresponding variable (such as the real exchange rates or net exports) in levels, rather than growth rates.

Together with the usual assumption that the structural shocks ε_t are uncorrelated and have unitary variance, positing that $C^{xm}(1) = 0$ is enough to identify ε_t^z. This restricts the unit root in the variable x_t to originate solely in the technology shock. In practice, in order to estimate impulse responses to the technology shock we follow the Bayesian approach for just-identified systems discussed in Doan (1992). For each country, we begin by estimating the following 4th-order reduced form VAR:

$$Z_{j,t} = \alpha + B_j(L) Z_{j,t-1} + u_{j,t}, E u_{j,t} u'_{j,t} = \Sigma_j, \tag{2}$$

where $Z_{j,t} = \begin{bmatrix} \Delta x_{j,t} \\ \Delta y_{j,t} \end{bmatrix}$, and u_t is the one-step-ahead forecast error in $Z_{j,t}$. Also, Σ_j is a positive definite matrix. It is well-known that positing a non informative prior of the Normal-Wishart family and a Gaussian likelihood implies that the posterior for parameters of the reduced form VAR above is also Normal-Wishart (see Uhlig [1994] for a formal derivation), whose parameters including Σ can be estimated by OLS applied to each equation. The structural economic shocks, ε_{jt}, are related to u_{jt} by the following relation (dropping the subscript j):

$$u_t = A_0^{-1} \varepsilon_t, E\varepsilon_t \varepsilon'_t = I.$$

As in (1), without loss of generality, we suppose that ε_t^z is the first element of ε_t, and $B(L) = A_0^{-1} C(L)^{-1}$. The assumption that $C^{xm}(1) = 0$ implies that the first column of A_0^{-1}, depicting the effects of a technology shock on the variables in the VAR, is uniquely defined by:

$$A_0^{-1} = \widetilde{B}(1) \left[chol \left(\widetilde{B}(1)^{-1} \Sigma \widetilde{B}(1)^{-1'} \right) \right]^{-1}, \widetilde{B}(1) = [I - B(1)].$$

Therefore, for each draw from the known posterior of the reduced-form VAR we can compute a unique A_0^{-1} and the associated impulse responses.[13]

4 The international transmission of permanent productivity shocks to tradables production

In this and the next section, we report our results for five G7 countries (US, Japan, Germany, UK, Italy) in our sample. Our data are displayed in the appendix, Figures A1-A5. We consider the sample period 1973-2004, the longest for which we have data, which also corresponds to the period of nominal flexible exchange rates among the US, Japan, the UK (but for a brief period in the ERM), Germany, and Italy. While we started with all the G7 countries, we were forced to drop France and Canada from the analysis because for these countries unit-root tests rejected the hypothesis of nonstationarity in the measure of labor

[13] Our results are based on 1000 draws.

productivity differential with the ROW.[14] In this section, we report results based on our benchmark specification, in which all variables are in growth rates. In the following section we will discuss sensitivity analysis, introducing variables in levels, and carrying out subsample stability analysis.

4.1 Baseline specification

Figures 1 through 5 display the impulse response functions for our benchmark difference specification, along with 68 percent pointwise posterior confidence intervals. For instance, Figure 1 displays the response of US relative productivity, manufacturing output (Y-Y*), and aggregate consumption (C-C*), all in log differential with ROW, along with nominal net trade over GDP (NX/Y), the PPI relative to the services CPI, and our three alternative international relative prices (RER), based on the CPI, the PPI and the export deflator. Each figure shows the OLS estimates (the black solid line), the median (the red solid line) and the 16th and 84th percentiles (the blue dashed lines) of the posterior distribution.

Starting with the US, our main results are as follows. First, the median impact effect of the shock on relative manufacturing output and aggregate consumption is slightly negative but statistically insignificant in the short run; both variables however converge to a permanently higher level after three years. Second, the long-run increase in both these variables is of the order of 0.5 percent, against a permanent increase of 1.5 percent in the productivity differential. Note that the rise in relative consumption and productivity are estimated with higher precision than the rise in output. Third, the technology shock leads to a prolonged, statistically significant fall in both net exports and the relative price of domestic tradables. The latter corresponds to a Balassa-Samuelson effect, according to the conventional wisdom about the relative price implications of productivity gains in manufacturing. Note that this result provides some support to the identification scheme underlying our analysis, against the possibility of symmetric productivity innovations across all sectors (which is unlikely to cause a significant appreciation of nontradables).

The fall in net export may be found surprising, in light of some applied and policy literature. As discussed above, some contributions in this literature postulates that a productivity increase in tradables bring about an improvement in net trade. Against this presumption, our empirical results suggest that the deterioration in net trade peak after about three years, standing at roughly 0.15 percentage points of nominal GDP, and persist in the long-run. While this very persistent effect reflects the assumption — strongly supported by unit root tests — that the net-trade-to-GDP ratio is nonstationary, it is by no means a mechanical implication of that assumption.[15]

[14] Precisely, in the case of France (Canada) both the Phillips-Perron and the GLS Dickey-Fuller tests rejected the null of nonstationarity at the 1 (10) percent confidence level.

[15] See Engel and Rogers [2005] for further evidence on the nonstationary behavior of US net trade.

Fourth, the CPI-based RER temporarily appreciates (an increase is an appreciation) in the aftermath of the shock, and then goes back to its previous long run level. Notably, in light of the response of relative consumption, the response of the CPI-based RER is at odds with the condition for efficient consumption risk sharing — consistent with the (unconditional) evidence in Backus and Smith [1993]. Finally, the other two measures of international relative prices display the same pattern as the CPI-based RER. As these two measures are built using PPIs (i.e. price indexes including a larger share of tradables than the CPI) and export deflators (including only the price of traded goods), our results suggest that the RER appreciation reflects more than the classical Balassa-Samuelson effect: it also captures important terms of trade effects, as well as deviations from the law of one price (LOP) for traded goods.

We report the same set of impulse responses for Japan, Germany, the UK and Italy, in Figures 2-5, respectively. Relative to the US, these countries display overall similar patterns, but also some important differences. Starting with similarities first, in all these countries a positive shock increases the consumption differential after a few quarters; it decreases both the nominal net trade relative to GDP as well as the relative price of manufacturing in terms of services/overall CPI — with the exception of Japan, where the latter variable initially rises, albeit insignificantly. The initial positive response of relative manufacturing output consolidates in a permanent increase in Japan, the UK and Italy, but it is significant only in Japan, where it levels off at around 1.5 percent. Relative output instead displays a permanent and significant fall in Germany. Conversely, relative consumption increases permanently in all four countries by around 0.5 percent, albeit insignificantly in Japan. The deterioration of net exports over GDP is stronger in the UK and Germany, where it is also permanent; in Italy this variable displays a similar qualitative behavior but is significantly negative for just a couple of quarters one year after the shock. As in the US case, these permanent effects reflect the assumption that the net-trade-to-GDP ratio is nonstationary, in line with results from unit root tests. In Japan net exports — modelled as stationary — reach a minimum 8-10 quarters after the shock, and then slowly revert to their baseline value. Finally the relative price of manufactured goods in terms of services falls permanently in all countries, although significantly so only in Germany and Italy.

The similarities with the US, however, end here. With the exception of Japan, where all measures of international relative prices, including the CPI-based RER, significantly appreciate in the first few quarters after the shock, the other countries display different patterns. The response of international relative prices is a permanent depreciation in the case of Italy and the UK. The response of international relative prices is small and insignificant in the case of Germany. We emphasize two dimensions of these results. First, as for the US, in each of the country in our sample, our three measures of relative prices display the same behavior despite a rising weight of tradable goods in the corresponding price index. This result lends support to the hypothesis that terms-of-trade and deviations from the law of one price play a crucial role in driving the CPI-based real exchange rate dynamics in the aftermath of the productivity shock. Second, the relatively depreciation in UK and Italy points toward an international transmission of productivity shocks closer to the conventional view. Productivity gains are retained by the domestic economy (relative consumption rises) but also benefit the other countries through a deterioration in the international price of domestic tradable goods.

To summarize our baseline results on the international transmission of productivity shocks to manufacturing, we first find that a positive shock leads to an increase of domestic consumption above foreign consumption, and worsen the trade balance. The finding that the external account response is persistently negative is especially relevant for the case of the US. Our results are at odds with the view expressed in recent policy contributions, that productivity growth in US manufacturing could lead to an early and relevant improvement in the US external trade balance (e.g. Obstfeld and Rogoff 2005). According to our VAR evidence, other things equal, the dynamics of domestic demand in response to productivity shocks is not likely to contribute to a US current account reversal at least in the short and medium run. On the other hand, we lend support to the conventional policy view, that productivity growth in the rest of the (industrial) world could help reducing the US current account deficit, also when it benefits the production of foreign tradables.

Second, with the exception of Japan, where this effect turns out to be insignificant, productivity gains in manufacturing lower the PPI relative to the (services) CPI. As the latter index includes a much larger share of nontraded goods, this is evidence in support of the Balassa-Samuelson hypothesis: in response to sector-specific productivity gains, nontraded good prices appreciate relative to tradables.

Third, the real exchange rate response is heterogenous across countries, and differentiated by country size and degree of openness. However, in each individual country our three measures of the real exchange rate move in very similar ways — despite the different degree of tradability of the goods included in the corresponding price indexes (CPI, PPI or export deflator). In the case of the US and Japan — the two largest and least open countries in our sample — productivity gains lead to a short-run appreciation in all our measures of the real exchange rate. In our baseline specification, the response is instead non significant for Germany. In the case of the UK and Italy — the smaller and more open economies in our sample —, we detect permanent depreciations. So, while we find evidence of a Balassa-Samuelson increase in the domestic relative price of nontradables in all countries, the CPI-based real exchange rate seem to be driven by a country's terms of trade, proxied by our export-deflator based real exchange rate.

4.2 Sensitivity analysis

In this subsection we investigate the sensitivity of our analysis along two dimensions. First, we allow some variables to enter the VAR specifications in levels, with possibly deterministic trends; second we verify subsample stability. Sensitivity along a further dimension, the choice of variables to include in the analysis, was obtained as a by-product of the above analysis, as changing the particular international relative price included in the VAR did not have any impact on the results.[16]

4.2.1 Results with level specifications

It is well-known that VAR's with long-run restrictions may be sensitive to mistakenly modelling stationary series as nonstationary because of the ensuing specification error due to overdifferencing (see Christiano et al. [2004]). Since unit-root tests yield conflicting results about nonstationarity of some of our series, we run additional VARs with these variables in levels, detrending them when appropriate. Note that, by construction, this entails a zero long-run response of these variables. Specifically, our unit root tests give conflicting results for at least one measure of international relative prices in all countries, and for net exports over GDP in the case of the UK and Italy. This latter variable is stationary in Japan and nonstationary in the US and Germany according to all tests considered.[17]

The results of our sensitivity analysis are reported in Figures 6 through 10 with the same variables' mnemonics and format as before. Namely, each figure shows the OLS estimates (the black solid line), the median (the red solid line) and the 16th and 84th percentiles (the blue dashed lines) of the pointwise posterior distribution. For the case of US and Japan, Figure 6 and 7 make it clear that our baseline results are not sensitive to alternative assumptions about stationarity of international relative prices. In these figures we assume that all our measures of international prices are all stationary around a deterministic trend: as in the case of Figure 1 and 2, all these relative prices appreciate in the short run in response to a positive technology shock, both substantially and significantly.

However, some baseline results turn out to be sensitive to the level specification for Germany, the UK and Italy. While the response of consumption and output differentials, as well as of the relative price of nontradables are generally unchanged, we detect changes in the behavior of relative prices. Figures 8 and 9 show that all measures of international relative prices markedly appreciate in the short run in the case of Germany and the UK. Conversely, the responses of relative prices in Italy — shown in Figure 10 — turn out to be small and not significantly different from zero. Finally, modelling net exports in levels does not change the sign of their response either in the UK (Figure 9) nor in Italy, as they continue to deteriorate after a few quarters, albeit not significantly.[18]

[16] We also estimated specifications of the model including other domestic and international variables, like total and non-residential investment, and aggregate GDP, obtaining broadly similar results to those discussed in the text.

[17] For these latter two variables, besides the Phillips-Perron and GLS Dickey-Fuller tests, we also run KPSS tests (see Kwiatkowski et al., [1992]). The null of stationarity was rejected at least at the 5 percent level, even when we included a deterministic trend in the variables' level specification.

[18] We also run a specification for Germany with also the detrended consumption differential in level, given that the Phillips-Perron test without a constant rejected a unit root in this

In light of these results, we conclude that the international transmission of productivity shocks is clearly at odds with the conventional view — that higher supply leads to terms of trade depreciation — in the cases of USA and Japan; this may also be the case for Germany. The conventional view of the transmission mechanism is instead verified for Italy — although the response of the international prices and net exports may be small. For the UK, results vary depending on the assumptions about stationarity of the real exchange rates.

4.2.2 Subsample stability

In this subsection we briefly discuss subsample stability, focusing on the benchmark specification. Stock and Watson [2004], among others, have argued that the world economy has become less volatile after the 1970s — the "great moderation" — and that this resulted in a structural change in VAR's. Moreover, one can observe that the first years in our sample were characterized by the transition from the Bretton-Woods regime of fixed exchange rates, to the current regime of floating rates. Finally, the beginning of the 21st century has witnessed several changes in the global economy, with the rapid growth of large emerging market countries such as China and India, the launch of the European common currency, and the emergence of large current account imbalances across the world. This subsection assesses the robustness of our conclusions to the possibility of subsample instability due to these changes.

Panels A and B of Figure 11 — referred to the US – display the estimated impulse responses of the variables in our baseline system, for the pre-1999Q1 and post-1978Q4 sample periods, respectively. As before, each figure shows the OLS estimates (the black solid line), the median (the red solid line) and the 16th and 84th percentiles (the blue dashed lines) of the pointwise distribution in the indicated subsample. To save on space, we do not show the results for the other countries, as these substantially confirm our findings for the US.

The key results are as follows. First, the qualitative patterns of all variables responses are broadly similar across periods, and in full accord to our estimates for the full sample. The US net exports deteriorate persistently and international relative prices appreciate on impact in both subsamples. Second, both the median and OLS estimates for each sample period would lie well within the 68 percent confidence intervals in the full sample. This is consistent with the view that the responses in the subperiods are the same as they are for the full sample. However, the estimated effects of technology appear somehow less significant, perhaps due to the loss of degrees of freedom entailed by reducing the number of observations. Overall, this evidence is consistent with the view that the responses in the subperiods are the same as they are for the full sample and there is no break in the international transmission of tradable technology shocks.

variable at the 5 percent level. Since results are very similar results to those displayed in Figure 8 we do not report them in this version of the paper.

5 Discussion and implications for open-economy modelling and policy analysis

In this paper, we provide empirical evidence on international transmission of productivity shocks among G7 countries. Relative to the literature, our contribution is novel in at least two respects. First, it applies time series methods with minimal identifying assumptions to international data. Second, we jointly study the dynamics of the international transmission and international relative prices, distinguishing between the relative price of nontradables, the real exchange rate and the terms of trade.

Our main result is that the international transmission of productivity shocks in manufacturing — which we identify with the tradable sector — is not identical across countries, but varies with their size and degree of openness. Namely, both the real exchange rate and the terms of trade appreciate in the largest and less open economies —-the US and Japan — in contrast with a widespread view of the international transmission. Conversely, international relative prices depreciate in a small open economy such as Italy — similar results for the UK turn out to depend on assuming a unit root in the real exchange rate. Second, with the exception of Japan where this effect is insignificant, productivity gains in manufacturing lower the PPI relative to the (services) CPI. As the latter index includes a much larger share of nontraded goods, this is evidence in support of the Harrod-Balassa-Samuelson hypothesis.

The results for the US and Japan challenge a popular view of the core transmission mechanism in DSGE models of the international economy. They suggest that price movements may raise the international consumption risk of productivity fluctuations, as countries with larger supplies will also rip further gains from favorable terms of trade movements; by the same token, the sign of the spillovers from productivity shocks may be negative, with relevant policy implications.

Finally, permanent productivity shocks in manufacturing drive domestic consumption above foreign consumption, and worsen the trade balance. The negative response of net exports is stronger in the case of our three largest countries; it is insignificant in some specifications of the empirical model for Italy and the UK. This finding that the external account response is persistently negative is especially relevant for the case of the US. Our evidence is in fact at odds with the view expressed in recent policy contributions, that productivity growth in manufacturing could play an important role in improving the US external trade balance (e.g., Obstfeld and Rogoff [2004]). Our results stress that, other things equal, the dynamics of domestic absorption in response to productivity shocks is likely to prevent a US current account reversal, at least in the short and medium run.

Appendix 1 Appendix: description of the data

[to be completed]

United States

Labor productivity: Index of output per hour of all persons in manufacturing sector, seasonally adjusted, 1992 = 100 (Bank of International Settlements and Dept. of Labor).

Manufacturing output: Index of industrial production in manufacturing, seasonally adjusted, 2000 = 100 (Federal Reserve Board)

Consumption: Private final consumption expenditure, volume in national currency, seasonally adjusted (OECD, Economic Outlook).

Nominal GDP: Gross domestic product, value, market prices in national currency, seasonally adjusted (OECD, Economic Outlook)

Net exports:Net exports of goods & services, value in national currency, season-

ally adjusted (OECD, Economic Outlook)

PPI index: Producer price index of manufactured products, seasonally adjusted, 2000 = 100 (OECD, Main Economic Indicators)

CPI total: Consumer price index all items, seasonally adjusted, 2000 = 100 (OECD, Main Economic Indicators)

CPI services: Consumer price index for services less energy services, seasonally adjusted; 1982-84 = 100, monthly converted to quarterly averages (BLS)

Export deflator: Exports of goods and services, deflator, seasonally adjusted, national accounts basis; 2000 = 100 (OECD, Economic Outlook)

CPI-based real exchange rate: Index of ratio of US CPI (total) to aggregate CPI (total) of 9 OECD countries, all in current US dollars, weighted with GDP shares at annual PPP values, 1970q1 = 100

PPI-based real exchange rate: Index of ratio of US PPI (manufacturing) to aggregate PPI (manufacturing) of 9 OECD countries, all in current US dollars, weighted with GDP shares at annual PPP values, 1971q1 = 100

Terms of trade: Index of ratio of US export deflator (goods and services) to aggregate export deflator (goods and services) of 9 OECD countries, all in current US dollars, weighted with GDP shares at annual PPP values, 1970q1 = 100

Japan

Labor productivity: Monthly index of output per hour of all persons in manufacturing, not seasonally adjusted, 2000 = 100 (Bank of International Settlements).

Manufacturing output: Index of industrial production in manufacturing, seasonally adjusted, 2000 = 100 (Federal Reserve Board)

Consumption: Private final consumption expenditure, volume in national currency, seasonally adjusted (OECD, Economic Outlook).

Nominal GDP: Gross domestic product, value, market prices in national currency, seasonally adjusted (OECD, Economic Outlook)

Net exports:Net exports of goods & services, value in national currency, seasonally adjusted (OECD, Economic Outlook)

PPI index: Producer price index of manufactured products, seasonally adjusted, 2000 = 100 (OECD, Main Economic Indicators)

CPI total: Consumer price index all items, seasonally adjusted, 2000 = 100 (OECD, Main Economic Indicators)

CPI services: Consumer price index for services less rents, seasonally adjusted; 2000 = 100 (OECD, Main Economic Indicators)

Export deflator: Exports of goods and services, deflator, seasonally adjusted, national accounts basis; 2000 = 100 (OECD, Economic Outlook)

CPI-based real exchange rate: Index of ratio of Japanese CPI (total) to aggregate CPI (total) of 9 OECD countries, all in current US dollars, weighted with GDP shares at annual PPP values, 1970q1 = 100

PPI-based real exchange rate: Index of ratio of Japanese PPI (manufacturing) to aggregate PPI (manufacturing) of 9 OECD countries, all in current US dollars, weighted with GDP shares at annual PPP values, 1971q1 = 100

Terms of trade: Index of ratio of Japanese export deflator (goods and services) to aggregate export deflator (goods and services) of 9 OECD countries, all in current US dollars, weighted with GDP shares at annual PPP values, 1970q1 = 100

Germany

Before 1991, all series were obtained on the basis of West Germany growth rates applied to level variables of unified Germany.

Labor productivity: Monthly index of output per hour of all persons in manufacturing and mining, seasonally adjusted, 2000 = 100 (Bank of International Settlements).

All other series were form the same sources as Japanese series, but for CPI services which is not available.

United Kingdom

Labor productivity: (a) From 1970 to 1995:q1, quarterly index of output per hour of all persons in manufacturing, seasonally adjusted, 1990 = 100 (Bank of International Settlements); (b) from 1995:q1 to 2004q4 , quarterly index of output per person in manifacturing, seasonally adjusted, 2002 = 100 (Bank of International Settlements), divided by the quarterly index of average hours worked per person in manufacturing (from Eurostat and). The series were joined by using growth rates over overlapping periods.

All other series were from the same sources as Japanese series, but for CPI services which was not available.

Italy

Labor productivity: Hourly labor productivity in manufacturing, seasonally adjusted, in 1995 national currency (Bank of International Settlements). A missing value in 1999q1 was filled by interpolation with output in manufacturing.

All other series were from the same sources as Japanese series, but for PPI from 1970 to 1980 which is the monthly price index of domestical finished manufactures, 1980 = 100 (BIS). The MEI and BIS monthly series were joined by using growth rates over overlapping periods and then converted by quarterly averaging.

Rest of the world

For the each country the rest of the world comprises the other six G7 countries (alternatively US, Japan, Germany, UK, Italy, France, Canada) plus Australia, Sweden and Ireland. This choice was dictated by data availability regarding hourly productivity in manufacturing.

Individual country's variables were aggregated by first taking quarterly growth rates to remove national basis effects; then cross-country average growth rates were computed with weights based on each country's GDP share in the 9-country aggregate calculated at annual purchasing power parity (PPP) values. Average growth rates were then cumulated starting form initial base year to obtain levels.

PPP based GDP shares are from the IMF's World Economic Outlook from 1980; before 1980 they were computed directly on the basis of annual GDPs at PPP values form OECD's Economic Outlook.

Labor productivity: Aggregate of country-specific indexes of output per hour of all persons in manufacturing sector, seasonally adjusted, 1970q1 = 100 (authors calculations based on national statistical sources)

Manufacturing output: Aggregate of country-specific indexes of industrial production, manufacturing, seasonally adjusted, 1970q1 = 100 (authors calculations based on national statistical sources)

Consumption: Aggregate of country-specific private final consumption expenditure, volumes in national currency, seasonally adjusted, 1970q1 = 100 (authors calculations based on OECD, Economic Outlook).

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FIGURE 1 - US BASELINE SPECIFICATION

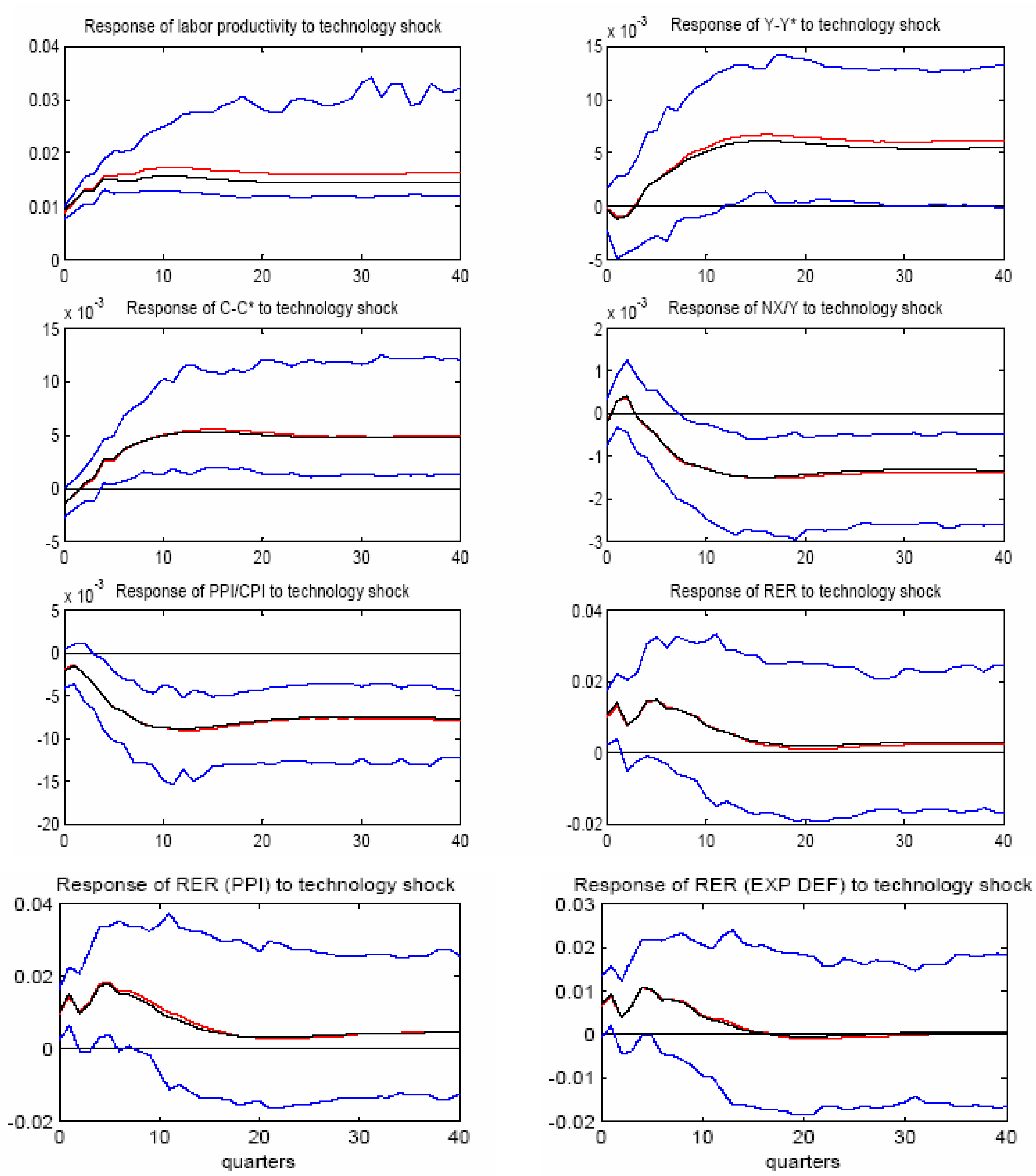


FIGURE 2 - JAPAN BASELINE SPECIFICATION

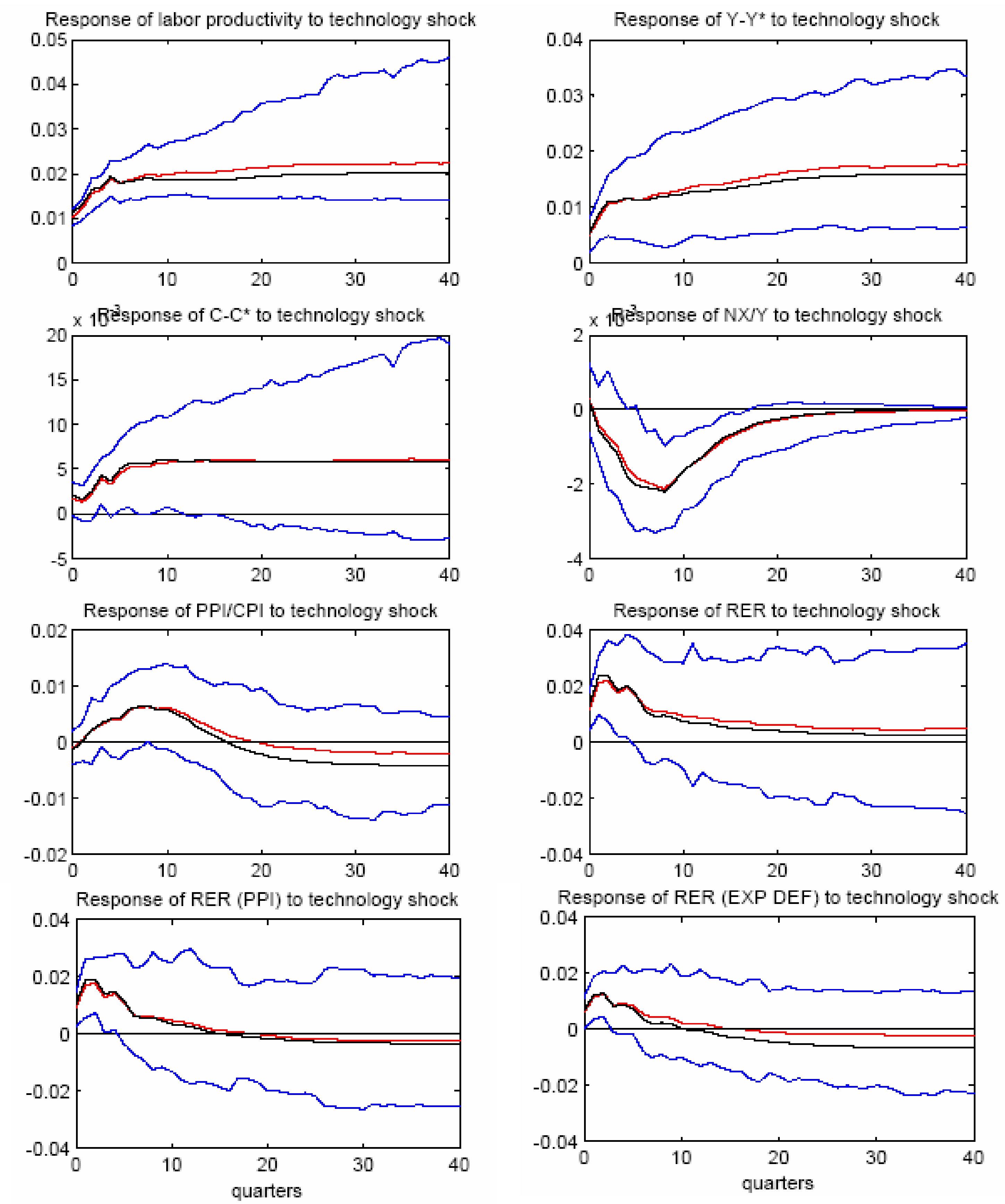


FIGURE 3 - GERMANY BASELINE SPECIFICATION

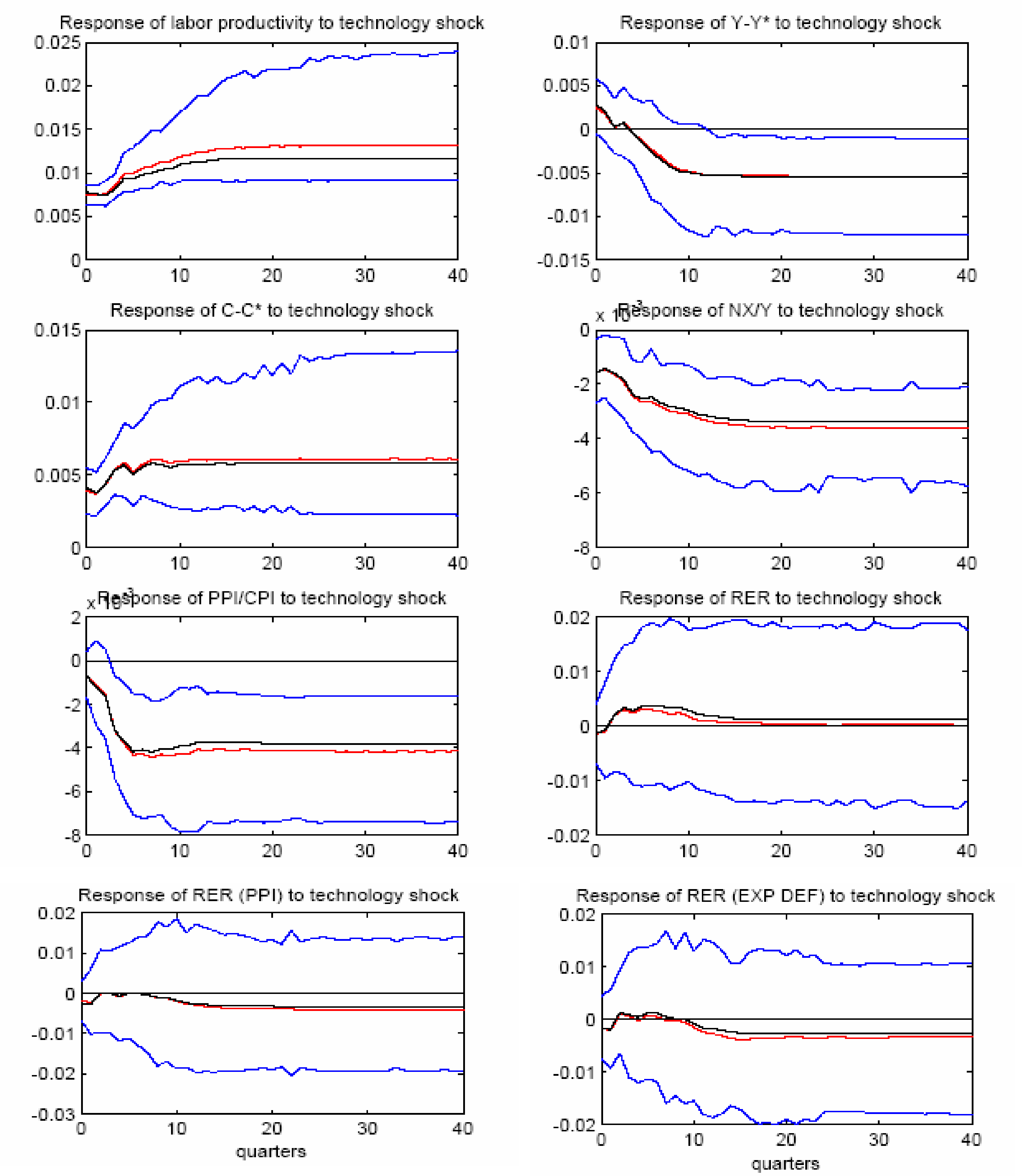


FIGURE 4 - UK BASELINE SPECIFICATION

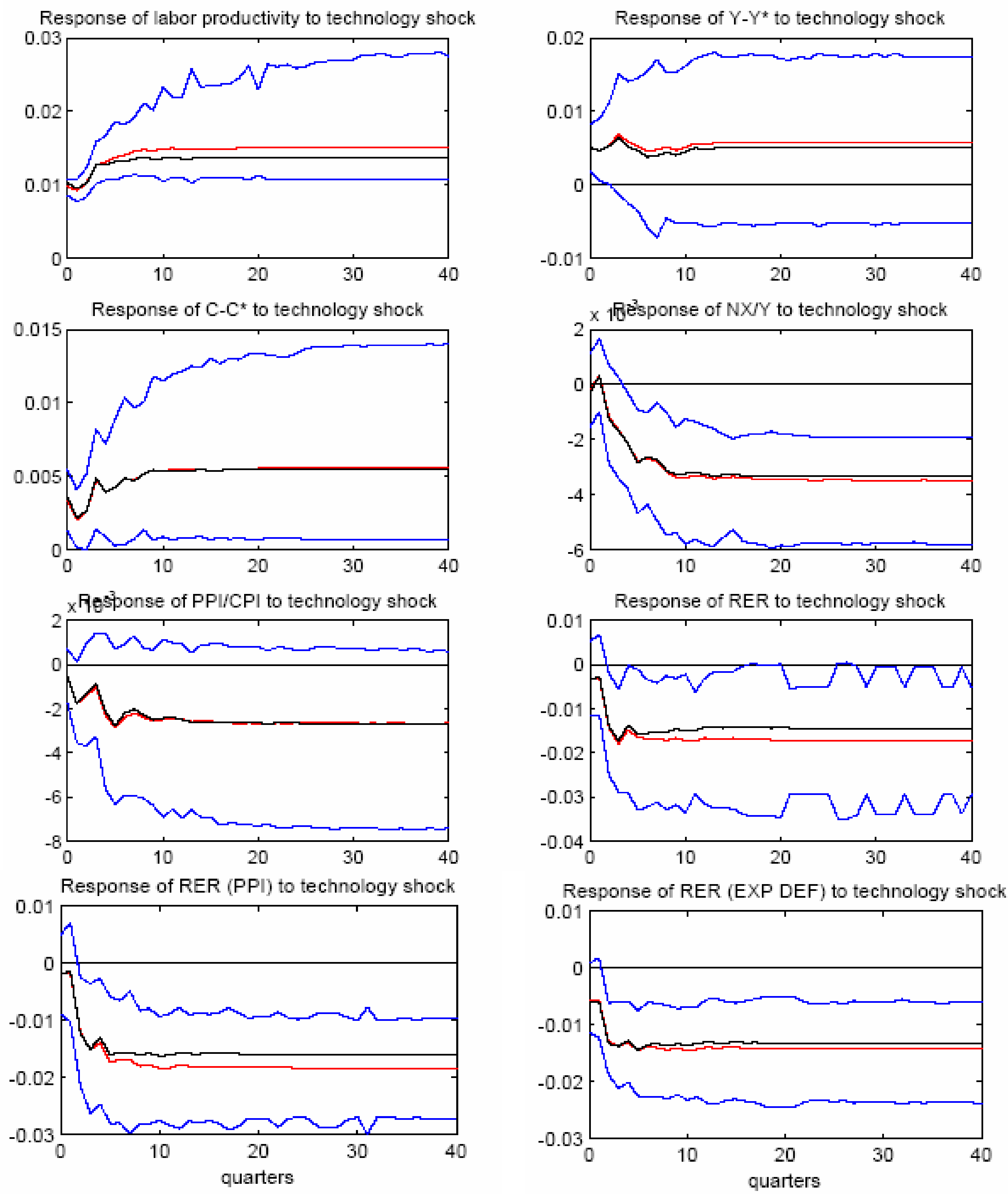


FIGURE 5 - ITALY BASELINE SPECIFICATION

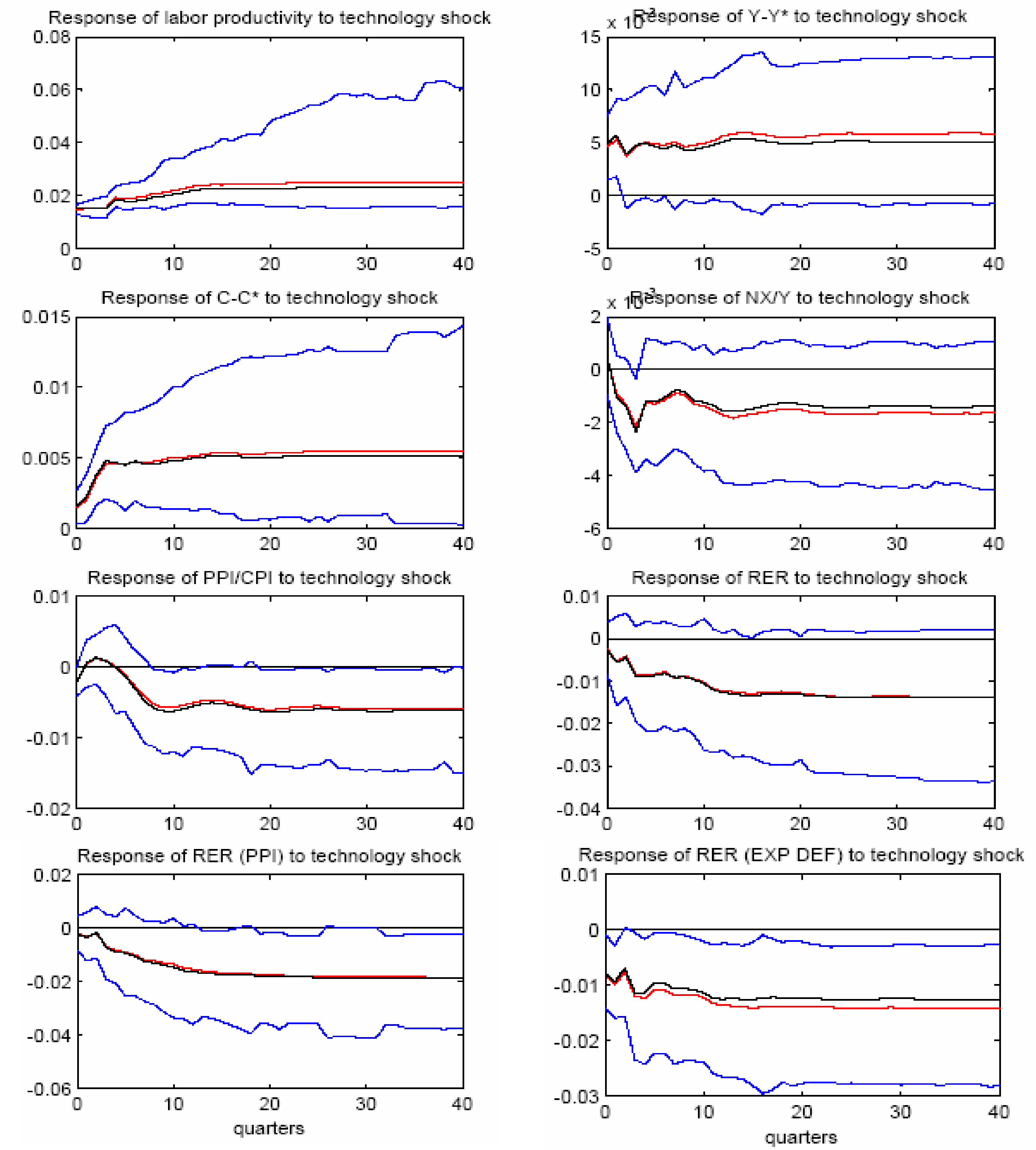


FIGURE 6 - US LEVEL SPECIFICATION

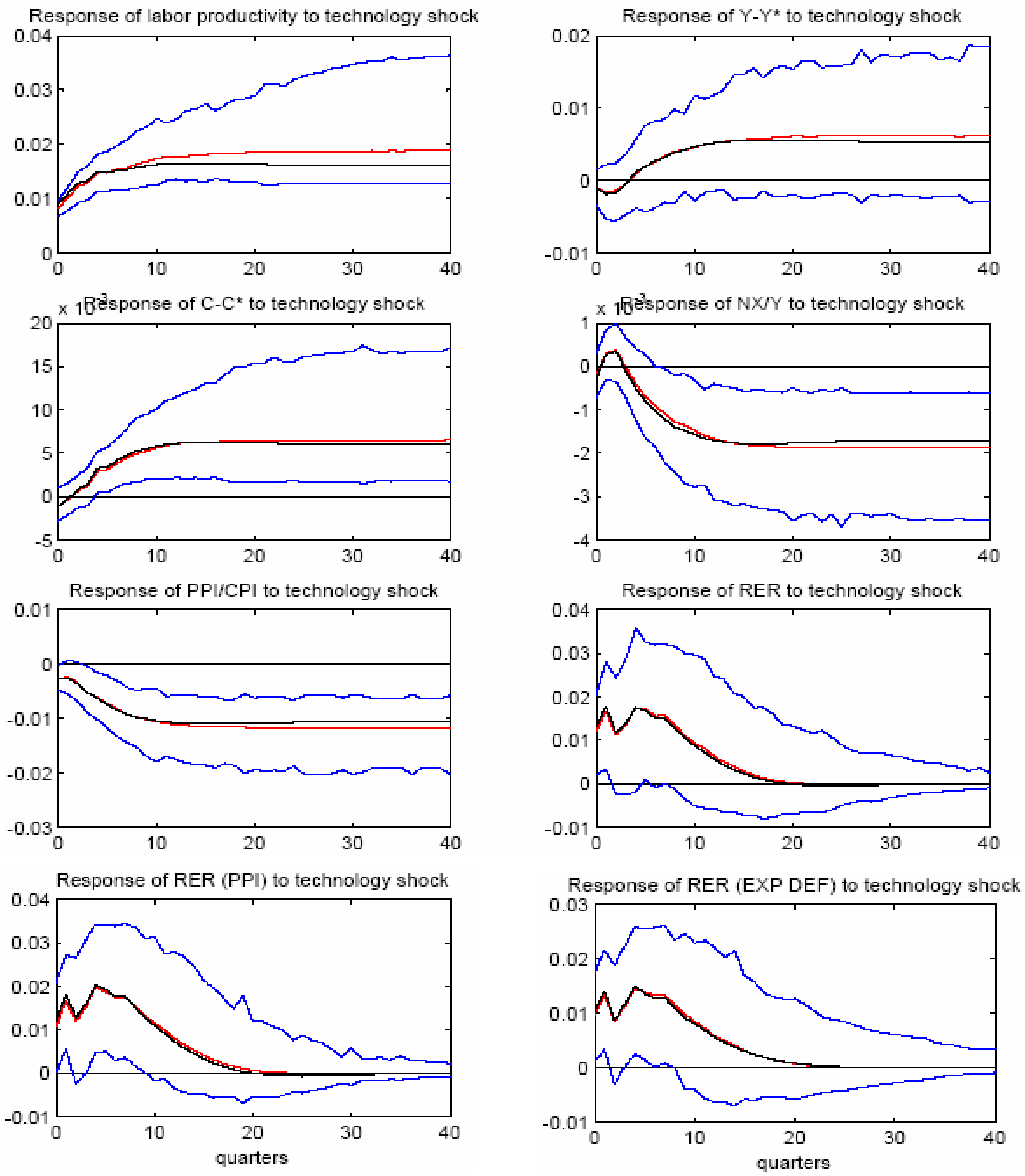


FIGURE 7 - JAPAN LEVEL SPECIFICATION

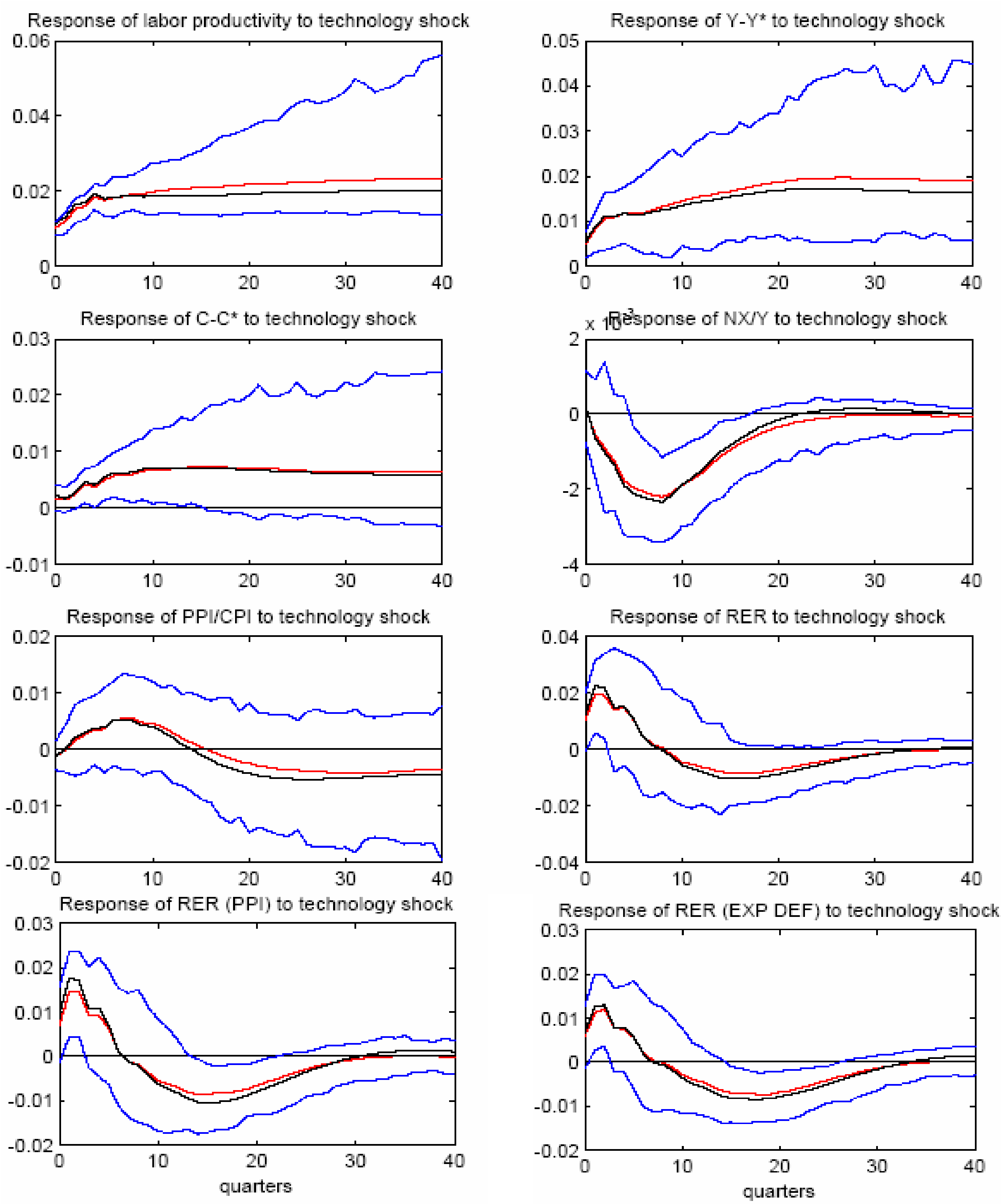


FIGURE 8 - GERMANY LEVEL SPECIFICATION

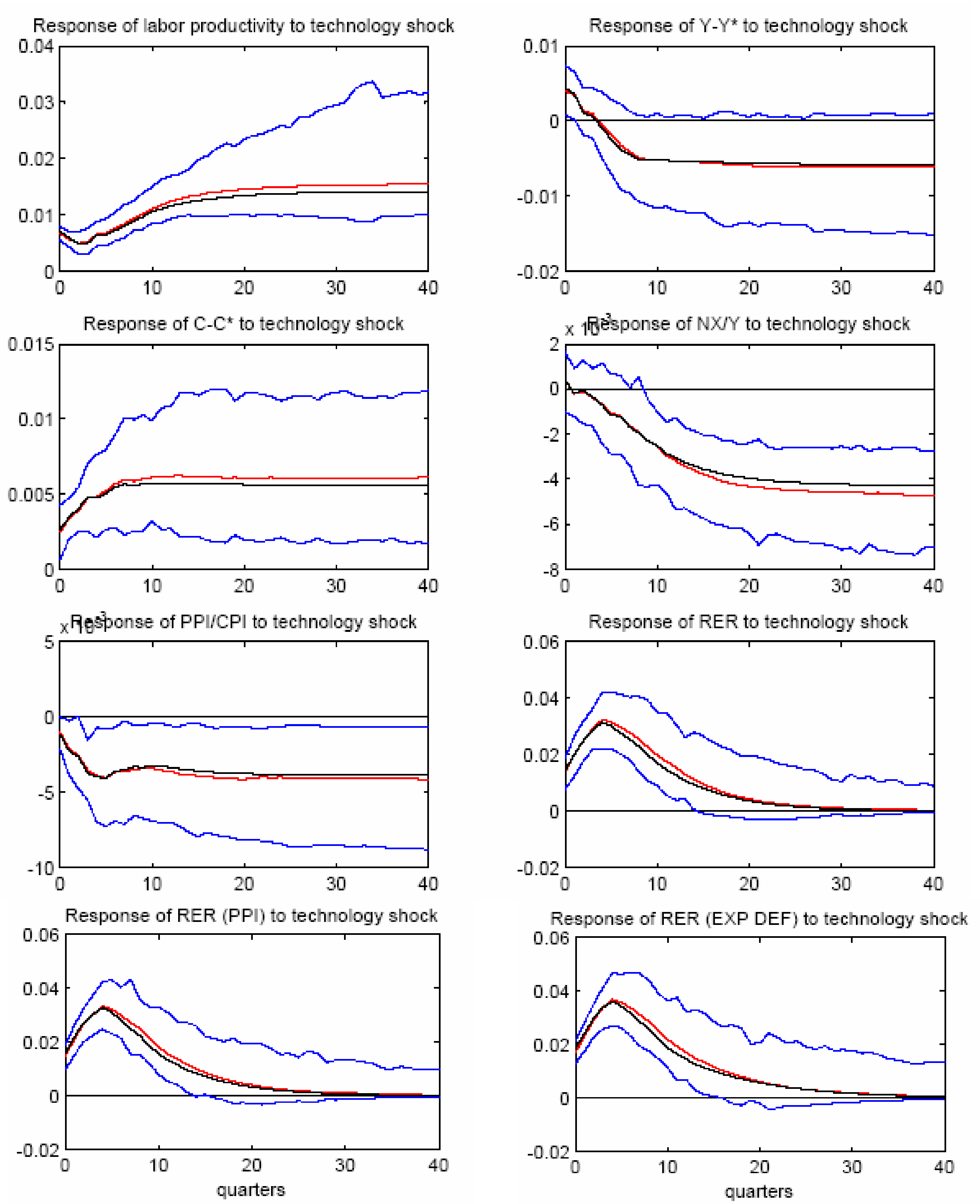


FIGURE 9 - UK LEVEL SPECIFICATION

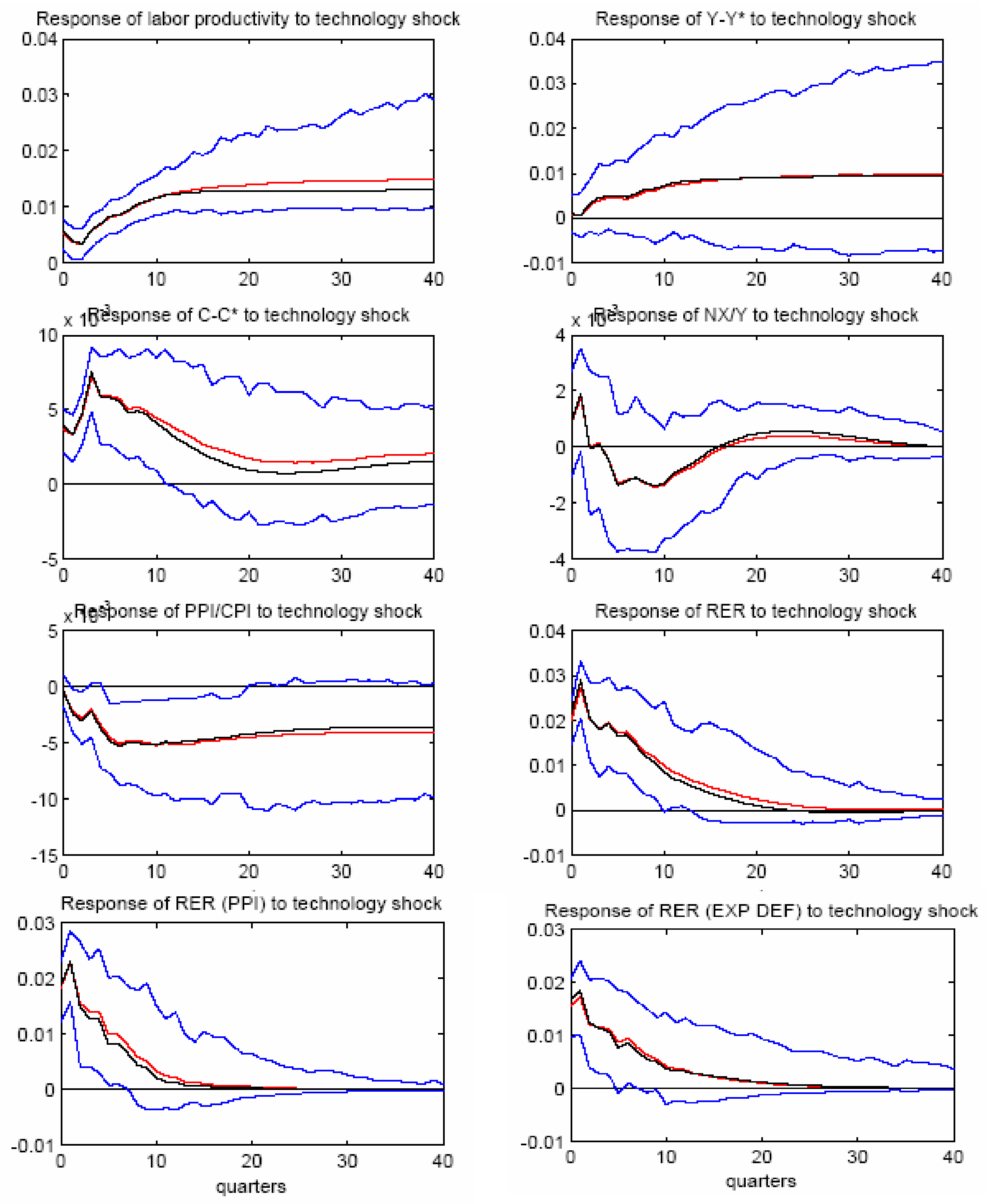


FIGURE 10 - ITALY LEVEL SPECIFICATION

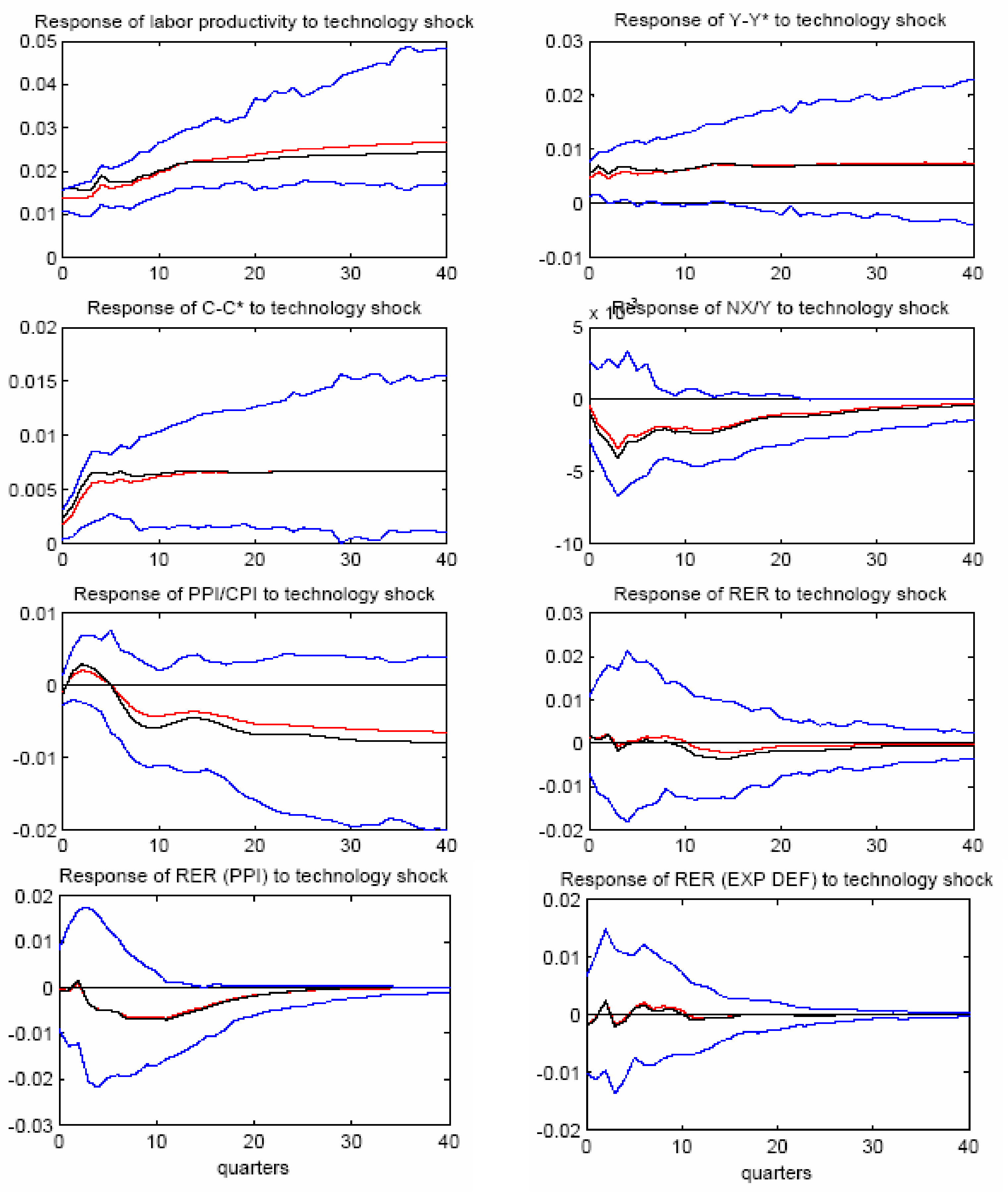
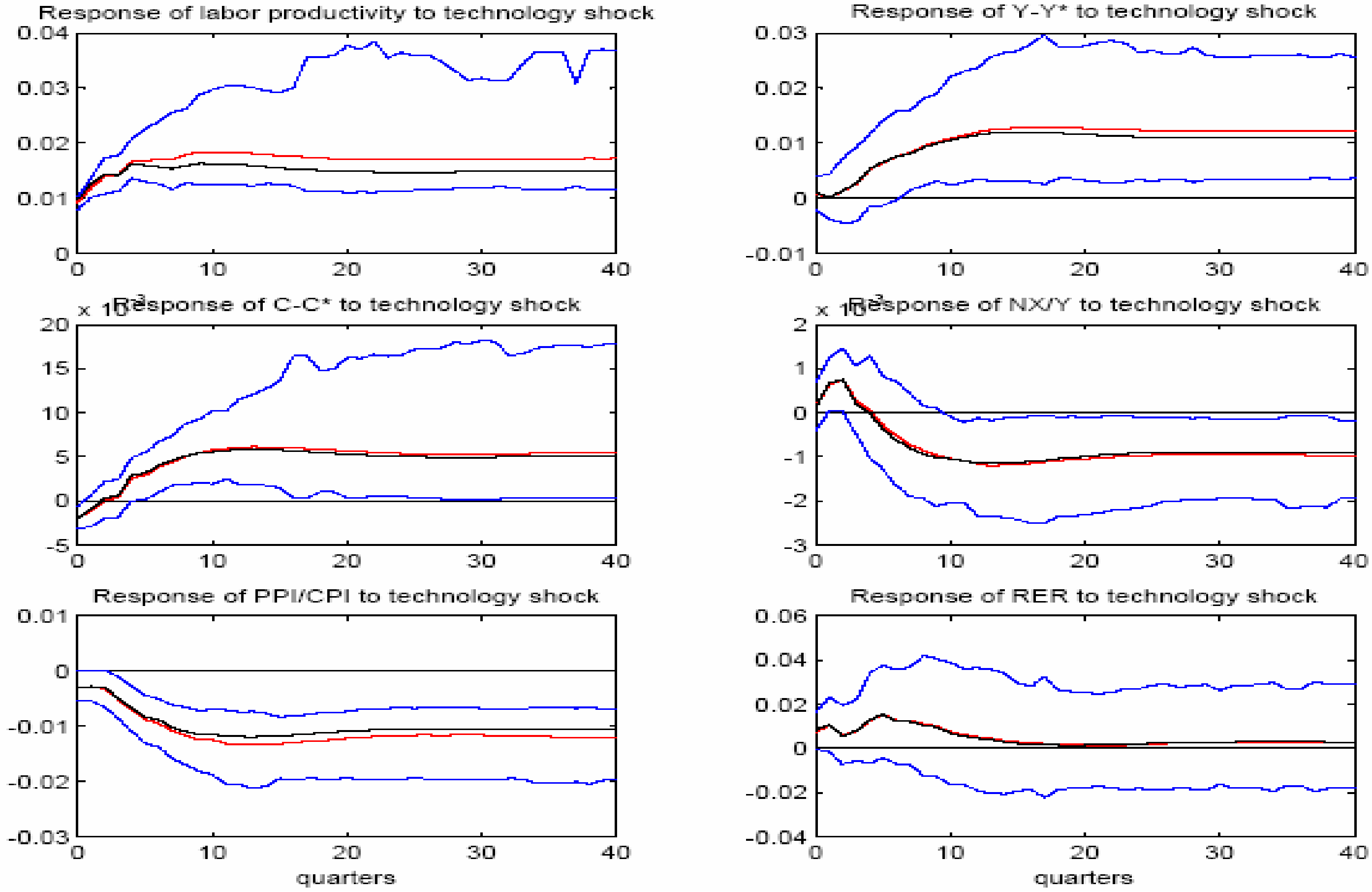


FIGURE 11 - US SUBSAMPLE ANALYSIS

PANEL A - US SUBSAMPLE 1973-1998



PANEL B - US SUBSAMPLE 1979-2004

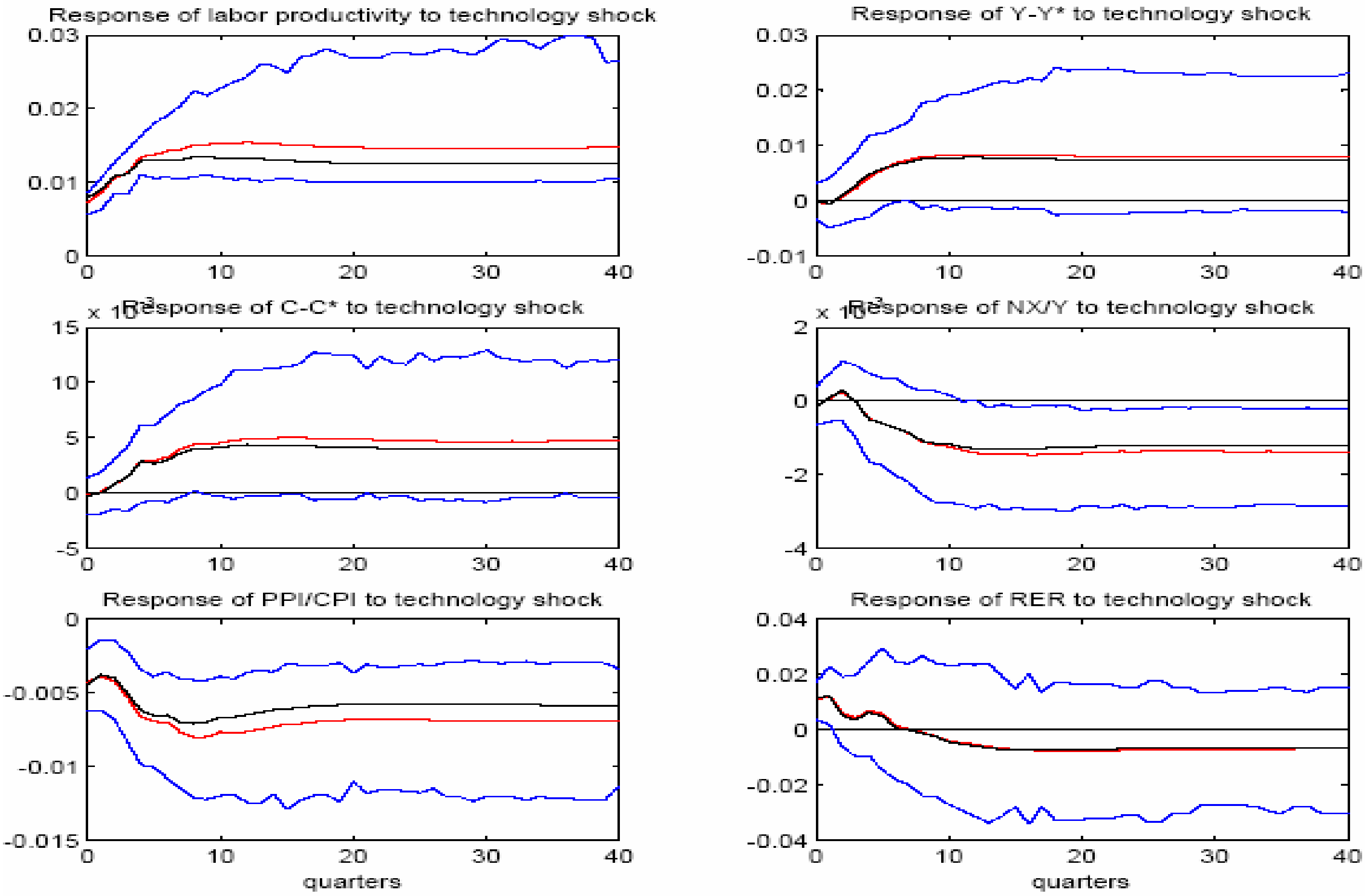


FIGURE A1 - US VAR DATA

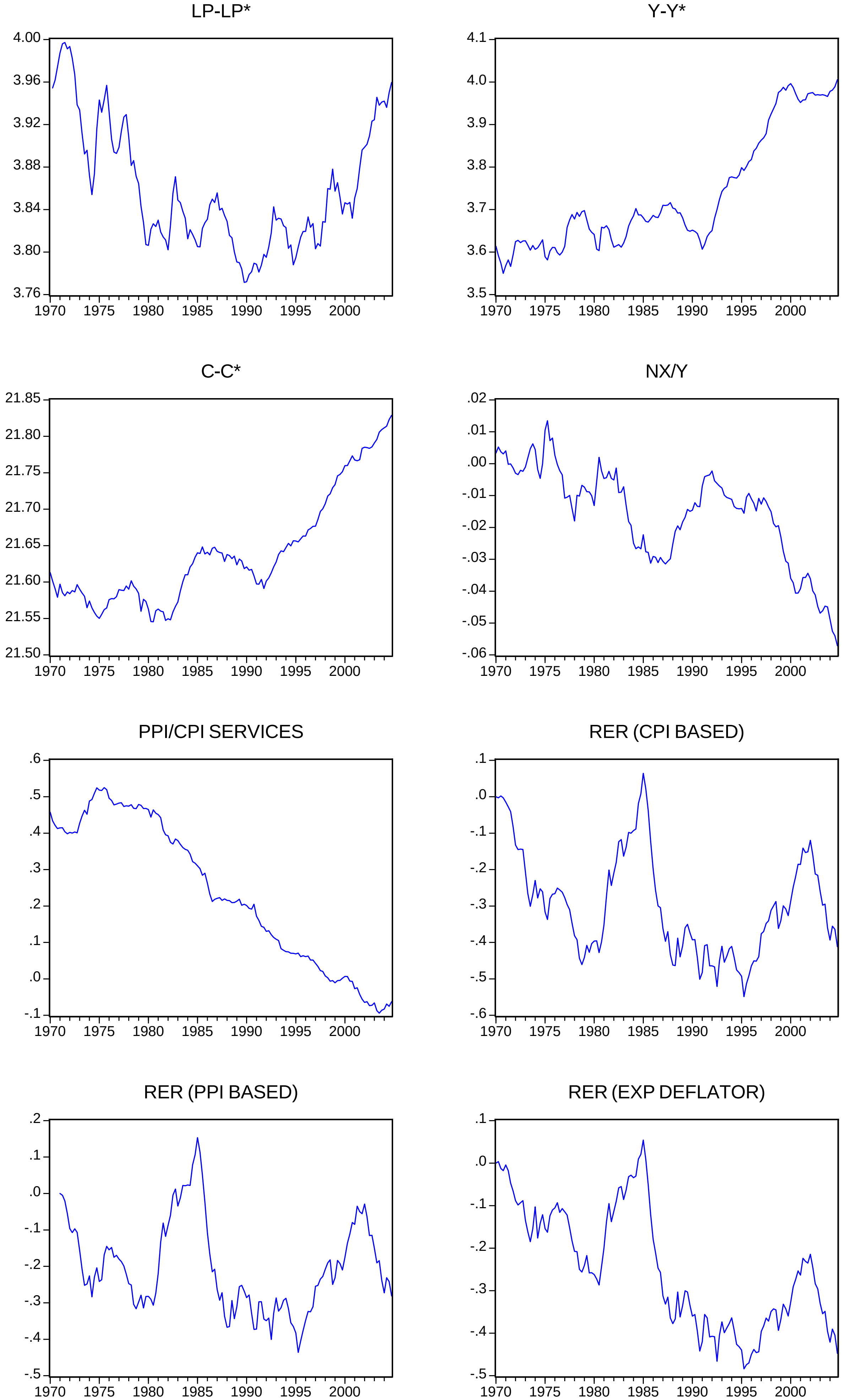


FIGURE A2 - JAPAN VAR DATA

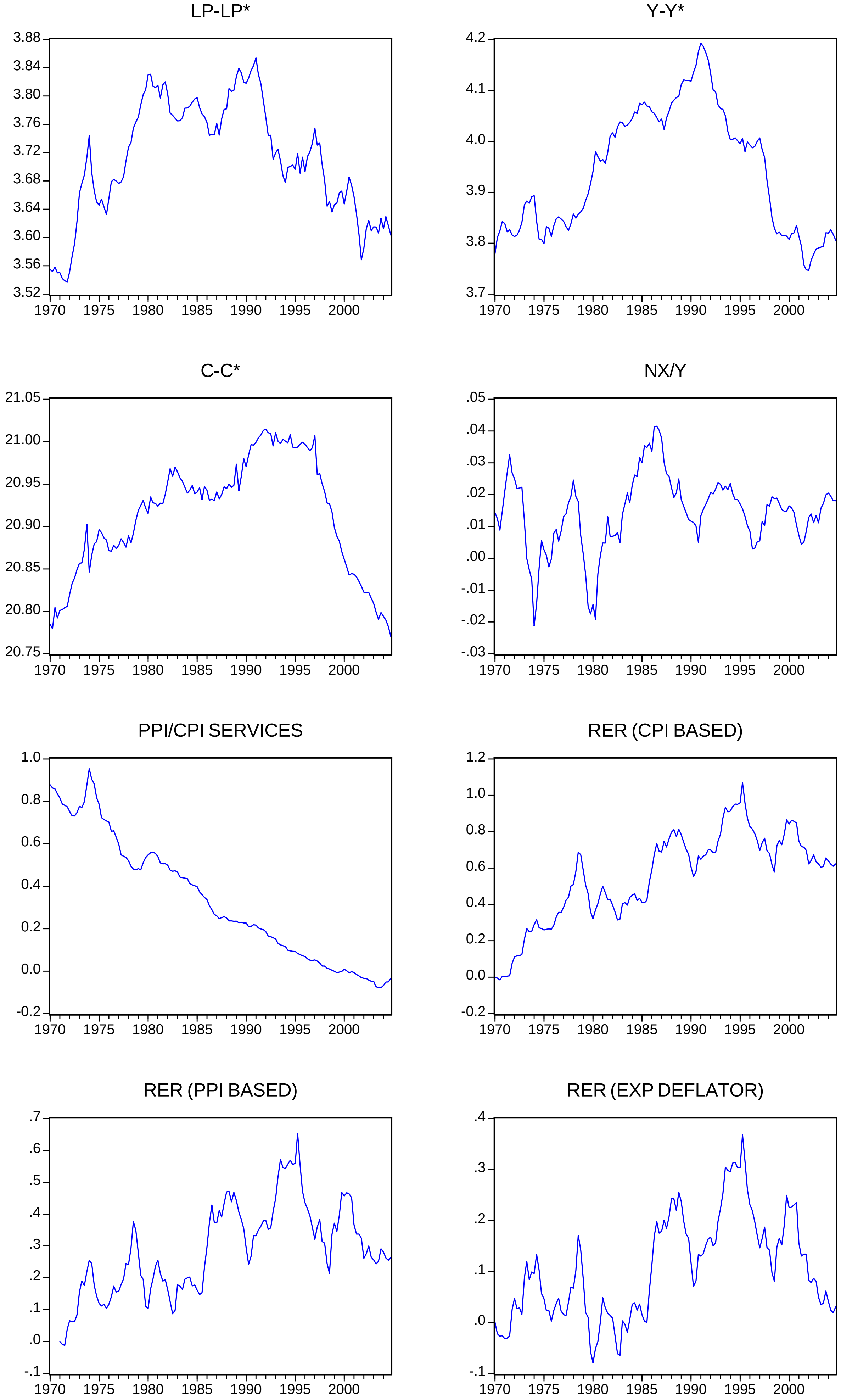


FIGURE A3 - GERMANY VAR DATA

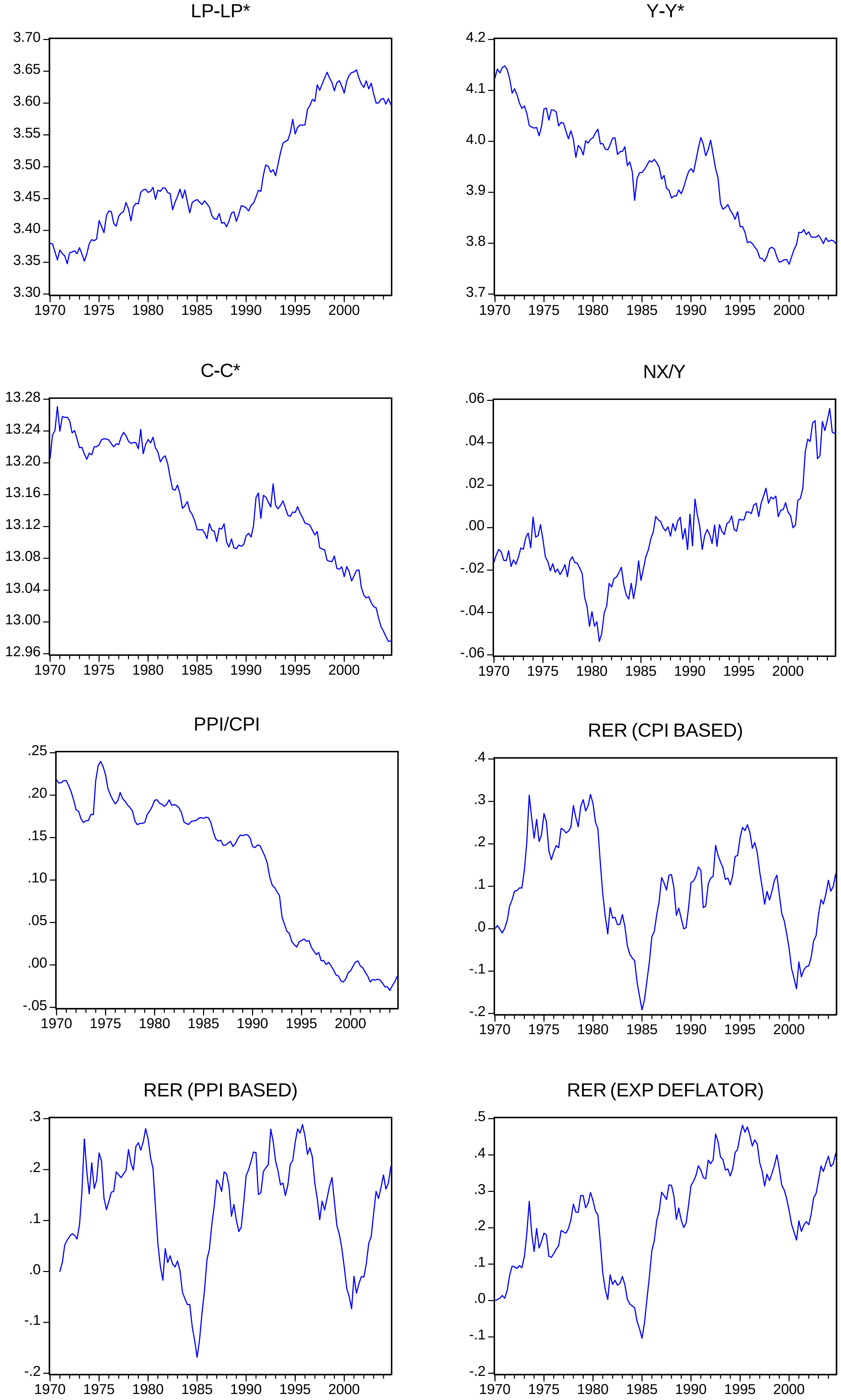


FIGURE A4 - UK VAR DATA

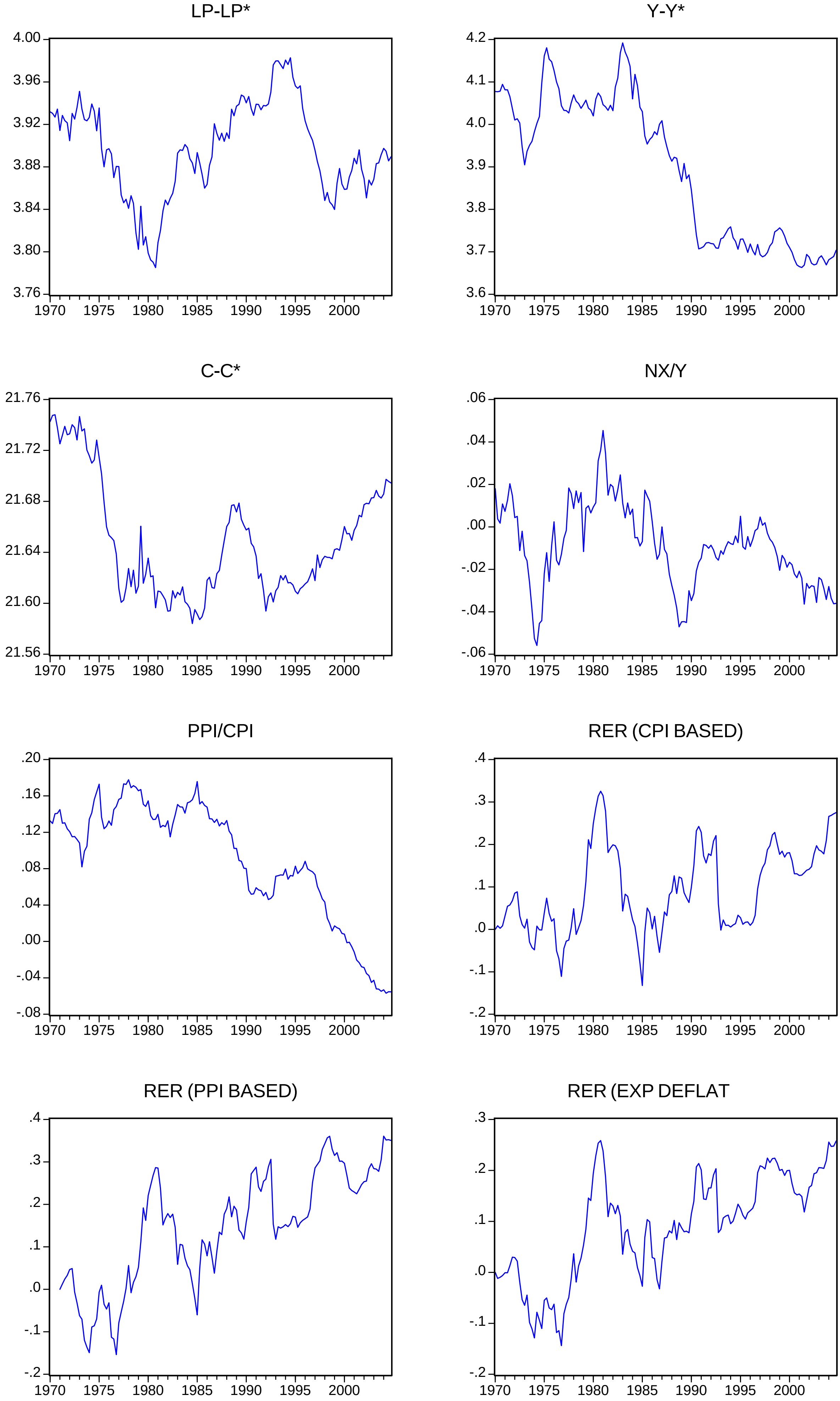


FIGURE A5 - ITALY VAR DATA

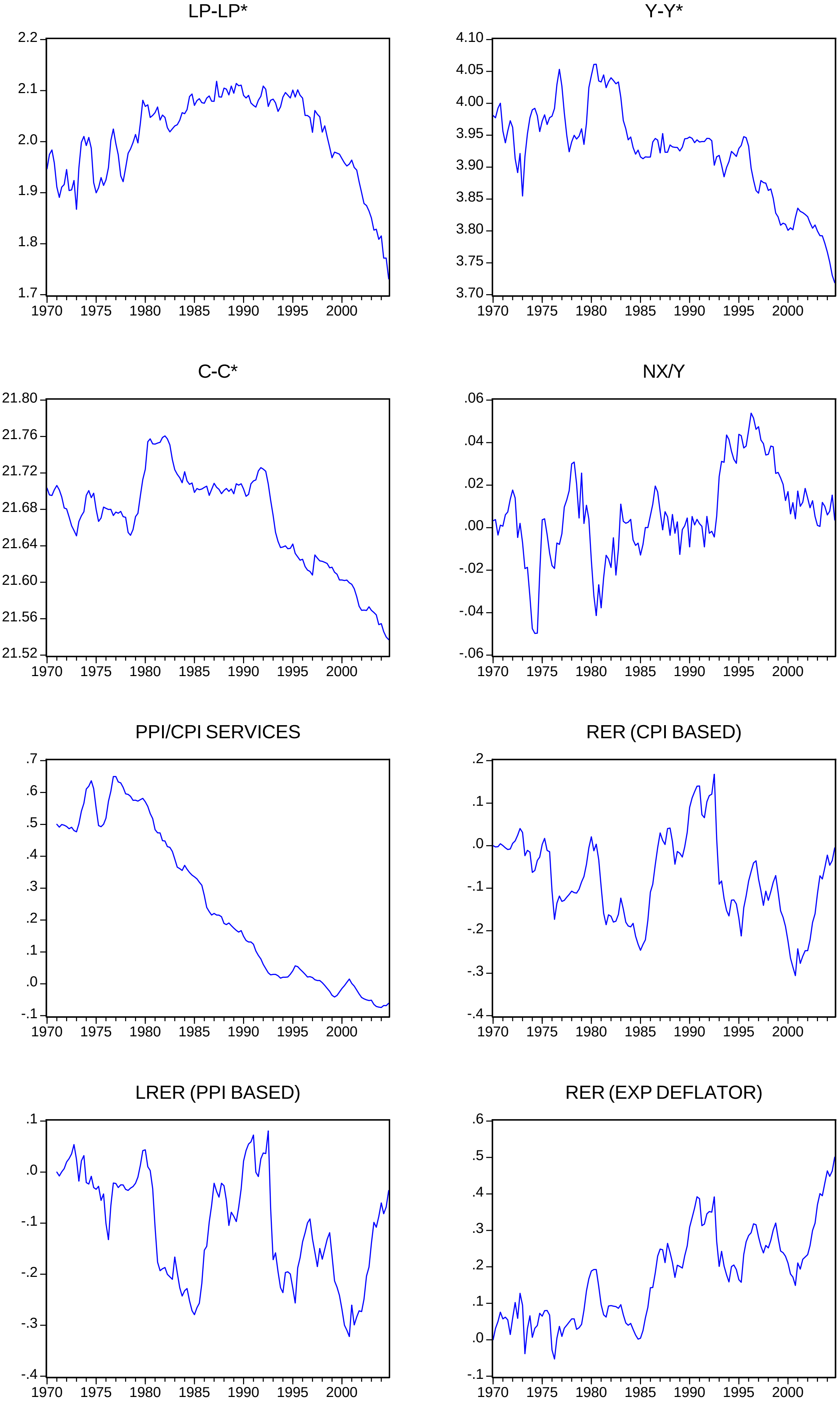


Table A1

Results of unit root tests for USA against ROW

Sample is 1973:1-2004:4

	Test specification for differenced series	PP* test statistic	p-value***	Test specification for level series	DF-GLS** test statistic	p-value***
Labor productivity in manufacturing						
USA	constant	2.7669	1.00	constant, linear trend	0.008538	pvalue>0.1
ROW	constant	-0.7540	0.83	constant, linear trend	-2.280369	pvalue>0.1
Differential	constant	-1.6774	0.44	constant, linear trend	-0.824595	pvalue>0.1
	none	0.0962	0.71	constant	-0.941589	pvalue>0.1
Output differential	constant	0.1959	0.97	constant, linear trend	-1.407352	pvalue>0.1
	none	1.8321	0.98	constant	0.917944	pvalue>0.1
Consumption differential	constant	1.2960	1.00	constant, linear trend	-0.262079	pvalue>0.1
	none	2.0439	0.99	constant	2.798769	pvalue>0.1
Net exports over GDP	none	0.0842	0.73	constant	-0.087946	pvalue>0.0
	constant	1.0842	0.93	constant, linear trend	0.912054	pvalue>0.1
PPI/CPI						
CPI SERVICES	constant	0.674595	0.9912	constant, linear trend	1.064373	pvalue>0.1
Int. relative prices						
RER CPI	none	-0.4388	0.52	constant	-1.356705	pvalue>0.1
	constant	-2.4182	0.14	constant, linear trend	-2.059058	pvalue>0.1
RER PPI	none	-0.8923	0.33	constant	-2.142593	pvalue<0.05
	constant	-2.3484	0.16	constant, linear trend	-2.625866	pvalue>0.1
EXP DEF	none	-0.0055	0.68	constant	-0.327176	pvalue>0.1
	constant	-1.6585	0.45	constant, linear trend	-1.761566	pvalue>0.1

Notes

*Phillips-Perron test with critical values from MacKinnon (1991, 1996)

**Augmented DF test modified according to Elliot et al . (1996); critical values from MacKinnon (1991, 1996)

***A p-value less than 0.1 (0.05) means that the null of a unit root is rejected at the 10 (5) percent confidence level

Table A2

Results of unit root tests for Japan against ROW

Sample is 1973:1-2004:4

	Test specification for difference	PP* test statistic	p-value***	Test specification for level series	DF-GLS** test statistic	p-value***
Labor productivity in manufacturing						
Japan	constant	-1.581681	0.489	constant, linear trend	-1.883897	pvalue>0.1
ROW	constant	1.710243	0.9996	constant, linear trend	-0.860656	pvalue>0.1
Differential	constant	-1.536393	0.5121	constant, linear trend	-0.871536	pvalue>0.1
	none	-0.111406	0.6435	constant	-0.890574	pvalue>0.1
Output differential	constant	-0.979977	0.759	constant, linear trend	-0.792318	pvalue>0.1
	none	-0.1599	0.6266	constant	-0.898556	pvalue>0.1
Consumption differential	constant	0.038817	0.9596	constant, linear trend	0.02179	pvalue>0.1
	none	-0.599213	0.456	constant	-0.544825	pvalue>0.1
Net exports over GDP	none	-1.86411	0.0596	constant	-2.822581	pvalue<0.01
	constant	-2.814488	0.059	constant, linear trend	-3.035634	pvalue<0.05
PPI/CPI						
CPI SERVICES	constant	-1.182787	0.6806	constant, linear trend	1.064373	pvalue>0.1
Int. relative prices						
RER CPI	none	-0.080443	0.654	constant	-0.724922	pvalue>0.1
	constant	-2.445101	0.1316	constant, linear trend	-2.0698	pvalue>0.1
RER PPI	none	-0.659916	0.4295	constant	-1.420449	pvalue>0.1
	constant	-2.506998	0.1162	constant, linear trend	-2.63375	pvalue>0.1
EXP DEF	none	-1.380222	0.155	constant	-1.981002	pvalue<0.05
	constant	-2.217913	0.201	constant, linear trend	-2.431013	pvalue>0.1

Notes

*Phillips-Perron test with critical values from MacKinnon (1991, 1996)

**Augmented DF test modified according to Elliot et al . (1996); critical values from MacKinnon (1991, 1996)

***A p-value less than 0.1 (0.05) means that the null of a unit root is rejected at the 10 (5) percent confidence level

Table A3

Results of unit root tests for Germany against ROW

Sample is 1973:1-2004:4

	Test specification for difference	PP* test statistic	p-value***	Test specification for level series	DF-GLS** test statistic	p-value***
Labor productivity in manufacturing						
Germany	constant	0.174953	0.97	constant, linear trend	-1.532099	pvalue>0.1
ROW	constant	1.003887	0.9965	constant, linear trend	-1.820061	pvalue>0.1
Differential	constant	-1.026498	0.7425	constant, linear trend	-1.547087	pvalue>0.1
	none	2.049603	0.9903	constant	0.512553	pvalue>0.1
Output differential	constant	-1.249848	0.6513	constant, linear trend	-2.377607	pvalue>0.1
	none	-1.420197	0.1444	constant	0.220451	pvalue>0.1
Consumption differential	constant	0.413563	0.9829	constant, linear trend	-1.656287	pvalue>0.1
	none	-2.339206	0.0192	constant	2.151105	pvalue>0.1
Net exports over GDP	none	-0.904337	0.3227	constant	-0.133904	pvalue>0.1
	constant	-0.7614	0.8261	constant, linear trend	-1.623257	pvalue>0.1
PPI/CPI						
CPI Total	constant	-0.078896	0.9484	constant, linear trend	-1.659919	pvalue>0.1
Int. relative prices						
RER CPI	none	-1.624913	0.0981	constant	-2.191148	pvalue<0.05
	constant	-2.168403	0.2189	constant, linear trend	-2.272668	pvalue>0.1
RER PPI	none	-1.301696	0.1775	constant	-2.191301	pvalue<0.05
	constant	-2.433337	0.1347	constant, linear trend	-2.346221	pvalue>0.1
EXP DEF	none	-0.350547	0.5569	constant	-1.094891	pvalue>0.1
	constant	-1.884669	0.3386	constant, linear trend	-2.223682	pvalue>0.1

Notes

*Phillips-Perron test with critical values from MacKinnon (1991, 1996)

**Augmented DF test modified according to Elliot et al . (1996); critical values from MacKinnon (1991, 1996)

***A p-value less than 0.1 (0.05) means that the null of a unit root is rejected at the 10 (5) percent confidence level

Table A4

Results of unit root tests for UK against ROW

Sample is 1973:1-2004:4

	Test specification for differenced series	PP* test statistic	p-value***	Test specification for level series	DF-GLS** test statistic	p-value***
Labor productivity in manufacturing						
UK	constant	0.630927	0.9901	constant, linear trend	-1.485368	pvalue>0.1
ROW	constant	0.762981	0.9931	constant, linear trend	-2.917834	pvalue<0.1
Differential	constant	-1.814605	0.3721	constant, linear trend	-1.521984	pvalue>0.1
	none	-0.334428	0.563	constant	-1.30747	pvalue>0.1
Output differential	constant	-0.763321	0.8256	constant, linear trend	-2.032963	pvalue>0.1
	none	-0.746914	0.3911	constant	-0.489868	pvalue>0.1
Consumption differential	constant	-2.1273	0.2344	constant, linear trend	-0.927952	pvalue>0.1
	none	-0.298068	0.5766	constant	-0.873383	pvalue>0.1
Net exports over GDP	none	-1.883786	0.0571	constant	-2.182391	pvalue<0.05
	constant	-2.300727	0.1734	constant, linear trend	-2.567268	pvalue>0.10
PPI/CPI						
CPI Total	constant	0.452297	0.9844	constant, linear trend	1.020843	pvalue>0.1
Int. relative prices						
RER CPI	none	-1.171089	0.2197	constant	-2.101924	pvalue<0.05
	constant	-2.206316	0.2051	constant, linear trend	-2.897819	pvalue<0.10
RER PPI	none	-0.291671	0.579	constant	-0.501317	pvalue>0.1
	constant	-1.496524	0.5323	constant, linear trend	-2.68954	pvalue>0.1
EXP DEF	none	-0.668291	0.4258	constant	-0.596741	pvalue>0.1
	constant	-1.742741	0.4074	constant, linear trend	-2.622335	pvalue>0.1

Notes

*Phillips-Perron test with critical values from MacKinnon (1991, 1996)

**Augmented DF test modified according to Elliot et al . (1996); critical values from MacKinnon (1991, 1996)

***A p-value less than 0.1 (0.05) means that the null of a unit root is rejected at the 10 (5) percent confidence level

Table A4

Results of unit root tests for Italy against ROW

Sample is 1973:1-2004:4

	Test specification for differenced series	PP* test statistic	p-value***	Test specification for level series	DF-GLS** test statistic	p-value***
Labor productivity in manufacturing						
Italy	constant	-2.204301	0.2059	constant, linear trend	-0.883729	pvalue>0.1
ROW	constant	1.594922	0.9995	constant, linear trend	-1.013203	pvalue>0.1
Differential	constant	0.395478	0.9821	constant, linear trend	-0.03336	pvalue>0.1
	none	-0.761495	0.3846	constant	-0.25524	pvalue>0.1
Output differential	constant	-0.181216	0.9367	constant, linear trend	-1.328729	pvalue>0.1
	none	-0.93902	0.3082	constant	-0.677483	pvalue>0.1
Consumption differential	constant	0.036218	0.9594	constant, linear trend	-1.038549	pvalue>0.1
	none	-0.922371	0.3151	constant	-0.151934	pvalue>0.1
Net exports over GDP	none	-2.455012	0.0142	constant	-2.486968	pvalue<0.05
	constant	-2.575099	0.1008	constant, linear trend	-2.844862	pvalue<0.10
PPI/CPI						
CPI SERVICES	constant	-0.288019	0.9224	constant, linear trend	-2.10485	pvalue>0.1
Int. relative prices						
RER CPI	none	-1.911597	0.0537	constant	-2.132607	pvalue<0.05
	constant	-2.61669	0.0922	constant, linear trend	-2.548289	pvalue>0.10
RER PPI	none	-1.574812	0.1082	constant	-1.68943	pvalue<0.1
	constant	-2.56929	0.1021	constant, linear trend	-2.378501	pvalue>0.1
EXP DEF	none	0.233667	0.7525	constant	-0.361994	pvalue>0.1
	constant	-0.893053	0.7878	constant, linear trend	-3.129265	pvalue<0.05

Notes

*Phillips-Perron test with critical values from MacKinnon (1991, 1996)

**Augmented DF test modified according to Elliot et al . (1996); critical values from MacKinnon (1991, 1996)

***A p-value less than 0.1 (0.05) means that the null of a unit root is rejected at the 10 (5) percent confidence level