# How could a shock to growth in China affect growth in the United Kingdom?

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- This article assesses how a shock to Chinese growth could affect the UK economy using an empirical model of the world economy that exploits the historical comovement between international business cycles.

- We find that a 1% slowing in China is likely to reduce UK GDP by around 0.1%. This impact arises mainly from the increasingly important role of China in the global economy — that is, via the United Kingdom's indirect links with China through its main trading partners.

## Overview

China's importance to the global economy has grown in recent years. In 2015, China accounted for around 17% of the level of, and a third of growth in, global economic activity.
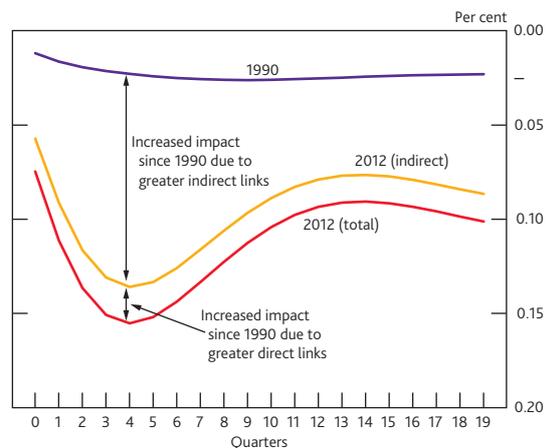
GDP growth in China has slowed in recent years and some further slowing is expected as the Chinese authorities rebalance the economy towards consumption and away from investment. A key question is: how might that slowing affect UK growth? And how would the shock be transmitted (through direct bilateral linkages or through other more indirect channels)?

We find that, today, a 1% negative shock to Chinese GDP is likely to lower UK GDP by 0.1% (**summary chart**, red line). This estimate captures a combination of trade, financial and confidence channels as well as an expected offset from lower oil prices. This impact is much larger than direct trade linkages alone would imply.

By way of comparison, the impact of China slowing on the United Kingdom is one third of the size of an equivalent slowing in the euro area, where our trade links are ten times bigger. Our estimates indicate that the impact is now four times larger than it would be if global trade linkages were at 1990 levels (**summary chart**, purple line).

We show that this increase in the impact of a China slowdown is due to stronger ties between China and the United Kingdom's traditional trading partners such as the United States and the euro area ('indirect' effect), rather than stronger direct linkages between the United Kingdom and China ('direct' effect).

Summary chart  The changing impact of a negative 1% shock to Chinese GDP on UK GDP — direct versus indirect channels



Sources: IMF *International Financial Statistics*, OECD, Thomson Reuters Datastream and Bank calculations.

When decomposing this increase into 'direct' and 'indirect' effects, we find that the latter accounts for almost all the fall in UK GDP (**summary chart**, orange line).

Our best guess is that these estimates are likely to understate the overall impact, particularly in the event of a sharp slowdown in China, where the spillovers to other countries and through financial links would probably be larger than our linear model would suggest.
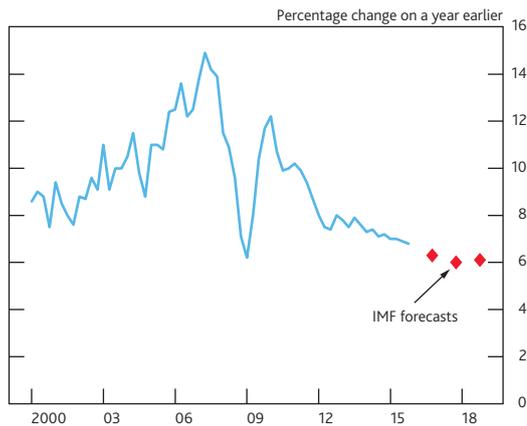
**Click here for a short video that discusses some of the key topics from this article.**

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(1) The authors would like to thank James Benford, David England, Dan Nixon and Jumana Saleheen for their help in producing this article.

## Introduction

GDP growth in China has slowed significantly in recent years. Some further slowdown is expected (**Chart 1**) as the Chinese authorities attempt to rebalance the economy towards consumption and away from investment.  There remains considerable uncertainty around how smooth that rebalancing will be, though.  And there is a risk that growth could slow more sharply than expected.[1]

**Chart 1**  Chinese GDP growth



Sources:  IMF *World Economic Outlook* (*WEO*) October 2015 and National Bureau of Statistics of China.

Developments in China are likely to have important implications for the world economy and, in turn, for the UK economic outlook.  Moreover, given the increasingly important role of China in the global economy, the impact of developments in Chinese economic activity may have changed over time.  Indeed, while in 1990 China accounted for around 4% of world GDP, China is now the largest economy in the world, accounting for more than 17% of world GDP.[2]  And Chinese imports account for around 10% of global trade.

This article assesses how a shock to Chinese growth could affect the UK economy.  Note that 'China' refers to mainland China throughout (ie it does not include Hong Kong).  The first section sets out the various channels through which developments in China could spill over to the United Kingdom. The second section describes an empirical model that can be used to estimate the international transmission of shocks originating in different countries on the United Kingdom.  And the final section runs through the results, focusing on how and why the impact of China on the United Kingdom has changed over time.  A short **video** discusses some of the key topics from this article.[3]

## Through which channels could a shock to China spill over to the United Kingdom?

A shock to Chinese growth is likely to affect the United Kingdom through a number of different channels. In order to think about the overall impact of China on the

United Kingdom, it is helpful to think about how large these different channels could be.  So this section provides an overview of the different channels that could be important.[4]

### Trade channels

A key transmission mechanism through which a shock to Chinese GDP might spill over to the United Kingdom is international trade.  A slowing in Chinese GDP would reduce the demand for goods and services produced by UK firms.  And as the United Kingdom is an open economy, with exports accounting for around 30% of GDP, the trade channel could be an important part of the transmission of world shocks.

While the trade channel may be theoretically important, the share of UK exports that go directly to China is smaller than other trading partners — less than 4% in 2014.  So, at first sight, it may seem that Chinese growth should only have a limited impact on the demand for UK exports and, therefore, GDP growth.

But China is now the world's largest goods exporter and the indirect trade links (links between China and the United Kingdom through other countries) are potentially sizable.  While China only accounts for a small share of UK exports, it is a far more important source of export demand for some of our key trading partners, such as the euro area and United States:  exports to China make up just under 10% of total goods exports for both the United States and euro area.  Moreover, roughly 10% of the euro area's exports go to other Asian economies, who are in turn heavily reliant on Chinese demand.[5]

The importance of the trade channel is likely to have risen significantly over the past two decades.  In the late 1990s, China only accounted for around 2% of world imports of goods and services, and 3% of world exports.  But by 2014, those shares had risen to 10% and 11%, respectively, making China the world's second largest importer and the largest exporter.  At the same time, UK exports to China have risen significantly, from around 0.5% through the 1990s to 4% in 2014.

### Financial channels and confidence effects

In addition to trade, financial channels can also play an important role in the transmission of international shocks. A recent *Quarterly Bulletin* article found that financial linkages

(1)  See, for example, the November 2015 *Inflation Report*;
     www.bankofengland.co.uk/publications/Documents/inflationreport/2015/nov.pdf.
(2)  These figures are computed by converting GDP to international dollars using
     purchasing power parity rates.
(3)  https://youtu.be/JPmwRlD1rnE.
(4)  For a discussion of the different channels through which external shocks can affect
     the United Kingdom, see Chowla, Quaglietti and Rachel (2014).
(5)  Additional details on China's international trade linkages can be found in a box
     'How would a slowdown in China affect the UK economy?' on page 2 of the
     November 2015 *Inflation Report*;
     www.bankofengland.co.uk/publications/Documents/inflationreport/2015/nov.pdf.

are likely to account for the majority of the impact of world shocks on the United Kingdom since 2007.[1]  Given China's size in the global economy, we might expect such spillovers to be significant.  In what follows we review some of the most relevant channels.

Financial spillovers from China could operate directly through the UK banking sector.  For example, UK-owned banks have direct exposures to Chinese financial institutions, corporates and households through their foreign lending activities.  As a result, UK banks could suffer losses as a result of a weakening in Chinese demand conditions if it were associated with a rise in non-performing loans.  Losses abroad could, in turn, bear down on banks' willingness and ability to lend to the UK real economy.  They could also lead to an increase in banks' funding costs, particularly if combined with a deterioration in financial market sentiment.  Increased funding costs would then feed through into a higher cost of borrowing for UK businesses and households.  In addition, losses suffered by Chinese financial institutions could weigh on lending to UK affiliates, or their supply of wholesale funds to UK banks.

This 'direct' exposure, however, is relatively small, since only 1.6% of UK-owned banks' foreign claims is directed to Chinese banks.  But, similarly to trade linkages, indirect linkages may play an important role.  For example, the total exposure when including Hong Kong — which, in turn, has important linkages with China — amounts to just over US$530 billion, or around 16% of UK-owned banks' foreign claims.  For this reason, the Bank's 2015 stress test included a severe scenario for these economies, with sharp reductions in GDP growth, and property and equity prices, to ensure that the UK banking system was sufficiently capitalised to withstand the risks on these foreign exposures.

Financial spillovers to the United Kingdom could also operate through non-banking channels.  For example, slowing in China could be reflected in falls in asset prices both in China and elsewhere.  Such falls would in turn push up UK companies' cost of capital and reduce households' wealth.  And indeed, despite the small share of China in global equity market capitalisation (at slightly less than 10% in 2014), financial market developments through the summer of 2015 highlighted that global asset prices can be very sensitive to developments in China.[2]

Financial linkages between China and the rest of the world have also become increasingly important.  For example, since the early 1990s China's total external liabilities have increased from less than 0.5% of world GDP to around 6%.  And UK-owned banks' exposures to China have risen roughly tenfold over the past decade, to US$169 billion in 2015 Q3.

A slowing in China could also raise uncertainty about the outlook for growth there and elsewhere;  this could affect

UK households' and companies' confidence and so weigh on their spending decisions.  China is now the largest economy in the world (on a purchasing power parity basis) and has contributed more to global growth than all advanced economies over the past eight years (**Chart 2**).  So any shock to the Chinese growth outlook might be expected to have significant effects on the United Kingdom and other countries through global sentiment and risk aversion.

**Chart 2**  Contributions to world GDP growth



Sources:  IMF *WEO* October 2015, OECD, Thomson Reuters Datastream and Bank calculations.

## Commodity prices

It is likely that slower Chinese growth would weigh heavily on commodity prices.  China has been, by far, the largest individual driver of demand growth for oil and industrial metals such as copper and aluminium.  For example, China has accounted for around one third of the total increase in global oil demand since 1990.  It now accounts for over 10% of world oil demand and roughly 50% of copper demand.  During the 2009–12 period, China contributed on average 40% to global aluminium consumption.  As a result, commodity prices tend to be very sensitive to Chinese growth developments.

Unlike the previously discussed channels, a decline in oil and other commodity prices should boost UK GDP growth, given that the United Kingdom is a net importer of those goods.  Household real incomes should also be boosted by the decline in prices, leading to increased consumption.[3]  And UK firms will benefit from lower commodity prices overall, due to lower costs of energy and other inputs.  In the other direction, though, investment spending of the United Kingdom's extraction sector is likely to fall.  Demand elsewhere in the world is also likely to benefit, supporting UK exports, although

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(1) See Chowla, Quaglietti and Rachel (2014).
(2) See, for example, the November 2015 *Inflation Report*, pages 1–9; www.bankofengland.co.uk/publications/Documents/inflationreport/2015/nov.pdf.
(3) Note here that the United Kingdom is a net importer of oil since the mid-2000s.  For a full discussion of the impact of lower oil prices on the UK economy, see the box on pages 32–33 of the February 2015 *Inflation Report*; www.bankofengland.co.uk/publications/Documents/inflationreport/2015/feb.pdf.

commodity producers would be likely to cut back their spending in response.  Overall, the decline in commodity prices should provide some offset to the drag from trade, financial channels and confidence.

## Modelling spillovers from China:  a global vector autoregressive model

To quantitatively assess how a shock to China might affect the United Kingdom, it is important to estimate the impact of *all* channels of transmission.  As explained in the previous section, a shock to Chinese growth is likely to affect the United Kingdom through a number of channels.  And there are also complex interlinkages between the United Kingdom and China via third countries (ie 'indirect' effects).  All of these links need to be captured when attempting to assess how a slowing in China might affect the United Kingdom.

One model that has the potential to capture all of these various channels is the global vector autoregressive (GVAR) model.[1]  Unlike other empirical models, the GVAR allows shocks to propagate across the world economy through many channels of interdependence, including trade, financial, confidence and third-country effects.  And the model also captures the effect of commodity prices.

### An overview of the model
The GVAR approach consists of two steps.[2]  First, individual models of the economy are built for a large number of countries.  In these models, a number of key domestic variables — real GDP, inflation, equity prices, interest rates and the exchange rate — are all affected by each other, as well as by international variables.  The international variables include the oil price and global measures of each of the domestic variables — for example, world GDP and world inflation.

Second, the individual country models are linked through the international variables to construct a global model of the world economy.  In the GVAR, shocks in one country can spill over to other countries.  The intuition is as follows:  when growth in one country falls, that will lower measures of world GDP.  As a result, GDP in each of the countries included in the GVAR model will be affected, as will all the other domestic variables.  The impact on growth in each country will be determined by how domestic GDP has tended to respond to movements in international variables over the past.

The GVAR is flexible enough to also take into account that one country may be important for some countries (such as its main trading partners) but not for others.  The importance of one country for another in the GVAR is determined by country-specific weights.  These weights are used to construct the international variables, so as to reflect the relative importance of each of the foreign economies for each domestic economy.  In the version of the model used in this article, export weights are used to aggregate the foreign variables.  So, for the United Kingdom, a large weight is placed on the euro area when constructing the international variables — as a large share of UK exports go to the euro area.  But only a small weight is placed on China, as the direct export links are limited.  These weights also vary over time, to take into account changes in the relative importance of different countries over time.

### Advantages of the model
The GVAR model has several advantages relative to some other modelling approaches:

- **It is a truly global model**:  the GVAR models the economies of more than 30 countries, accounting for more than 90% of world GDP.

- **All channels of transmission are captured**:  the country models estimate the average response over the past of domestic variables to international ones.  For example, the model estimates how domestic GDP or equity prices tend to respond to movements in world GDP.  This means that the model will implicitly capture the total impact of a change in international variables on domestic ones, rather than just estimating the impact of one channel.

- **Shocks can spill over through third countries (ie 'indirect' effects)**:  the use of country-specific weights means that spillovers of shocks via third countries are captured in this model.  For example, if there were a shock to US GDP this would initially have a direct impact on the United Kingdom through its effect on UK-weighted measures of world GDP, world inflation etc.  But the change in US GDP would also affect the economies of all other countries in the model, which would in turn feed back to the United Kingdom.  Given this, the GVAR model is able to capture the amplification of shocks through third countries.

- **The model captures historical comovement across countries**:  the GVAR is an empirical model so its results are driven by the correlations seen in the data.  Therefore, the model captures the scale of spillovers of shocks that have typically been seen in the past.

### Possible weaknesses of the model
While the GVAR is a very useful tool for measuring spillovers across countries, there are at least two possible drawbacks to this approach.  First, the GVAR is linear.  This means that, in the model, the impact on the United Kingdom of a 5% shock to US GDP is five times larger than a 1% shock to US GDP.  But it is possible that in periods of crisis, when the shocks are larger, there could be greater spillovers than a linear model

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(1)  The model was originally developed by Pesaran, Schuermann and Weiner (2004) and Dees *et al* (2007).
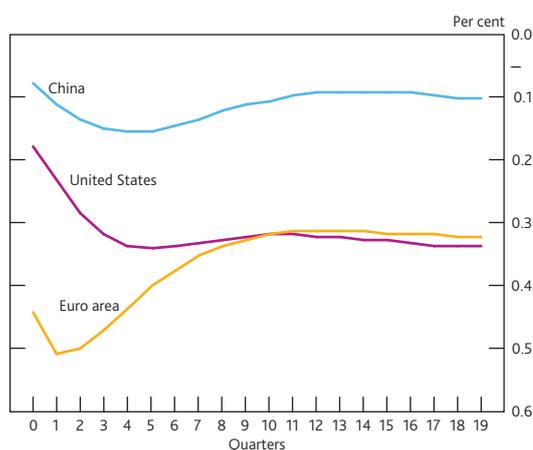(2)  Additional details on the model are provided in the annex.

suggests. And second, the GVAR (as with many other empirical models) can only distinguish between different sources of a shock by making a number of assumptions. In what follows the focus of our analysis is on the study of the transmission of GDP shocks across countries. No attempt is made to identify the source of the shocks, whether they are due to demand, supply, productivity or monetary policy which could, in practice, affect the impact on the United Kingdom. Uncertainties around the GVAR estimates are discussed at the end of the next section.

## The changing impact of China on the United Kingdom

### Results of the global VAR

Using the GVAR, we can estimate what the impact of a slowdown in Chinese GDP growth on the United Kingdom might be. The blue line in **Chart 3** shows the impact on the level of UK GDP of a permanent negative 1% shock to the level of GDP in China. On impact, the model suggests the shock would reduce UK GDP by slightly less than 0.1%. That effect would then build over time to a peak of 0.15%, before falling back to around 0.1% in the long run. The estimated impacts shown here use 2012 trade weights when constructing the foreign variables. This means that they assume that the importance of each country to each other is as it was in 2012.

**Chart 3** The impact of a negative 1% shock to GDP in the United States, euro area and China on UK GDP[(a)]



Sources: IMF *International Financial Statistics*, OECD, Thomson Reuters Datastream and Bank calculations.

(a) The impact is computed using 2012 trade weights.

The GVAR estimates suggest that the spillovers to the United Kingdom from China could be much larger than direct trade linkages alone would imply. Simple ready reckoners (ie 'mechanical' estimates based on the share of UK exports going to China and the share of UK exports in UK GDP) suggest that the negative shock to Chinese GDP would only reduce UK output by around 0.03% through direct trade links. The fact that the GVAR estimates are almost four times larger

than the direct trade channel suggests that additional channels and indirect linkages play an important role in amplifying spillovers to the United Kingdom. It is worth noting, however, that not all these channels work in the same direction. For example, in the model, the negative shock leads to a fall in oil prices of about 3%, which supports UK growth.

To put these results into context, it is helpful to compare the impact of an equivalent shock to the United States and the euro area (magenta and orange lines in **Chart 3**, respectively). A 1% GDP shock in either the United States or euro area would be expected to have a larger impact on the United Kingdom than an equivalent shock in China; the long-run impact of shocks to these two regions is around three times that of the China shock. Considering just the direct trade linkages would have suggested a larger difference in the results: the United Kingdom's trade links with China are around ten times smaller than with the euro area, and five times smaller than with the United States. Again, this highlights the importance of channels other than direct trade links.
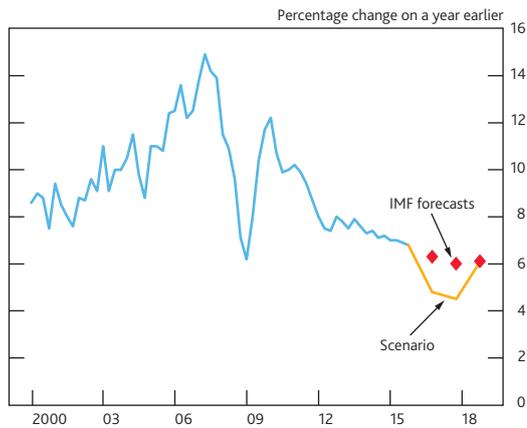
It is also interesting to note that the long-run UK impact of a shock to the United States and euro area is very similar, despite the much closer trade links with the euro area. This may reflect the fact that financial channels are likely to be a more important part of the transmission of shocks from the United States than from the euro area. In addition, the United States plays a more important role in global demand than the euro area, amplifying the third-country effects.

### An illustrative scenario

Here we consider a simple scenario to illustrate the results of the GVAR. As shown in **Chart 4**, the International Monetary Fund (IMF) is forecasting growth in China to slow gradually over the next three years to around 6% in 2018. Given that there is a great degree of uncertainty around the outlook for the Chinese economy, we show what might happen to UK GDP if Chinese growth were to fall more sharply in the near term. We consider an alternative scenario in which growth is assumed to be 1.5 percentage points weaker than the IMF's forecast in 2016 and 2017, before returning to 6% in 2018 (**Chart 4**). This means that, overall, the level of Chinese GDP is around 3% lower by the end of 2018.

**Chart 5** shows the impact we would expect such a scenario to have on UK GDP. If Chinese growth were 1.5 percentage points weaker than expected by the IMF in 2016 and 2017, the GVAR suggests this could reduce growth in the United Kingdom by around 0.14 percentage points in both years. Growth would then pick up as GDP growth in China returns to the rates forecast by the IMF from 2019. The negative impact on the level of UK GDP would peak at 0.3%, falling back to around 0.2% by 2019.
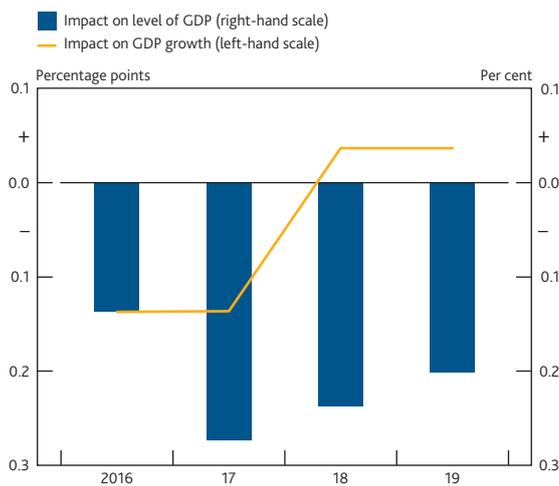
**Chart 4** Chinese growth: IMF forecast and illustrative scenario[a]

Percentage change on a year earlier

IMF forecasts

Scenario

Sources: IMF *WEO* October 2015 and National Bureau of Statistics of China.

(a) The chart shows the historical path of Chinese GDP and its forecast over the 2016–18 period. The orange line displays a scenario in which growth is assumed to be 1.5 percentage points weaker than the IMF's forecast in 2016 and 2017.

**Chart 5** Impact of illustrative scenario on UK GDP[a]

■ Impact on level of GDP (right-hand scale)
— Impact on GDP growth (left-hand scale)

Percentage points                                    Per cent

Sources: IMF *International Financial Statistics*, OECD, Thomson Reuters Datastream and Bank calculations.

(a) The chart shows the impact on UK GDP of the scenario described in the main text and depicted in **Chart 4** (orange line).

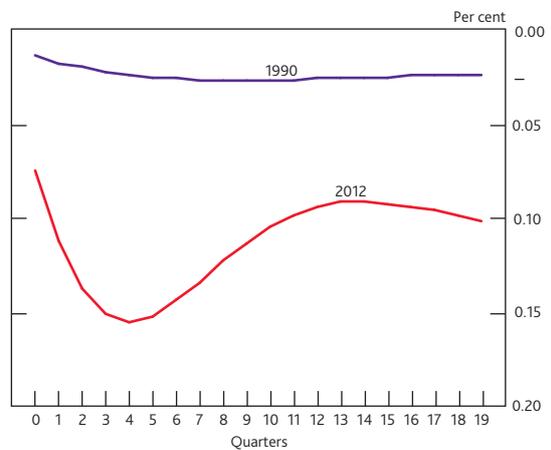## How has the impact of China changed over time?

It is likely that the impact of China on the United Kingdom and other countries has changed significantly over the past couple of decades. Indeed, as discussed above, China's role in the global economy has increased markedly since the early 1990s. Given this, a shock to Chinese growth should now have a much larger impact on the global economy, and in turn the United Kingdom, than would have been the case a couple of decades ago.

With the GVAR we can answer the question, how have spillovers from China to the United Kingdom changed over time? Specifically, this section looks at how the impact of a Chinese GDP shock today compares to the spillovers we would have expected in 1990. To see how the UK impact varies over time, we exploit the time-varying nature of the weights used to construct the international variables in the country models.

Specifically, we simulate the GVAR using the weights from 1990 and 2012 to estimate the impact on the United Kingdom of a shock to China at those specific points in time.[1]

The impact on the United Kingdom of a negative 1% shock to Chinese GDP using both 1990 and 2012 weights is shown in **Chart 6** (the 2012 estimate is equal to that shown in **Chart 3**). The impact of shocks from China has increased significantly over time. The long-run multiplier is now around four times larger than it was in the 1990s. And the short-run impacts are greater still. That is in contrast to the United States and euro area, where the impact of shocks has diminished a little over time.[2]

**Chart 6** The changing impact of a negative 1% shock to Chinese GDP on UK GDP

Per cent

1990

2012

Quarters

Sources: IMF *International Financial Statistics*, OECD, Thomson Reuters Datastream and Bank calculations.
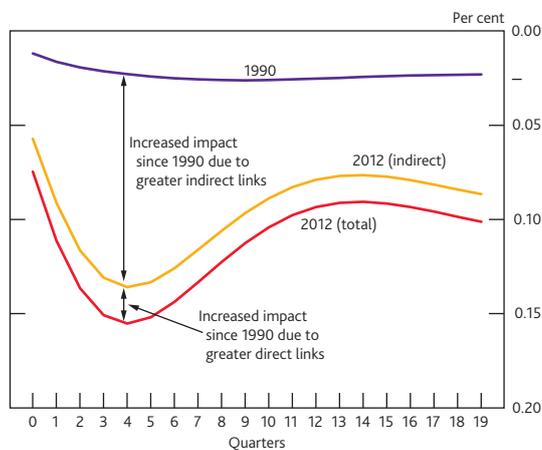
## Why has the impact of China changed over time?

It is interesting to ask why the impact of China on the United Kingdom has increased so much. In particular, is this increase due to stronger bilateral linkages with China ('direct' effect)? Or is it due to the stronger impact of China on the United Kingdom's largest trading partners ('indirect' effect)?

In order to answer this question, we construct a new set of weights. These are identical to the 2012 country weights, with one exception: the United Kingdom's export share to China is set back to its 1990 level. This implies that the bilateral linkages used to simulate the model will be almost identical to the ones in our baseline, with the exception of the direct links between China and the United Kingdom, which will be significantly smaller.[3]

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(1) For a more detailed explanation of this procedure, see Cesa-Bianchi *et al* (2012).
(2) A 1% negative shock to US GDP decreases UK GDP by about 0.3% using both 1990 and 2012 weights, while a 1% negative shock to euro-area GDP decreases UK GDP by 0.4% using 1990 weights and 0.3% using 2012 weights. These estimates are not reported in the main text but are available from the authors upon request.
(3) The difference between China's 1990 and 2012 export shares for the United Kingdom was redistributed proportionally to the remaining countries excluding the United States and the euro area (which were left unchanged at their 2012 levels to avoid overestimating the 'indirect' effects).

The purple line and the red line in **Chart 7** are the UK impacts obtained under 1990 and 2012 weights (as shown in **Chart 6**). Therefore, the gap between the two lines represents the total increase of the impact of Chinese shocks on UK GDP from 1990 to 2012. The orange line, which is obtained under the counterfactual trade shares described above, shows that much of the increased impact is due to indirect linkages. In other words, if today China still accounted for less than 1% of the United Kingdom's exports (as it did in 1990), the impact of a Chinese shock would nonetheless have increased from the purple line to the orange line given China's increased links with other countries.

**Chart 7** The changing impact of a negative 1% shock to Chinese GDP on UK GDP — direct versus indirect channels



Sources: IMF *World Economic Outlook* (*WEO*) October 2015, OECD, Thomson Reuters Datastream and Bank calculations.

This is clear evidence that the changed linkages between China and the rest of the world are affecting the United Kingdom not only via stronger bilateral linkages, but more importantly through stronger ties between China and the United Kingdom's major trading partners.

### Uncertainty around the estimates

While the GVAR is a useful model for capturing the spillovers from China to the United Kingdom, the results are subject to some uncertainty. In particular:

• As in any empirical model, the estimated coefficients of the GVAR may change over time. Using the time-varying weights (export shares) captures the change in the distribution of exports. But it is possible that the

United Kingdom could have become more sensitive to foreign shocks after the financial crisis. Only a model with time-varying parameters could properly account for this issue.

• As mentioned earlier, the GVAR is a linear model, so it cannot account for the non-linearities that typically arise in crisis periods or in a particularly severe scenario. This means that if there were a very sharp slowing in China, often referred to as a 'hard landing', then the GVAR model could underestimate the spillovers to the United Kingdom.

Given the above, the multipliers implied by **Chart 3** are likely to underestimate the scale of the impacts.

## Conclusion

This article asks three questions: first, how large an effect could a shock to Chinese GDP have on UK output? Second, to what extent has the impact of shocks emanating from China increased over time? And third, through which channels — direct bilateral linkages or indirect channels of interdependence — has that change come through?

To answer these questions we use a global VAR that includes country-specific macroeconomic and financial variables, global variables and the price of oil. This model implicitly accounts for many different channels of transmission including trade, financial and confidence channels, and third-country effects.

As expected, we find that shocks emanating from China have a bigger impact on the UK business cycle today than in the past. Specifically, if China were to slow down from 6% to 5% over the next few quarters UK growth would be expected to slow by around 0.1%. By way of comparison, the impact of a 1% shock to China's GDP is one third of the size of an equivalent 1% shock to euro-area GDP.

That said, we view the multipliers implied by **Chart 3** as likely to underestimate the true impact, particularly in the event of a sharp slowdown in China, where the spillovers to other countries are likely to be larger given the associated non-linearities that our model does not explicitly account for.

Finally, we have also shown that the increased influence of China on the United Kingdom is mostly through stronger ties with the United Kingdom's traditional trading partners (the United States and the euro area), rather than direct linkages.

## Annex
## A quick overview of the GVAR model

This section presents a simple overview of the GVAR methodology and discusses some of its underlying assumptions.

The GVAR modelling strategy consists of two main steps. First, each country is modelled individually as a small open economy by estimating a country-specific VAR model in which domestic variables are related to both country-specific foreign variables and global variables that are common across all countries (such as the price of oil).  Second, a global model is constructed combining all the estimated country-specific models and linking them with a matrix of predetermined (that is, not estimated) cross-country linkages.

Consider $N + 1$ countries in the global economy, indexed by $i = 0,1,2,\dots N$.  In the first step, with the exception of country 0 (which in our application is the United States), all other $N$ countries are modelled as small open economies in which a set of domestic variables ($x_{it}$, to be specified below) is related to a set of country-specific foreign variables, $x_{it}^*$, using an augmented VAR model (VARX*) specification.  Specifically, for each country $i$, we set up a VARX*($p_i$, $q_i$) model in which the $k_i \times 1$ vector, $x_{it}$, is related to the vector of country-specific foreign variables, $x_{it}^*$ (abstracting from constant, trend, higher lag orders and global variables for simplicity):

$$x_{it} = \phi_i\, x_{it-1} + \wedge_{i0}\, x_{it}^* + \wedge_{i1}\, x_{it-1}^* + u_{it}$$

where the foreign variables $x_{it}^*$ are constructed as:

$$x_{it}^*\left(W_{i,\tau(t)}\right) = \sum_{j=0}^{N} W_{ij,\tau(t)}\, x_{jt}$$

and where $W_{ij,\,\tau(t)}$ is a matrix that contains the weights of $j$ in country $i$ at time $t$, for a given $\tau(t)$.  Here $\tau(t)$ is a generic rule that indexes the time-varying weights at each time period $t$. For instance, in our empirical application, for each quarter $t$, $\tau(t)$ refers to a three-year average of weights for the current year, $t$, and the previous two years, $t$-1 and $t$-2.

The foreign variables provide the link between the evolution of the domestic economy and the rest of the world and, in the country-specific model estimations, are taken as (weakly) exogenous — an assumption that is tested and holds in the data.

In the second step, the GVAR model is set up by stacking the estimated individual country-specific models and linking them with a matrix of predetermined cross-country linkages. Having estimated the country-specific parameters using the time-varying weights, the estimated country-specific models can now be combined and solved for any given trade weights based either on a particular year or on an average of weights from different time periods.

## References

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