Comovement in GDP Trends and Cycles
Among Trading Partners[☆]

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Abstract

It has long been recognized that business cycle comovement is greater between countries that trade more intensively with one another. Surprisingly, no one has previously examined the relationship between trade intensity and comovement of shocks to the trend level of output. Contrary to the result for cyclical fluctuations, we find that comovement of shocks to trend levels of real GDP is significantly weaker among countries that trade more intensively with one another. We also find that this relationship has remained stable, or become stronger in recent decades, while the role of trade in generating cyclical comovement has diminished over time. By examining the impact of trade linkages on both cyclical and trend comovement, we can quantify the effect of trade on overall output growth comovement between countries. We simulate changes in ten-year output growth correlations corresponding to the estimated effects of trade and find that the impact on trend comovement is quantitatively more important than its effect on cyclical comovement.

Keywords: Output Comovement, International Business Cycles, Trade Linkages
JEL Classification: F42, C22, E32

1. Introduction

It has long been recognized that business cycle comovement is greater between countries that trade more with one another. Frankel and Rose (1998) first demonstrated stronger correlations between business cycle fluctuations in real GDP for trading partners. A large ensuing literature has demonstrated that this result is robust to the inclusion of a battery of additional explanatory variables, country-pair effects, and is also present for intra-industry and infra-national trade.[1]

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[1]See for example Baxter and Kouparitsas (2005), Burstein et al. (2008), Levchenko and di Giovanni (2010), and Clark and van Wincoop (2001).

Unlike the empirical relationship, the theoretical relationship between output comovement and trade is ambiguous. A positive shock in one country can generate increased demand for foreign goods, so that the foreign country also experiences an increase in output (i.e., the demand channel). On the other hand, the positive shock in one country may cause production and investment to be reallocated away from foreign suppliers, so that foreign production relatively declines (i.e., supply channels). In particular, if trade and production are concentrated in differentiated goods sectors with increasing returns to scale, then the well-known home market effect predicts that a positive shock to GDP at home will cause suppliers to disproportionately locate or invest in the domestic market, and will lead to fewer purchases of differentiated goods from the - now relatively smaller - foreign market. This reallocation of suppliers, which is larger among close trading partners, generates negative comovement, offsetting the positive comovement from the demand channel. For business cycle fluctuations, the evidence to date suggests that the demand channel dominates such that greater trade intensity leads to greater positive comovement.

Surprisingly, no one has previously examined the relationship between trade intensity and comovement of shocks to countries' trend levels of output. This omission is important, as changes in GDP trends are potentially driven by different types of shocks than are business cycle fluctuations. The propagation of these shocks across national borders, and the relationship of this propagation to trade linkages, may also differ. The effect of trade linkages on the long-run distribution of suppliers across countries and sectors (the supply channels) may be more important when explaining cross-country correlations in shocks to GDP trends. Thus, the sole focus of the existing literature on business cycle fluctuations may give an incomplete picture of the relationship between trade intensity and the comovement of output across countries.

Beyond the implications for the relevance of demand or supply mechanisms for the transmission of shocks across countries, our focus on trend comovement is also important in that shocks to the trend account for a quantitatively important source of output fluctuations. In particular, the evidence shows that for the majority of countries in our sample, shocks to the trend account for over half the variance of quarterly real GDP growth. This suggests that the effect of trade on trend shock comovement will substantially pass through to comovement of short-horizon output growth

for many country pairs. Also, as shocks to the trend have permanent effects on the level of output, while cyclical fluctuations are transitory, trend shocks will be the dominant source of comovement in long-horizon output growth. Thus, we can expect the effect of trade on correlations in long-horizon output growth to work principally through its effects on trend comovement. Finally, the extent of comovement in GDP trends is substantial, with the median absolute correlation between trend shocks equal to 0.3 over our sample period.[2] Thus, the capacity of trade to decouple trend fluctuations across countries is of important policy relevance.

Contrary to the standard result for cyclical fluctuations, we find that the correlation between shocks to GDP trends is significantly *weaker* among G7 countries that trade more intensively with one another, suggesting a dominance of supply channels for trend comovement.[3] The negative association between trade and trend comovement is quantitatively important. A one-standard deviation increase in trade intensity between countries reduces the correlation in shocks to their output trend by approximately one-third of a standard deviation. We also find that the influence of international trade on comovement in shocks to the trend has remained stable, or become stronger in recent decades, while the role of trade in generating cyclical comovement has diminished over time. Having estimated the effect of trade on comovement in both cyclical fluctuations and trend shocks, we then perform a simulation experiment to quantify the relative importance of each effect on overall output growth. We find the negative effect of trade on trend comovement in quantitatively more important in explaining ten-year output growth correlations.

In contrast to the results for G7 countries, we find no relationship between trade and trend comovement for countries outside the G7. We argue that the key economic characteristic of G7 nations that drives the negative impact of trade on trend comovement is their relative concentrations of production and trade in differentiated sectors. The shares of total production and total exports that are in differentiated goods sectors among G7 nations are approximately 67% and 85%, re-

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[2]Trend shock correlations are also persistently large over each decade in our sample. By contrast, Doyle and Faust (2005) demonstrate that comovement in cyclical output fluctuations among G7 nations has become weaker in recent decades.

[3]As with cyclical comovement, the average correlation in trend fluctuations across all country-pairs is positive, with very few country-pairs experiencing negative correlations across the entire sample. Thus the negative impact of trade on the correlation between GDP trend fluctuations indicates a movement in correlations toward zero, or weaker comovement, on average.

spectively. Outside the G7 the concentration of economic activity in differentiated sectors is much lower, with non-G7 nations producing 57% of total output and selling 71% of total exports in differentiated sectors. When countries trade differentiated goods produced with increasing returns to scale, Krugman (1980, 1989) argues that the relatively larger country will attract a greater investment by suppliers, who wish to exploit greater scale economies. Moreover, this home market effect predicts that relatively larger countries will be net exporters in differentiated sectors, with little terms of trade effects that might lead to increased demand for foreign goods.[4] A positive GDP shock in one country increases its size relative to its trading partners, and a permanent shock to the trend is likely to induce firms to reconsider the location of production and investment. Hence, it is in countries that are concentrated in differentiated sectors, like the G7, where we should expect trade opportunities to open the supply channel, and reduce trend comovement across borders.[5]

The specifics of our data and estimation methodology are as follows. We gather quarterly real GDP and bilateral trade flow data for 21 developed countries for the years 1980 to 2010 from the IMF's *International Financial Statistics* and *Direction of Trade Statistics*. The set of countries in our data set is similar to that used in previous comovement studies, so that differences in results for trends and cycles cannot be attributed to selection.[6] To obtain a measure of the trend and business cycle component of real GDP we use an unobserved-components model, which has been used extensively as a tool for trend and business cycle measurement.[7] The unobserved-components

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[4]Corsetti et al. (2007) model the transmission of productivity shocks and terms of trade effects when firms can make investments in the production of differentiated varieties. They provide evidence confirming that a positive growth shock does not lead to a depreciation of its terms of trade when countries also engage in R&D investments in the production of new varieties, mitigating the role of trade in transmitting shocks abroad via greater demand. In fact, they show that positive growth shocks within countries are associated with a stronger terms of trade when there is coincident investment in new products, consistent with the potential for international trade opportunities to weaken comovement in GDP trends.

[5] Our finding that the effect of trade on trend comovement is relatively more important for G7 country pairs is also consistent with the standard results for cyclical comovement in Kose et al. (2003) and Kose et al. (2008).

[6]Our sample produces the same stylized fact that trade exhibits a positive effect on cyclical comovement as found in previous studies.

[7]Examples of macroeconomic detrending using the unobserved-components framework include Harvey (1985), Watson (1986), Clark (1987), Harvey and Jaeger (1993), Kuttner (1994), Kim and Nelson (1999), Kim and Piger (2002) and Sinclair (2009). Also, as shown in Morley et al. (2003), the unobserved-components decomposition is consistent with the identification of trend and cyclical components used in the Beveridge and Nelson (1981) decomposition. For a recent example of measurement of macroeconomic trends using the Beveridge-Nelson decomposition, see Cogley and Sargent (2005).

model identifies trend versus business cycle fluctuations by assuming the trend represents the accumulation of the permanent effects of shocks to the level of real GDP, which is equivalent to the stochastic trend in real GDP. The business cycle component is the deviation of real GDP from this stochastic trend, and represents transitory fluctuations in the series. A key advantage of the unobserved-components approach for our purposes is its explicit characterization of both trend and cyclical components, each of which is needed for our empirical analysis. Other popular approaches for measuring business cycle variation, such as the band-pass filter of Baxter and King (1999) or first differencing, do not provide an explicit definition or measure of the trend component.

Our key dependent variable is the correlation between changes in the trend component of quarterly real GDP for each country pair. Bilateral trade intensity is measured as the total real valued trade flows between countries, divided by the sum of their real GDP levels. Both variables are measured for each country pair separately for each of the three decades in our sample, yielding a panel data set. We take several steps to ensure that the comovement patterns we describe are due to international trade relationships, and not other underlying factors. To avoid issues associated with potential trends in trade volumes between country-pairs over time, we control for decade fixed effects when estimating the effects of trade intensity. Country pairs may differ in their exposure to common shocks, as well as their incentives to trade with one another. Thus, we further include country-pair fixed effects when estimating the relationship between trade intensity and comovement. The substantial literature on cyclical comovement suggests other factors, such as patterns of industry specialization or membership in a currency union, that may contribute to comovement in output levels. Our empirical strategy incorporates these alternative channels which could potentially mitigate the consequences of international trade.[8] The main result regarding weaker trend comovement among trading partners is robust to the inclusion of these other potential determinants

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[8] Imbs (2004) and Imbs and Wacziarg (2003) argue that specialization patterns in output across countries independently affect comovement patterns. Baxter and Kouparitsas (2005) evaluate the robustness of other country-pair specific features in generating cyclical comovement and find strong support for the inclusion gravity variables (e.g., geography), which partially determine trade flows. Our use of country-pair fixed effects subsumes these gravity variables. There is also evidence that investment linkages impact comovement; see Prasad et al. (2007). Blonigen and Piger (2011) demonstrate that the best predictors of foreign direct investment patterns between countries are those suggested by gravity models. Thus our fixed-effects strategies also captures the motives for nations to invest in one another.

of comovement patterns.

The next section discusses some motivation for our empirical analysis from theory. Section 3 describes our methodology for estimating trend and cyclical fluctuations for the GDP series of each country, the calculation of comovement across country-pairs, and the details of our empirical specification linking comovement to trade intensity. Section 4 presents the results for the effects of trade on comovement patterns. The final section concludes.

2. Theoretical Motivation

Unlike the relationship between business cycle comovement and trade, there has been little attention to theories of why or how trade may affect the comovement of shocks to countries' GDP trends. In this section we outline a theoretical framework to motivate a link between output shocks, trade, and the reallocation of suppliers across countries. This framework suggests that increased trade intensity has a negative effect on the correlation between the output shocks of the trading countries. Further, we will argue that since the channel through which this effect operates involves costly location and investment decisions by firms, it is more likely to be relevant for permanent (trend) shocks to output.

An aspect that is commonly omitted from theories linking GDP comovement across countries is production and trade in differentiated sectors with technologies that exhibit increasing returns to scale. The canonical model of international business cycles in Backus et al. (1992) assumes that production of homogeneous goods occurs with constant returns to scale. Recent analyses in Burstein et al. (2008) and Johnson (2012) have incorporated the role of production and trade of differentiated inputs, but impose an Armington assumption such that inputs differ only by country origin, which ignores changes to investments in new products within countries that receive output shocks. The presence of scale economies in the production of differentiated goods, and the propensity to invest at the extensive margin, can each have a substantial impact on how shocks - to both the trend and cycle - are transmitted across trading partners.

While full international real business cycle model with differentiated goods and increasing returns to scale is beyond the scope of this paper, we can draw on previous (static) analyses of trade

and production for potential insights. Since we are interested in shocks to trend levels of output, the insights from models that focus on long-run outcomes may be more relevant. Krugman (1980) demonstrated that an increase in the size of one economy relative to its trading partners will cause it to attract relatively more suppliers of differentiated goods, who wish to better capture increasing returns to scale in the larger market. This is the well-known home market effect. Moreover, a positive shock in one country will cause it to become a net exporter of differentiated goods, rather than simply increasing the demand for goods produced in other countries. The propensity of firms to invest in differentiated products can make the terms of trade insensitive to output shocks realized within individual countries; see Krugman (1989). As a result, the trading partners of any country that receives a positive shock will be less likely to realize similar increases in output from greater demand originating abroad.

To formalize this argument we can describe a simple version of the home market effect in a two country setting with free trade. This derivation follows the simple two-sector framework in Feenstra (2004).[9] Suppose there are two traded sectors: one sector produces a homogeneous good (the numeraire) that requires a single unit of labor to produce, and a differentiated sector that produces many unique varieties with increasing returns to scale. Let x_i be the output of a typical firm in country i operating in the differentiated sector, and let L^i denote total labor usage. Then the technology used by all N^i firms for producing differentiated goods can be characterized by $L^i = a + bx^i$. Finally, let ϕ^{ij} be the share of total income that is spent on differentiated goods produced in country i by consumers in country j.

A positive productivity shock in country i is equivalent to an increase in its effective labor endowment, which in turn leads to an increase in total output. We write $\hat{L}^i$ as the percentage change in the effective labor endowment that results from a positive shock in country i, and set $\hat{L}^j = 0$. If two countries in a free trade equilibrium are initially the same size, and assuming each country purchases a larger share of differentiated products domestically than from any particular trading partner (i.e., $\phi^{ii} > \phi^{ij}$), then the home market effect can easily be demonstrated by considering the

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[9] More complete analyses of the home market effect with many industries, costly trade, and multiple countries are available in Crozet and TrionFetti (2008) and Behrens et al. (2009). Also see Feenstra et al. (1998) and Hanson and Xiang (2004) for evidence in support of the home market effect operating in differentiated sectors.

changes in the number of producers in each country following a shock $\hat{L}^i$:

$$\hat{N}^i = \frac{\phi^{jj}}{\phi^{jj} - \phi^{ij}}\hat{L}^i > 0 \ \text{ and } \ \hat{N}^j = \frac{-\phi^{ji}}{\phi^{jj} - \phi^{ij}}\hat{L}^i < 0 \ , \tag{1}$$

which indicates that when country i receives a positive shock it realizes a percentage increase in the number of differentiated good suppliers $\hat{N}^i$, while its trading partner realizes a reduction in the number of firms supplying differentiated goods. Given the tastes of consumers to purchase many varieties of differentiated goods, the relative changes in the number of suppliers across countries is equivalent to country i increasing its net exports of differentiated goods. This is the home market effect. Note further that the relocation of suppliers following a shock in country i is much greater when foreign consumption shares in each country (ϕ^{ij} and ϕ^{ji}) are large; i.e., when these countries trade intensively with one another.

A relative shift of suppliers between trading countries when one receives a shock implies that growth within one country will not result in greater demand for differentiated goods from its trading partners, and hence there is no avenue for trade to positively transmit growth shocks. Corsetti et al. (2007) provide direct evidence that positive growth shocks do not lead to a reduction in its terms of trade if there is coincident investments in the production of new varieties, shutting down the traditional avenue from the IRBC literature by which shocks are positively transmitted to trading partners. Also, it is likely that the location decisions of firms are tied more closely to the permanent changes in countries GDP series, rather than business cycle fluctuations.[10] Therefore we may expect there to be different trend versus cyclical comovement relationships between trading countries.

In our empirical analysis below we divide the sample based on G7 membership. There are two reasons to proceed in this manner. First, one of our goals is to highlight the opposite impact that trade has on trend comovement versus cyclical comovement. Much of the previous literature on cyclical comovement has emphasized differences in results based on G7 membership. To ensure

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[10]Burstein et al. (2008) make a similar assumption in their analysis of cyclical comovement. They argue that "the location of plants and assembly lines are unresponsive to shocks at business cycle frequencies...," effectively shutting down transmission mechanisms that result from firms choosing to relocate production across borders.

that our finding of weaker trend comovement among close trading partners is not due to the selection of countries in the sample, we estimate the impact of trade among countries both within and outside the G7.

Secondly, there are economic reasons to examine comovement separately for G7 and non-G7 countries. The home market effect discussed above is a mechanism that operates in environments where production and trade are concentrated in differentiated goods sectors, and there are stark differences in the concentration of economic activity in differentiated sectors for G7 and non-G7 countries. The average share of production in differentiated sectors for non-G7 countries is 57%, which is approximately three standard deviations below the mean of 67% for G7 nations. Looking to exports there are even greater differences, with approximately 85% of total exports in G7 countries by firms in differentiated sectors as compared to 71% outside the G7.[11] In addition to the concentrations of economic activity across sectors, there is previous evidence that the larger volume of trade in big countries is primarily due to exports of a greater number of products. Hummels and Klenow (2005) demonstrate that more than 60% of the larger volume of exports from big countries is attributable to the extensive margin. As they argue, this fact is inconsistent with models that impose an Armington assumption, such that goods are differentiated only by county origin.

In sum, the home market effect implies negative transmission of output shocks across trading partners, provided there is investment in differentiated goods. As countries trade more with each other, this effect is more prevalent. Also, the propensity of firms to make new investments likely differs depending on whether output shocks are permanent or transitory. This suggests the link between trade intensity and output comovemement could be very different for business cycle versus trend comovement. The evidence also indicates that large countries tend to produce and export a larger share of total output in differentiated sectors, suggesting the potential for trade to have

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[11]These percentages were computed using annual production and trade data across sectors during our sample period of 1980 through 2010 available from the OECD STAN database. Each sector corresponds to a 2 digit industry in the ISIC rev. 3 classification, and we classify sectors as being homogeneous or differentiated. The homogeneous sectors are Agriculture, Mining and Quary, Fishing, Food, Textiles, and Electricity, Gas & Water Supply. The differentiated sectors are Manufacturing including chemicals, wood, nonmetallic minerals, pulp and paper products (not food, tobacco or textiles), Transportation, and Leather. Sectoral production data are missing for Australia in many sectors across the whole sample period, and data are also missing for Sweden prior to 1990.

different impacts on comovement within, versus outside, the G7. The next section builds our empirical strategy considering the distinct roles of trade in transmitting trend versus cyclical shocks, and considering the varying impacts of trade across country groups.

3. Empirical Strategy

Our analysis proceeds in two steps. First, we separate changes in the real GDP series for each country into trend and business cycle components, and calculate cross-country correlations for the fluctuations in both of these components. Second, we relate these correlations to trade intensity between country-pairs. This section provides details about each step of our empirical strategy.

3.1. Estimating Trends and Cycles in Real GDP

The trend and business cycle components of real GDP are not directly observed. A large existing literature provides several alternative definitions of trend versus business cycle fluctuations, and corresponding methods to identify these defined components. Here, we define and identify trend versus business cycle components in real GDP using an unobserved-components (UC) model. The UC model has a long history in macroeconometrics as a tool for business cycle measurement.[12] In the UC framework, log real GDP for country i in period t, denoted $y_{i,t}$, is additively divided into trend ($\tau_{i,t}$) and cyclical ($c_{i,t}$) components:

$$y_{i,t} = \tau_{i,t} + c_{i,t}. \tag{2}$$

The UC framework then specifies explicit equations for the trend and cyclical components. The trend component is specified as a random walk process, while the cyclical component follows a covariance stationary autoregressive (AR) process:

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[12]Early examples of macroeconomic detrending using the UC framework include Harvey (1985), Watson (1986), and Clark (1987).

$$\tau_{i,t} = \mu_i + \tau_{i,t-1} + v_{i,t}, \tag{3}$$

$$\phi_i(L) c_{i,t} = \epsilon_{i,t}, \tag{4}$$

where $\phi_i(L)$ is a pth order lag polynomial with all roots outside the complex unit circle, $v_{i,t} \sim$ i.i.d. $N\left(0, \sigma_{v_i}^2\right)$, and $\epsilon_{i,t} \sim$ i.i.d. $N\left(0, \sigma_{\epsilon_i}^2\right)$. Following the bulk of the existing literature on business cycle measurement with UC models, we make the assumption of independence between trend and cyclical shocks, such that $\sigma_{v_i,\epsilon_i} = 0$.[13] The model in (2) - (4) is estimated via maximum likelihood, and estimates of the unobserved trend and cycle components constructed using the Kalman Filter.

The UC model identifies trend versus business cycle fluctuations by assuming the trend represents the accumulation of the permanent effects of shocks to the level of real GDP. In other words, the trend in real GDP is equivalent to its stochastic trend. The business cycle component is then the deviation of real GDP from this stochastic trend, and represents transitory fluctuations in the series. This identification strategy is consistent with a wide range of macroeconomic models in which business cycle variation represents temporary fluctuations in real GDP away from trend. As shown in Morley et al. (2003), the UC approach to detrending is also equivalent to the well-known Beveridge and Nelson (1981) decomposition, which measures the business cycle from the forecastable variation in real GDP growth.[14] Rotemberg and Woodford (1996) argue that this forecastable variation makes up the essence of what it means for a macroeconomic variable to be "cyclical."

The existing literature investigating the relationship between trade intensity and business cycle comovement has taken multiple approaches to measure the business cycle component of real GDP, including deterministic detrending (linear or quadratic), the band-pass filters of Hodrick and Prescott (1997) and Baxter and King (1999), and first differencing. For our purposes, determin-

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[13]See, e.g., Harvey (1985), Clark (1987) and Harvey and Jaeger (1993). Morley et al. (2003) provide analysis and application of UC models with correlated components.

[14]Specifically, Morley et al. (2003) show that given the same reduced form time-series model used to represent real GDP, the UC-based decomposition gives the same estimates of trend and cycle as the Beveridge-Nelson decomposition.

istic detrending is unsatisfactory, as we are interested in studying correlations between stochastic shocks to trend real GDP. Under the assumption of a deterministic trend, such stochastic shocks do not exist.

When real GDP contains a unit root, band-pass filters and first differencing will both produce a measure of the cyclical component that is partially influenced by shocks to the stochastic trend. For example, suppose that real GDP is generated by a stochastic process similar to equations (2) - (4). Then the first difference of real GDP and the business cycle component produced by a band-pass filter will be influenced by both the permanent and transitory shocks, v_t and ϵ_t. To the extent one believes that permanent shifts to real GDP appropriately belong in the trend of real GDP, this is problematic. As an example of this, Cogley and Nason (1995) and Murray (2003) demonstrate that if real GDP is itself a random walk, band-pass filters will generate a cyclical component.[15] As will be seen in Section 4 below, this seemingly extreme example is relevant for the real GDP series of a number of countries in our sample, for which the trend dominates the variance of real GDP growth.

Another advantage of the UC approach for our purposes is its explicit representation of trend versus cyclical components, estimates for both of which are required in our analysis. This makes interpretation of the components straightforward, and aids in the construction of variance decompositions designed to separate the sources of fluctuations in international real GDP growth. Such explicit characterizations of both trend and cycle are not always available from other popular filters. For example, the Baxter-King filter, while providing a clear definition and measure of the cyclical component, does not provide an explicit definition of the trend component.

The model for the trend component in (3) implies a constant average growth rate of μ for the trend component of real GDP. To relax this restriction, for each country we also estimate a version of the model in which equation 2 is replaced with:

$$\tau_{i,t} = \mu_{i,0} + \mu_{i,1} D_{i,t} + \tau_{i,t-1} + v_{i,t}, \tag{5}$$

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[15]In the literature, this phenomenon is often, and not without controversy, referred to as a "spurious cycle." See, e.g., Cogley (2001) and Pedersen (2001).

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where $D_{i,t}$ is a dummy variable that is zero prior to the break date k_i, and one thereafter. This break date is estimated along with the other parameters of the model via maximum likelihood.[16] We then report results based on the UC model with either equation (3) or (5) by choosing that model that minimizes the Schwarz Information Criterion.

3.2. Variable Construction

For each country-pair in our sample, we require the correlation between trend fluctuations and the correlation between cyclical fluctuations for those countries. Measured across all the country-pairs, these correlations then make up the cross section for two different dependent variables used in our analysis. To create a time-series dimension to our sample, we measure correlations separately by decade. The correlation between cyclical fluctuations in countries i and j in decade d is given by:

$$\rho_{ijd}^c = corr_d\left(\widehat{c}_{i,t}, \widehat{c}_{j,t}\right), \tag{6}$$

where $corr_d\left(\cdot\right)$ indicates the sample correlation coefficient measured using data in decade d, and $\widehat{c}_{i,t}$ and $\widehat{c}_{j,t}$ represent the Kalman filtered estimates of the business cycle component for countries i and j respectively. For trend fluctuations, the level of the trend component contains a unit root by assumption, and second moments of this level are thus infinite. To study the correlation between trend fluctuations, we consider the correlation between first differences of the trend component. Given the random walk assumption for the trend component in (3), this is equivalent to considering the correlation between the permanent shocks to real GDP in the two countries:

$$\rho_{ijd}^\tau = corr_d\left(\widehat{v}_{i,t}, \widehat{v}_{j,t}\right), \tag{7}$$

where $\widehat{v}_{i,t}$ and $\widehat{v}_{j,t}$ represent the Kalman filtered estimates of the shocks to the trend component for countries i and j.

Our goal is to relate comovement patterns to the strength of trade relationships across countries.

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[16]We assume that the break date does not occur in the initial or terminal 20% of the sample period.

As with previous studies of cyclical comovement we weight trade flows between countries by their respective GDP levels. The variable, $Trade_{ijd}$, measures trade between countries i and j during decade d, and is calculated by

$$Trade_{ijd} = \frac{1}{T_d} \sum_{t \in d} \left(\frac{X_{ijt} + M_{ijt}}{Y_{it} + Y_{jt}} \right), \tag{8}$$

where T_d is the total number of quarterly time periods observed in each decade d, $X_{ijt} + M_{ijt}$ is real valued exports plus imports between countries i and j expressed in \$US, and Y_{it} and Y_{jt} are real GDP for countries i and j expressed in \$US. Thus this measure has the interpretation of the amount of trade between countries i and j, relative to the total economic size of these two countries.[17]

Our choice of decades as the time-series unit of observation is driven by several factors. First, this time interval matches the earlier literature, for example Frankel and Rose (1998), Calderon et al. (2007) and Kose et al. (2003), which aids comparability of our results. Second, while a longer time interval holds the promise of more accurate estimates of output correlations, it also increases the probability of computing correlations over periods that include structural changes in international output processes. In their study of G7 business cycle correlations, Doyle and Faust (2005) find structural breaks in time-series processes for international real GDP series that correspond roughly to traditional decade definitions. This suggests decades as the maximum time period over which to compute correlations without contamination from structural breaks. Finally, as shown by Leibovici and Waugh (2012) among others, international trade flows are strongly procyclical. Differences in bilateral trade flows over shorter time spans than a decade are more likely to reflect these cyclical fluctuations, rather that capturing the role of trade relationships in determining comovement patterns.

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[17]Several previous studies have employed measures of trade intensity identical to equation (8) except that nominal values of trade and GDP are used instead of real values. Such a measure only has an interpretation as a real measure of trade intensity when the proper deflator for the trade terms and each of the GDP terms are identical. If this is not true, and there is no reason to believe that it would be, then the trade intensity measure constructed using nominal data will be affected by various relative price level changes.

3.3. Data

GDP data come from the International Financial Statistics, made available by the IMF. For 21 countries, we observe quarterly output from 1980:Q1 to 2010:Q4.[18] By restricting ourselves to the post-1980 period we are able to include a relatively large number of countries from different regions of the world and at different stages of development.[19] The set of countries in our sample also corresponds to those studied in previous analyses of comovement, limiting the potential for sample selection to generate any differences in our results for trend versus cyclical comovement.

We choose to measure GDP quarterly, as there is substantial evidence in the existing literature that both the business cycle and trend components account for a substantial portion of quarterly fluctuations in international real GDP growth series.[20] We will present evidence consistent with this result for our sample of countries in Section 4 below. Previous studies have estimated cyclical comovement patterns for a longer time series, but generally have relied on annual data that can mask some of these important higher frequency fluctuations. For example, annual data will average away business cycle episodes that last only a few quarters.

Information about bilateral trade flows come from the Direction of Trade Statistics. We observe total imports and exports between country-pairs. Trade flows are expressed in nominal US dollars, which we deflate directly as described in Section 3.2 above. In several instances export values do not correspond precisely to import values reported by the destination country. Our results are insensitive to which country's reported value of trade is used for any given country-pair. [21]

Using the quarterly real GDP data we construct estimates of the cycle and trend components and the corresponding country-pair cycle and trend shock correlations as described in Sections 3.1 and 3.2 above. The correlations are computed for each of the three decades in the sample, 1980-1989, 1990-1999 and 2000-2010. The average bilateral trade value over each of these decades is also computed for each country-pair. The final data set is then a panel with 210 unique trading

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[18]The countries in our sample are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

[19]New Zealand is a slight exception in that we do not observe the real GDP series until mid 1982.

[20]See, e.g., Cogley (1990), Morley et al. (2003), and Aguiar and Gopinath (2007).

[21]Note that the trade measures have been scaled (x 100) to improve exposition of tables that report point estimates for the effects of trade on comovement patterns.

Table 1: Comovement Summary Statistics

	Variable	Obs	Mean	Std. Dev.	Min	Max
Full Sample	Cycle corr	630	0.248	0.416	-0.950	0.986
	Trend corr	630	0.211	0.242	-0.422	0.793
	Trade	630	0.223	0.531	0	5.664
G7 Nations	Cycle corr	63	0.513	0.473	-0.890	0.975
	Trend corr	63	0.234	0.299	-0.422	0.793
	Trade	63	0.961	1.194	0.057	5.664
80s	Cycle corr	210	0.285	0.435	-0.668	0.968
	Trend corr	210	0.115	0.179	-0.409	0.714
	Trade	210	0.187	0.448	0.001	4.374
90s	Cycle corr	210	0.099	0.396	-0.950	0.935
	Trend corr	210	0.105	0.209	-0.422	0.753
	Trade	210	0.229	0.547	0.001	5.490
00s	Cycle corr	210	0.359	0.371	-0.510	0.986
	Trend corr	210	0.414	0.195	-0.353	0.793
	Trade	210	0.252	0.588	0	5.664

partners and 3 time series observations corresponding to the three decades in the sample. Table 1 presents summary statistics for the cycle correlation, trend shock correlation, and bilateral trade flow measure for the full sample, for each decade, and for samples separating country pairs that involve two G7 member countries from those country pairs including a non-G7 country.

3.4. Relating Comovement to Trade

To estimate the differences in comovement patterns across country-pairs with varying trade relationships we estimate the following regression equation:

$$\rho_{ijd}^{h} = \alpha + \beta Trade_{ijd} + \Gamma X_{ijd} + \eta_{ij} + \delta_d + \xi_{ijd} \tag{9}$$

where $h = c, \tau$. Our primary interest is in explaining variation in ρ_{ijd}^{τ}, the correlation between permanent shocks, across country pairs. However, we also estimate (9) where the dependent variable is the correlation between transitory (cyclical) shocks, that is ρ_{ijd}^{c}, to verify that our sample is consistent with the patterns highlighted previously in the literature. We present results where these two equations are estimated separately, though our conclusions are identical when we estimate the two models as a system of seemingly unrelated regressions.

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The variable δ_d is a decade specific fixed effect used to control for trends in both the correlation and trade variables. Doyle and Faust (2005) estimated structural breaks in comovement statistics among G7 nations and found that, on average, cyclical comovement became weaker over the period 1960-2002. Table 1 confirms this result for cyclical correlations, but also shows a subsequent increase in average cyclical correlations during the 2000s. Table 1 also shows increases in the average correlation between trend shocks in the 2000s, after remaining stable in the 1980s and 1990s. Finally, Table 1 demonstrates that, on average, trade has grown steadily over the sample period. Given these trends, decade specific fixed effects helps protect us from estimating a spurious regression in the trade-comovement relationship. In addition, we also include a full set of interactions between trade intensity and the decade effects to investigate whether the role of trade in generating comovement has changed over time.

Trade patterns are clearly related to the innate characteristics of each country-pair. For example the gravity model predicts that exogenous differences in geography and distance will cause bilateral trade patterns to vary.[22] The importance of gravity variables in generating comovement in countries GDP series is emphasized by Baxter and Kouparitsas (2005). There is also evidence that financial linkages may promote output comovement between countries; see Prasad et al. (2007), among others. Blonigen and Piger (2011) demonstrate that gravity variables are among the most robust predictors of foreign investment activities between countries. Table 1 demonstrates that both average trend correlations and average trade intensity are higher for higher income country pairs (as proxied by G7 membership). The term η_{ij} is a country-pair fixed effect included when we estimate (9) to account for the varying incentives for countries to trade and invest with one another, and any other fixed exposure to shocks in output between countries.

We also estimate (9) separately for the sample of country pairs that involve two G7 member countries. Previous studies have demonstrated that the impact of trade linkages on business cycle comovement varies substantially across levels of industrial development; Calderon et al. (2007) provide evidence that the effect of trade on cyclical fluctuations is much different among developing countries than for high income nations, and Kose et al. (2003) demonstrate specifically the

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[22]Redding and Venables (2004) provide robust evidence on the effects of geography on international trade patterns.

importance of estimating the effect of trade separately for G7 and non-G7 nations. Also, as discussed above, theoretical predictions regarding the directional effect of trade intensity on comovement (i.e., the prevalence of demand versus supply channels) differ depending on whether traded goods are homogeneous or differentiated with scale economies present, and there are substantial differences in the concentrations of economic activity across differentiated and non-differentiated sectors based on G7 membership.

The vector X_{ijd} incorporates several control variables suggested previously in the comovement literature. Imbs and Wacziarg (2003) show that comovement patterns are systematically related to patterns of industry specialization. To account for similarity in specialization patterns, Imbs (2004) suggests controlling for the combined income levels, as well as differences in income, between country-pairs.[23] Rose and Engel (2002), and subsequent studies, argue that nations within a currency union exhibit stronger comovement in cyclical output. We include an indicator variable, CU_{ijd}, that equals one if country-pair ij belongs to a currency union during period d. In contrast Baxter and Kouparitsas (2005) perform a general robustness analysis of the determinants of comovement across countries. They argue that bilateral trade is a robust predictor of business cycle comovement, while patterns of industrial specialization and membership in a currency union are not. We present evidence from specifications with and without these control variables and obtain similar results.

4. Results

4.1. Trend & Cycle Components of Real GDP

Table 2 reports results regarding the estimated trend and cyclical components of real GDP across countries. The second column gives the estimate of μ_i, which has the interpretation of the average quarterly growth rate of the trend component for country i. For those countries where the model with a one-time structural break in μ is the preferred model, Table 2 reports the estimates of both $\mu_{i,0}$ and $\mu_{i,1}$, along with the estimated date of the structural break (in parenthesis). For

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[23]We note that our inclusion of relative income levels between countries does not conform exactly to the specification in Imbs (2004). He estimated a static model in a simultaneous equations framework, whereas here we exploit time series variation in the sample. Thus the role of national incomes across our specifications differs somewhat.

Table 2: Trend and Cyclical Components of Quarterly Real GDP Series

	Country	Avg Trend Growth	StDev of Trend Shock	StDev of Cycle Shock	Frac. from Trend
			Trend & Cycle Components		Variance Decomposition
	Australia	0.008	0.005	0.005	0.40
	Austria	0.006	0.009	0.002	0.89
	Belgium	0.006	0.008	0.002	0.90
	Denmark	0.004	0.012	0.003	0.94
	Finland	0.006	0.011	0.005	0.65
	Korea (2000:1)	0.019, 0.010	0.013	0.001	0.89
Non-	Mexico	0.006	0.011	0.010	0.47
G7	Netherlands	0.005	0.008	0.002	0.81
	New Zealand	0.007	0.012	0.014	0.32
	Norway	0.006	0.010	0.008	0.27
	Portugal	0.005	0.011	0.002	0.83
	Spain (2004:3)	0.007, 0.004	0.008	0.002	0.79
	Sweden	0.005	0.011	0.002	0.76
	Switzerland	0.004	0.003	0.004	0.12
	Canada	0.007	0.000	0.006	0.00
	France	0.005	0.003	0.003	0.45
	Germany	0.005	0.008	0.003	0.77
G7	Italy (2001:1)	0.004, 0.001	0.005	0.004	0.54
	Japan (1990:3)	0.012, 0.003	0.008	0.004	0.79
	United Kingdom	0.005	0.004	0.004	0.27
	United States	0.007	0.004	0.005	0.30

most countries, average annualized trend growth rates range from between 1.6% to 3.2%. Korea displays faster growth than all other countries over the entire sample period, although this growth rate slows in the last decade of the sample period. During the first decade in the sample period, Japan also displays faster than typical trend growth, before slowing significantly at the start of the 1990s. Two other countries, Spain and Italy, also display evidence of a changing trend growth rate, which in both cases are growth slowdowns in the early to mid 2000s.

Our primary interest in this paper is in the stochastic shocks hitting the trend and business cycle components. The second and third columns of Table 2 give the estimated standard deviation of these shocks, σ_{vi} and $\sigma_{\epsilon i}$. Comparing across countries, there are large differences in the estimated standard deviations for shocks to the trend component. Eight of the countries in the sample experience quarterly shocks to the trend component with a standard deviation of 4% of real GDP or higher on an annualized basis, while for seven others this standard deviation is below 2% of real GDP. For nearly all countries, shocks to the trend component are substantial, with Canada being the only case where trend shocks have a standard deviation less than 1% of real GDP. For shocks

to the business cycle component there is more uniformity, although three countries, Mexico, New Zealand, and Norway, stand out for having larger than typical business cycle shocks.

A novel feature of our paper is the focus on the relationship between trade intensity and co-movement in trend fluctuations. Thus, it is of particular interest to gauge the relative importance of the trend versus the cycle for generating variability in real GDP growth. If the trend component was relatively unimportant in this respect, the effect of trade on trend comovement would be of less interest. To measure the relative importance of the trend we calculate variance decompositions. Note that from (2), quarterly output growth can be expressed as:

$$\Delta y_{i,t} = \Delta \tau_{i,t} + \Delta c_{i,t}.$$

Given the independence of shocks to the trend versus the cyclical component, the variance of quarterly output growth is then given by:

$$Var\left(\Delta y_{i,t}\right) = Var\left(\Delta \tau_{i,t}\right) + Var\left(\Delta c_{i,t}\right).$$

Each of the components on the right hand side of this equation can be computed analytically using the estimates of the parameters of the unobserved-components model. In particular, $Var\left(\Delta \tau_{i,t}\right) = \sigma_{vi}^2$, while $Var\left(\Delta c_{i,t}\right)$ can be recovered from the autoregressive specification of the cyclical component. Given these components, we then compute a decomposition for the proportion of the variance of quarterly output growth due to the trend component as $Var\left(\Delta \tau_{i,t}\right) / \left(Var\left(\Delta \tau_{i,t}\right) + Var\left(\Delta c_{i,t}\right)\right)$.

The final column of Table 2 reports these variance decompositions, which reveal that the trend component contributes substantially to the overall variance of quarterly real GDP growth in most countries. The average share of the trend component in the variance decomposition across countries is 0.58. Also, the variance decomposition is above 0.25 for all but two countries, Switzerland and Canada, and is above 0.75 for ten countries. These results suggest that fluctuations in the trend component are a quantitatively significant source of total quarterly output fluctuations for a large number of countries.

This evidence also highlights the potential danger of using first differences or a band-pass filter

Table 3: Trade and Cyclical Comovement

	(1)	(2)	(3)	(4)	(5)
Trade	0.167***	0.166***	0.304***†	0.604***†	0.634***†
	(0.033)	(0.0303)	(0.083)	(0.172)	(0.159)
90s		-0.193***	-0.141***	-0.143***	0.0543
		(0.0398)	(0.043)	(0.0335)	(0.0794)
00s		0.0634*	0.084	0.0833***	0.593***
		(0.038)	(0.041)	(0.0308)	(0.199)
Trade x 90s			-0.252**†	-0.299***†	-0.292***†
			(0.109)	(0.11)	(0.107)
Trade x 00s			-0.119†	-0.192***†	-0.192***†
			(0.092)	(0.069)	(0.068)
SumGDP					-0.580***
					(0.215)
DiffGDP					0.0482
					(0.158)
Currency Union					-0.136**
					(0.056)
Constant	0.211***	0.254***	0.228***	0.172***	0.839***
	(0.0169	(0.030)	(0.032)	(0.036)	(0.244)
FEs	NO	NO	NO	YES	YES
Observations	630	630	630	630	630
R-squared	0.045	0.114	0.129	0.208	0.229
Number of pair				210	210

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, †$F < 0.05$

to measure a business cycle component defined as the transitory fluctuations in economic activity. As was discussed in Section 3.1 above, such approaches to detrending will produce measures of the business cycle that mix permanent and transitory fluctuations. Given that the permanent component produces a substantial amount of quarterly real GDP fluctuations in our sample, this contamination could be significant.

4.2. Comovement and Trade Intensity

We now turn to estimating the relationship between trade and comovement patterns across countries. We first examine cyclical comovement patterns to confirm that our data sample and empirical strategies are consistent with previous studies. We then turn to our question of primary interest: how does trade influence the correlation between shocks to the trends in real GDP series across countries?

Table 3 reports estimates from the regression in (9), where the dependent variable is the correlation between cyclical fluctuations in real GDP. Robust standard errors are in parenthesis. For

each specification we find that bilateral trade intensity has a positive effect on cyclical fluctuations in output. Since the average correlation between cyclical components is positive across countries, the positive effect of trade indicates increased correlation. These specifications and results are consistent with previous literature. In column (1) we include only measures of trade intensity to confirm the result first obtained by Frankel and Rose (1998). Doyle and Faust (2005) demonstrate that comovement patterns have become weaker in years prior to 2002, consistent with the negative estimate we obtain for the 90s decade effect in column (2). However, the recent global recession has lead to a sharp increase in cyclical comovement during the 2000s. In column (3) we also allow the effect of trade to vary over time. The impact of trade on cyclical comovement has become significantly weaker over time, as is apparent from the negative coefficient on each interaction between trade and the decade effects. While the impact of trade on cyclical comovement has declined over time, we still estimate a positive and significant effect across the whole sample. An F-test supports the overall positive effect of trade on cyclical comovement at conventional levels of significance.

Column (4) introduces country-pair fixed effects to control for differences in the propensity of countries to trade and to share common shocks to GDP. Again, consistent with previous literature, we find that trade intensity is associated with stronger cyclical comovement patterns. Attributes specific to each country-pair appear to play a substantial role in comovement patterns. For example, the estimated effect of trade in the 1980s nearly doubles from 0.304 to 0.604 in column (4) once pair fixed effects are included, with comparable changes in the effect of trade in later decades. This suggests that relationship-specific effects may also be important cofactors when we examine comovement in GDP trends. Finally, in column (5) we introduce controls for country attributes that previous literature has suggested affect comovement relationships independently. The positive impact of trade is robust to these additional controls.

The preferred estimates from column (5) of Table 3, which includes the full set of controls, suggest that the average effect across decades of the trade variable on cyclical correlations is 0.47. Table 1 reports that the standard deviation in trade flows is approximately 0.53 for the full sample of countries. Thus, a one standard deviation increase in trade between the average country-pair will

Table 4: Trade and Trend Comovement

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Full Sample of Countries				G7 Nations			
Trade	0.223*	-0.012	0.015	0.002	-0.086	-0.189*	-0.094*†	-0.079†
	(0.131)	(0.045)	(0.059)	(0.048)	(0.152)	(0.094)	(0.051)	(0.051)
90s		-0.0101	-0.005	0.162***		-0.0536	-0.0813	0.643***
		(0.018)	(0.019)	(0.048)		(0.067)	(0.083)	(0.193)
00s		0.300***	0.301***	0.704***		0.439***	0.517***	1.98***
		(0.018)	(0.020)	(0.118)		(0.043)	(0.043)	(0.361)
Trade x 90s			-0.028	-0.014			0.0131†	0.0132†
			(0.030)	(0.027)			(0.040)	(0.033)
Trade x 00s			-0.012	-0.023			-0.0895***†	-0.0374†
			(0.032)	(0.028)			(0.019)	(0.023)
SumGDP				-0.495***				-1.93***
				(0.143)				(0.444)
DiffGDP				0.092				-0.033
				(0.094)				(0.289)
Currency Union				0.103***				-0.241***
				(0.038)				(0.066)
Constant	0.162***	0.117***	0.112***	0.689***	.316**	0.287***	0.204***	2.564***
	(0.029)	(0.012)	(0.015)	(0.169)	(0.146)	(0.073)	(0.053)	(0.532)
FEs	YES	YES	YES	YES	YES	YES	YES	YES
Observations	630	630	630	630	63	63	63	63
R-squared	0.014	0.474	0.475	0.504	0.003	0.742	0.787	0.853
Number of pair	210	210	210	210	21	21	21	21

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, † $F < 0.05$

increase the correlation in their cyclical fluctuations by approximately 0.25, which is equivalent to 0.6 of a standard deviation in cyclical correlations. This suggests that typical variation in trade is associated with non-trivial variation in cyclical correlations.

In Table 4 we turn to the primary focus of the paper: trend comovement. We present results for both the full sample of countries (columns 1-4), and for a sample that includes only country-pairs where both countries are a member of the G7 (columns 5-8). Each specification includes country-pair fixed effects. Robust standard errors are in parentheses.

The results in Table 4 for the effects of trade on the correlation between trend fluctuations are drastically different than those estimated for cyclical comovement. For the full sample, there is a positive and marginally statistically significant impact of trade on trend comovement when no controls beyond the fixed effects are included (column 1). However, this significance disappears when the decade effects are added (column 2), suggesting unaccounted for trends in the correlation and trade variable are driving the results in column (1). More importantly, the point estimate for the

effect of trade is negative in column (2), in contrast to the positive effect found for correlations in cyclical output. In column (3) we allow the effect of trade to vary across decades, while in column (4) additional controls are added. In both cases the effect of trade is statistically insignificant, and is estimated to be negative in certain decades.

When we restrict attention to G7 country pairs (columns 5-8), we find a consistently large and negative effect of trade on trend comovement. This effect is statistically significant for those regressions that include controls beyond fixed effects (columns 6-8). Focusing on the preferred estimates from the regression reported in column (8), which includes the full set of controls, the average effect of the trade variable on trend comovement across decades is -0.087, and an F-test of the hypothesis that trade has no effect on trend correlations in any decade is rejected (*p-value* < 0.05). The average correlation in trend shocks for these country pairs is positive, indicating that greater trade intensity leads to *weaker* comovement. This is in sharp contrast to the documented association between greater trade intensity and increased cyclical comovement.

From Table 1, the standard deviation of trade flows is approximately 1.19 for the sample of G7 countries, meaning that a one standard deviation increase in trade between the average country-pair will reduce the correlation in their trend shocks by approximately 0.10. This is equivalent to 0.33 of a standard deviation in trend shock correlations. While somewhat smaller than the similarly defined effect on cyclical correlations of 0.6 of a standard deviation, this effect is still substantial. Further, and in contrast to the declining effect of trade on cyclical comovement, the negative impact of trade on trend comovement is robust over time. Each interaction between trade and the decade effects is statistically insignificant, indicating no significant changes in the role of trade relationships over time.

4.3. *Quantifying the Effect of Trade on Output Comovement*

Tables 3 and 4 suggest that trade has a statistically significant effect on both cyclical and trend shock correlations. Becuase we have estimated the impact of trade linkages on the comovement of both cyclical fluctuations and trend shocks, we can decompose the effect of trade on the comovement of overall output growth between countries. In this section we report results of a simulation experiment to quantify the extent to which typical changes in these correlations due to changes in

trade intensity pass through to changes in output growth correlations. These results demonstrate that the extent of such pass-through depends on whether we measure output growth over shorter versus longer-run horizons.

A standard measure of output growth comovement for two countries is the correlation in quarterly output growth, which we term a short-run comovement measure. For this measure, both transitory cyclical shocks and permanent trend shocks are important for understanding the effect of trade on comovement, with the relative contribution of each depending on the magnitude of the effects of trade on cyclical versus trend shock correlations, as well as the relative importance of the trend versus cyclical component in driving the variance of quarterly output growth. Again, as was demonstrated in Table 2, for many countries the trend component accounts for the majority of quarterly output growth variance. Thus, in these cases, the change in the correlation of quarterly output growth induced by a change in trade could be more substantially driven by the change in trend shock correlation, even if the change in trend shock correlation was relatively small as compared to the change in the cyclical correlation.

Alternatively, we may be interested in comovement of output growth over a long horizon (such as a decade.) Because shocks to the trend component correspond to permanent changes in real GDP, while cyclical variation is transitory in its effects on output, trend shock correlations should be more important than cyclical correlations in determining these long-horizon output growth correlations. This will be true regardless of the importance of trend versus cyclical fluctuations in determining the variance of short-horizon output growth. Thus, for correlations in long-horizon output growth, we would expect the effects of trade to work primarily through the effect on trend shock correlations.

To provide a numerical example of the effects of trade on output comovement, we conduct a simulation experiment. We simulate quarterly real GDP series for two hypothetical countries over one decade, where each series follows a UC process as in (2) - (4), and each UC process is calibrated with identical parameters. We choose parameters to match a low, medium, and high case for the fraction of quarterly output growth variance accounted for by the trend component; these cases correspond to 0.25, 0.50 and 0.75 for this fraction. Over 100,000 such simulations,

Table 5: Simulation of Effect of Trade on Output Correlations

Simulation Parameters		Output Growth Correlation (Change from Baseline)	
Change in Correlation from Baseline	Fraction of Quarterly Output Growth Variance due to Trend	Quarterly Output Growth	Ten-Year Output Growth
	0.25	0.18	0.06
Increase in Cycle	0.50	0.12	0.03
Correlation of 0.25	0.75	0.06	0.01
	0.25	-0.03	-0.08
Recuction in Trend	0.50	-0.06	-0.09
Shock Correlation of 0.10	0.75	-0.08	-0.10

Notes: "Quarterly Output Growth Correlation" is the correlation of simulated quarterly output growth for the two countries. "Ten-Year Output Growth Correlation" is the correlation of simulated 10-year output growth for the two countries. The changes in cycle and trend shock correlations considered are based on the estimated effect of a one standard deviation increase in trade intensity.

we compute the correlation in simulated quarterly output growth, as well as the correlation in simulated ten-year output growth for the two countries.[24] We begin with a baseline experiment in which we set the correlation between trend shocks and the correlation between cyclical components each equal to 0.50. We then consider two additional experiments meant to assess the marginal effects of a one standard deviation increase in trade intensity, which in the first experiment raises the cyclical correlation by 0.25 and in the second lowers the trend shock correlation by 0.10.

Table 5 presents the changes (relative to the baseline experiment) in the correlation of short-run and long-run output growth that is generated by the change in the cyclical or trend shock correlation. The third column of Table 5 shows that the pass-through of changes in cyclical and trend shock correlations to quarterly output growth correlations depends substantially on the fraction of output growth variance due to the trend component. Specifically, when the fraction of quarterly output growth variance due to the trend component is low, an increase of 0.25 in the cyclical correlation is substantially passed through to quarterly output growth correlations, increasing this correlation by 0.18. However a decrease of 0.10 in trend shock correlations resulting from greater trade intensity has very little effect, decreasing quarterly output growth correlations by only 0.03. The opposite is true when the fraction of quarterly output growth variance due to the trend com-

[24]Each simulation yields 40 realizations of quarterly output growth for each country, and one realization of ten-year output growth for each country. The correlation for quarterly output growth is then computed based on 400,000 realizations of quarterly output growth, and 100,000 realizations of ten-year output growth.

ponent is high. It is notable that in this latter case, the marginal effect of the change in the trend shock correlation on the quarterly output growth correlation is larger than that for the change in the cyclical correlation, despite the fact that the change in the cyclical correlation corresponding to a standard deviation increase in trade intensity is substantially larger.

The final column of Table 5 shows that the change in the trend shock correlation passes through substantially to long-horizon output growth correlations. Regardless of the extent to which the trend component accounts for the variance of quarterly output growth, the correlation in ten-year output growth falls by roughly 0.10 as a result of the decrease in trend shock correlations of 0.10. This is in contrast to the increase in the cyclical correlation, which has very little marginal effect on correlation in long-horizon output growth. Although previous studies of comovement in output across countries have focused exclusively on cyclical correlations, these results highlight the importance of changes in trend shock correlations over the long-run, due to the fact that trend shocks reflect permanent changes in output levels.

5. Conclusion

In the current volatile economic climate, policymakers are increasingly focused on the policies established in countries with which they have close economic relationships. International trade linkages can potentially transmit episodes of output contraction across borders. The results presented here suggest that such concerns are less warranted when considering long-run, permanent, changes in real GDP. While trade has been shown to increase cyclical comovement between countries, here we have found that closer trade relationships reduce the correlation between shocks to G7 countries' trend levels of output. For countries outside the G7, we find no statistically significant effect of trade intensity on trend comovement. We argue that there is a key economic distinction between these groups of countries that drives these different results, namely concentrations of activity in differentiated sectors. With increasing returns to scale in the production of differentiated goods, the adjustments that economies realize in response to shocks are plausibly different than those in the absence of returns to scale, particularly in the long-run with regard to permanent shocks. While the literature on international real business cycles has made some progress in incorporating production and trade of differentiated goods, the role of scale economies

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and investments in new varieties has largely been ignored. We anticipate that this may be a fruitful avenue for future researchers.

Our evidence suggests that the effect of trade on trend comovement in the G7 is of substantial economic importance. For many countries in our sample, shocks to trend levels of output account for over half of the variation in their quarterly real GDP growth, suggesting that changes in trend shock correlations will substantially pass through to changes in output growth correlations for many country pairs. Also, while cyclical fluctuations have only transitory effects on output levels, trend shocks have permanent effects, meaning that fluctuations in output levels over longer horizons will be dominated by the trend. As a consequence, comovement in long-horizon output growth across countries will be dominated by correlations in trend shocks, rather than business cycle correlations. We also find that the effect of trade on trend comovement has remained largely stable over the past 30 years, while the effect of trade on cyclical comovement has declined.

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