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Spillovers of Domestic Shocks: Will They Counteract the 'Great Moderation'?*

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Abstract

The protracted decline in output volatility – the Great Moderation – began to reach its limits by the mid-1990s, and volatility even showed a mild rise in some countries. Domestic shocks did not typically rise but we find that they did spread more rapidly across borders. One reason for the faster transmission of domestic shocks was the increased fragmentation of production across multiple global locations that increasingly included the more volatile emerging markets. Although this development was generally benign, it had latent implications for triggering spikes in volatility since domestic stresses could rapidly spillover across borders. The cascading effects of such

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spillovers were vividly demonstrated by the trade collapse during the Great Recession of 2008–09.

I. Introduction

The precipitous decline in output and trade during the Great Recession of 2008–09 upended widely held presumptions of academics and policymakers. As financial markets gyrated, industrial production fell at the same rate as in the Great Depression and world trade tumbled even faster (Eichengreen and O'Rourke 2010). These developments came at a time when macroeconomists had come to regard the so-called 'Great Moderation' as an enduring feature of most advanced economies (Gali and Gambetti 2009). The expectation that macroeconomic stability would persist was reinforced by studies that viewed it as an outcome of advances in monetary policy, better inventory management and, even, financial innovation (Giannone et al. 2008; Gali and Gambetti 2009).[1] The possibility that the moderation was mainly due to 'good luck' (milder 'shocks' to the economic system) was generally discounted. The crisis came as a complete surprise to policy makers. In its assessment, the International Monetary Fund's Internal Evaluation Office (2011, p. 1) concluded: '... the IMF provided few clear warnings about the risks and vulnerabilities associated with the impending crisis before its outbreak. The banner message was one of continued optimism after more than a decade of benign economic conditions and low macroeconomic volatility'.

A new consensus is now emerging. Some view the crisis as marking the end of the Great Moderation (Qian et al. 2010). Indeed, Bean (2009) argues that the Great Moderation laid the seeds of its own demise by creating a false sense of security and excessive risk taking. In particular, the sense of security was enhanced by an inadequate appreciation of correlated risks across countries.

In this paper, we contribute to refining the new consensus. We describe the final years of the Great Moderation. These years continued to be characterized by relatively low aggregate volatility in most advanced economies, though with a tendency for increased volatility in some. There is also no indication, even in retrospect, that the factors that lay behind the Great Moderation were reversed. The change occurred largely outside the traditional focus of vulnerability analysis. The world's economies built strong linkages with each other, also bringing into the fold higher volatility emerging economies. The resulting

[1] Jaimovich and Siu (2009) argued that the changing age distribution of the workforce had helped: the labour input of young workers tends to be particularly volatile and the declining share of young workers in the workforce, they concluded, had accounted for one-fifth to one-third of the decline in GDP volatility.

interconnections between countries reinforced growth across borders but also implied that a 'negative shock' in one country would rapidly transmit to other countries, with strong cascading effects in periods of stress. The correlation of risks across countries increased not only because of financial interconnections but also because of trade linkages underlying the fragmentation of production across global locations. For the story we tell in this paper, the correlation of risks due to the unwinding of trade is important – this risk was manifest in the severe collapse of world trade following the onset of the crisis. Our analysis does not imply a trend reversal in the trajectory of output volatility. Rather, it suggests that volatility may spike episodically.

The Great Moderation was, in the first instance, a consequence of a widespread decline in domestic shocks on account of progress in policy-making and business practices. The decline in the variability of US GDP growth and the factors that lay behind it were noted about a decade ago by Kim and Nelson (1999), McConnell and Perez-Quiros (2000) and Blanchard and Simon (2001). Bernanke (2004) reported on similar declines in the volatility of output and inflation in other major industrial countries, with the exception of Japan.

There was also a favourable international component to the Great Moderation. In their study, Stock and Watson (2005) placed the global economy at centre stage. Their procedure allows for the decomposition of a country's GDP growth volatility into domestic, common international and spillover components. Common international shocks are defined as those experienced contemporaneously across countries and 'spillovers' are country-specific shocks that are transmitted to other countries with a lag. The Stock and Watson (2005) finding is that the Great Moderation was the consequence of a decline in international shocks.

However, the growing global interconnections had countervailing effects. Di Giovanni and Levchenko (2009a, 2009b) conclude that more openness to trade is associated with greater volatility because openness increases specialization in sectors that tend to be more volatile, with a larger role for big firms (see also Cecchetti et al. 2006). Global trade integration through vertical supply chains also increase business cycle correlation across countries, contributing to the possibility of spillovers of domestic shocks (Di Giovanni and Levchenko 2009c; Ng 2010). Moreover, Kalemli-Ozcan et al. (2010) find that international financial integration is associated with greater volatility since such integration increases the incentives to undertake riskier projects.

Thus, under the tranquil surface of the Great Moderation, there arose a growing potential for a sudden rise in global volatility. That potential lay not necessarily in a revival of domestic or common international shocks but rather in the significant and increasing share of international spillovers in the composition of volatility. The increasingly integrated global economy implied that a 'negative shock' in one country would be rapidly transmitted to other countries and from there to others, greatly amplifying the original shock. As long as domestic shocks

remained low, the volatility generated from spillovers was also limited. But that changed when the spillover potential was superimposed on larger shocks during the crisis. This phenomenon is distinct from other post-war episodes of international shocks and spillovers. For instance, the primarily common international oil shock in the 1970s was also reflected in spillovers as countries responded with different lags to the original shock.

To empirically assess the developments in the years before the recent crisis, we decompose the sources of volatility using the Stock and Watson (2005) framework on an expanded sample of countries and a longer panel of data. In particular, we increase the number of countries from the G-7 to 22 OECD members and extend the time period to the end of 2007. The larger number of countries over a longer time period reveals the emergence since the mid-1990s of more intense spillovers.

The paper has three main empirical findings. First, the trend reduction in output volatility may have ceased in many advanced industrialized countries by the mid-1990s, and a mild tendency towards increased volatility was evident in some countries. Besides Japan (documented by Bernanke 2004; Stock and Watson 2005), one large country experiencing an increase in output growth volatility was Germany. Second, and of greater significance for interpreting recent events, there was an increase in the contribution of spillovers to the still modest levels of volatility. Third, it was not the size of the spillover 'shocks' but the sensitivity of countries to these shocks that increased over time.

Our paper is related to the literature on the comovement of business cycles (Kose et al. 2005, 2008). In the cross-section, the higher a country's trade intensity, the higher is the comovement of its cycle with that of other countries; this, as noted, is particularly the case when trade is in the form of bilateral supply relationships (Di Giovanni and Levchenko 2009c; Ng 2010). However, an *increase* in global trade and finance intensities has not been accompanied by an *increase* in business cycle comovement. This is not altogether surprising. As Cecchetti et al. (2006) and Kose et al. (2008) note, comovement will not increase if greater integration is primarily associated with increased specialization. Hence, the extent of comovement depends on the nature of globalization. Our analysis suggests that in the mid-1990s, the tendency towards more rapid spillovers was associated with a particular form of trade integration, namely, an acceleration of vertical specialization. By linking countries in an international supply chain, such trade creates a tighter relationship between a country's exports and its imports, creating the conditions for swift production spillovers.[2]

[2]Forbes and Chinn (2004) conclude that bilateral trade linkages became substantially more important around 1995 in transmitting shocks across countries.

The analysis also highlights the role of emerging markets. Most visibly, Mexico, China and emerging Europe became nodal points in the global supply chain in the 1990s. Given their bilateral export and import relationships with key advanced industrialized economies, they served to transmit and amplify international shocks. Moreover, most emerging economies have not yet achieved the structural maturity necessary for dampening domestic volatility. Among countries with continuing high levels of volatility are Ireland and Iceland, both of which have also long been part of the global vertical specialization process. These countries thus contribute to the pool of international spillovers through their own national shocks and the transmission of external shocks to which they are subject.[3]

The rest of the paper is organized as follows. In Section II, we present the trends in output volatility, based on the Stock and Watson (2005) approach, but for a larger number of countries and through 2007. Section III then reports the decomposition of a country's volatility into its domestic, common international and spillover components. In Section IV, we decompose spillovers into the size of country shocks that contribute to global spillovers and the reactions to those shocks. In Section V, we relate the timing of increased spillover shares with the increase in vertical specialization and the role played by emerging markets in such specialization. The final section concludes.

II. Trends in Growth Volatility

We use quarterly values of the logarithm of per capita real GDP.[4] Stock and Watson (2005) cover the period 1950:Q1–2002:Q4, with several results presented for shorter samples, using the 'down-weighting' procedure discussed below. Their focus is on the G-7 economies. Our data start in 1960 and conclude in the last quarter of 2007, allowing estimation, and hence, analysis from 1977 through 2006. We add another 15 OECD economies to the sample of countries. Thus the countries for our analysis are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.[5]

[3]In interpreting the recent crisis, some may argue that emerging economies played a stabilizing role. However, our analysis points to their higher average volatilities as part of a feedback loop with material implications for global output volatility.

[4]The database used is the OETSADB, and the variable used is the 'Gross domestic product, volume, at market prices'. For population, we used population on December 31 in OECDALFS database, which was spliced quarterly to compute the per capita values.

[5]Of the OECD economies, we do not include the so-called transition countries – the Czech Republic, Hungary, Poland and Slovakia – since consistent data for them are available only from

As in Stock and Watson (2005), annualized quarter-on-quarter GDP growth rates are first detrended. For most of the analysis, the Baxter–King (1999) band pass (BP) filter with eight leads and lags and a pass-band of 6–32 quarters has been used. However, they use alternatives suitable for particular analyses, noting that the method of detrending does not influence the findings. The vector Y_t, of stacked detrended growth rates is regressed on its lag, Y_{t-1}.

$$Y_t = A(L)Y_{t-1} + \nu_t \tag{1}$$

Four lags for own country growth and one lag for other countries' growth are used. Thus, domestic shocks are assumed to have more lasting effects than foreign shocks.

Volatility is measured as the time-varying variance of this model. To compute volatility changes over time, rolling regressions are performed as follows. For each date, t, a regression is estimated by weighted least squares using two-sided exponential weighting. The observation at date s receives a weight of $\delta^{|t-s|}$, and δ is set to a value 0.97. Thus, observations further away from the point of interest, t, receive an exponentially lower weight. In our estimates s takes values between 1960:Q1 and 2007:Q4, while t takes values between 1977:Q1 and 2006:Q4. We allow t to run through the end of 2006 because we are interested in recent trends. But the implication is that the weighting is not symmetrical: in other words, observations towards the end of our sample have fewer observations ahead of them than the preceding observations.[6]

In Figure 1, the three lines represent the Stock and Watson (2005) estimates, our estimates when we use only the G-7 sample, and our estimates when all the 22 countries in our sample are included. It is reassuring that updating the sample does not change the story for the period covered by Stock and Watson (2005). The evidence of the Great Moderation through to the mid-1990s is clear even in the extended time period. What the extension does show is that the moderation does not persist beyond the mid-1990s, with some countries experiencing a modest increase from around 1995. The increase is most notable in Germany, and in Japan, which already had a documented high volatility. For the United States, the modest increase post-mid-1990s volatility is visible only

the mid-1990s. Also since increasing the size of the sample made the computation increasingly difficult, we dropped Luxembourg and New Zealand (which are relatively small) and Portugal and Greece (which did not add to the conclusions reached).

[6]We have estimated rolling variances of innovations with several starting and ending dates. As discussed below, our principal findings remain robust to the different time periods. The presentations focus on 1977–2006 because this period includes actual data for all countries, and has enough lags and leads to do all computations.

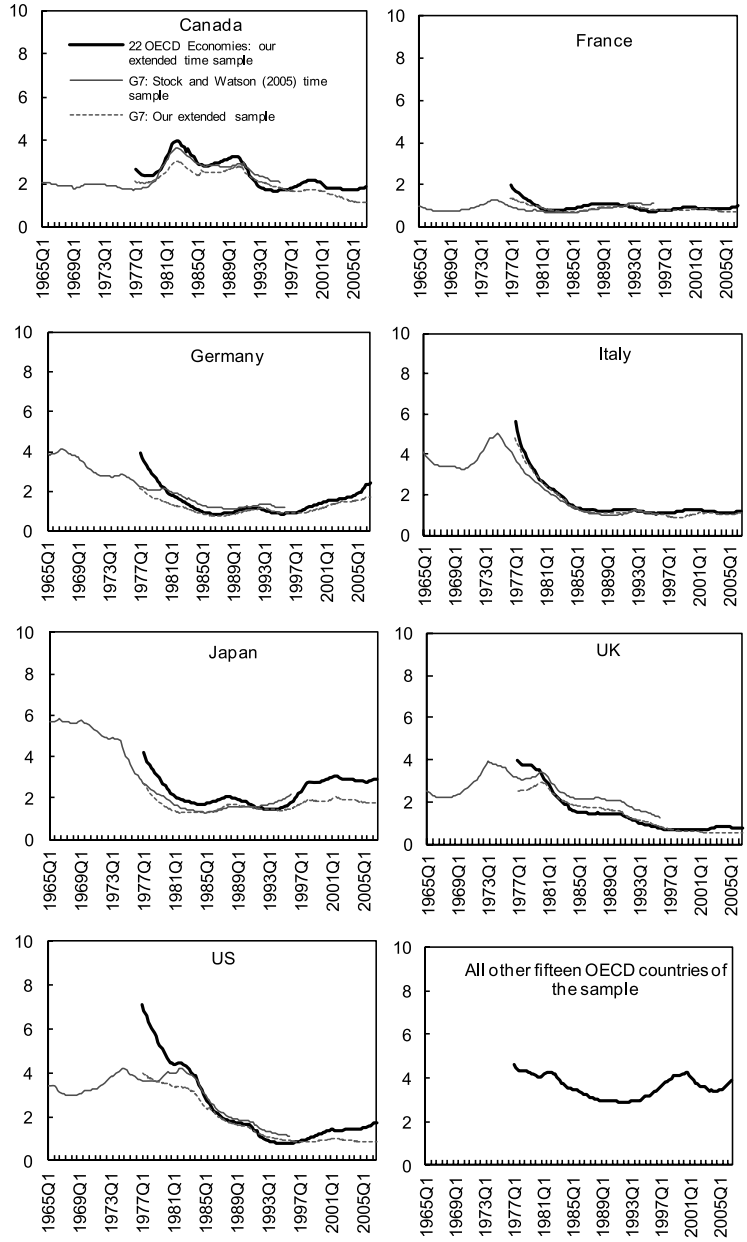

Figure 1: Evolution of output growth volatility in the main industrialized countries: different samples

Note: Output growth volatility measured as time-varying variance estimated with a two-factor structural Vector Autoregression, documented as in Figure 1 of this paper. For the last chart, Purchasing Power Parity weights have been used to compute the weighted average of the total output volatility of this group.

when the country sample is extended. The non-G-7 countries have had very varying experiences, although the evidence here is also suggestive of a flattening, or a mild increase, of volatility. The detailed results are shown for all countries in Appendix Figure A1, where a decomposition of the total volatility is also shown. While some of the advanced economies in that group have converged to low volatility levels, the emerging economies – Korea, Mexico and Turkey – and Ireland and Iceland have continued to experience high volatility.

In sum, after the long period of decline, output growth volatility stabilized and, more intriguingly, showed a modest tendency to increase in some countries. This increase is not definitive. Formal tests of breaks show evidence of a structural break in the period of interest for Belgium, Canada, Germany, Iceland, Ireland, Sweden and the United Kingdom (Table 1). Of course, the test allows only for a one-time break in variance. Hence, for some countries, the structural break is being picked up for an earlier break from a higher to lower volatility regime. Nevertheless, the fact that before the recent turmoil of 2008–09, there was a tendency for volatility to increase seems to us notable because it points to forces that were latent but had the potential of more virulent expression.

III. Sources of Volatility: The Role of International Spillovers

If the Great Moderation is moderating, or even reversing, can we gain further insight into this process by examining the sources of volatility? Stock and Watson (2005) attributed the decline in volatility associated with the Great Moderation, running from the 1960s through the mid-1990s, to the decline in common international shocks. We find that since the mid-1990s, when volatility has tended to stabilize or even increase, external impulses have once again been important, but this time not in the form of common global shocks but as spillovers.

To compute the decomposition of volatility, Stock and Watson (2005) use a reduced-form 'factor-structural' VAR (FSVAR). The FSVAR allows for a decomposition of the variance of the shocks into domestic shocks, common international shocks that affect all countries in the same quarter and spillovers – defined as country-specific shocks that affect other countries after one quarter. Thus, an event that occurs within the quarter is treated as a common shock whereas if the event affects countries sequentially spaced by at least a quarter, it is identified as a spillover.

The robust finding of this paper is the increase in the contribution of spillovers to country volatility. In the late 1970s, following the first oil shock of 1973 and in the midst of the second shock, international common shocks and, especially, international spillovers were the dominant contributors to the high volatility. Domestic volatility gained prominence in the mid-1980s. But spillovers re-emerged as a salient force in the mid-1990s. Despite the fact that the levels and trends

Table 1: Are the Changes in Volatility Pattern Statistically Significant? (Test for Breaks in Autoregressive Parameters)

		Conditional variance: break model	
	P	Break date	67% confidence interval
1. Australia	0.00	1985:2	1984:4–1986:4
2. Austria	0.00	1987:2	1987:1–1988:3
3. Belgium	0.00	1998:4	1994:3–1999:3
4. Canada	0.00	1991:2	1990:4–1993:1
5. Denmark	0.00	1991:3	1979:3–1991:4
6. Finland	0.00	1969:3	1961:2–1969:3
7. France	0.03	1980:2	1979:3–1984:3
8. Germany	0.03	1993:1	1992:3–1997:1
9. Iceland	0.00	1997:1	1989:3–1997:2
10. Ireland	0.00	1997:3	1993:1–1997:4
11. Italy	0.00	1984:4	1984:2–1986:4
12. Japan	0.05	1974:1	1973:1–1978:2
13. Korea	0.00	1980:2	1979:2–1981:4
14. Mexico	0.00	1979:4	1972:3–1980:2
15. Netherlands	0.00	1987:2	1987:1–1989:2
16. Norway	0.00	1977:4	1964:4–1978:1
17. Spain	0.00	1984:4	1969:3–1985:2
18. Sweden	0.00	1992:4	1992:3–1994:4
19. Switzerland	0.00	1972:2	1971:4–1973:2
20. Turkey	0.00	1986:4	1974:3–1987:1
21. United Kingdom	0.00	1990:4	1990:3–1992:2
22. United States	0.00	1983:2	1982:4–1985:2

Note: These results are based on Autoregressive mode, AR (4) models estimated using $\Delta\ln(GDPt/GDPt-1)$.
They refer to changes in the AR innovations (see Stock and Watson 2005).
The 'break model' allows a one-time break in the variance. The column labelled '*P*' is the *P*-value of the test statistic under the null hypothesis of no change.
'Break date' is the estimated date of a one-time shift in the parameters (reported only if the *P*-value is less than 5%); and the confidence interval is for the break date.

in volatility differ across countries, as discussed, the rise in the contribution of spillovers has played out in a remarkably similar manner across countries. Domestic shocks have declined to compensate for the increase in spillovers.

In Table 2, we decompose volatility (measured here as in Stock and Watson 2005, as the forecast error of the standard deviation) for the periods 1977–94 and 1995–2007. The share of spillovers in this forecast error increased in all countries – and typically at all horizons (as noted above, at the one-quarter horizon, spillovers are by assumption zero). With that increase, in the post-1995 period, at the four- and eight-quarter horizons, the share of spillovers ranged between half and three-quarters, thus forming the dominant source of volatility. The decline in the share of other sources of volatility occurred differently for

Table 2: Variance Decompositions Based on the Two-Factor Structural VAR: Common Shocks, Spillovers and Own-Country Shocks

		1977–94				1995–2007			
			Fraction of forecast error variance due to				Fraction of forecast error variance due to		
Country	Horizon	Forecast error standard deviation	International	Spillovers	Own shock	Forecast error standard deviation	International	Spillovers	Own shock
Australia	1	3.26	0.02	0.00	0.98	1.59	0.50	0.00	0.50
	2	2.51	0.01	0.09	0.89	1.25	0.48	0.19	0.33
	4	1.99	0.01	0.27	0.72	1.11	0.29	0.47	0.24
	8	1.61	0.02	0.46	0.52	1.19	0.10	0.79	0.12
Austria	1	2.22	0.28	0.00	0.72	0.46	0.01	0.00	0.99
	2	1.84	0.30	0.21	0.49	0.58	0.01	0.15	0.84
	4	1.39	0.32	0.28	0.40	0.62	0.01	0.57	0.42
	8	1.02	0.30	0.32	0.38	0.69	0.04	0.68	0.28
Belgium	1	0.64	0.52	0.00	0.48	1.08	0.07	0.00	0.93
	2	0.75	0.59	0.06	0.36	0.80	0.07	0.26	0.66
	4	0.91	0.58	0.18	0.24	0.86	0.06	0.61	0.33
	8	0.77	0.48	0.37	0.15	0.78	0.14	0.74	0.13
Canada	1	2.25	0.05	0.00	0.95	1.03	0.54	0.00	0.46
	2	2.11	0.07	0.12	0.81	1.09	0.46	0.20	0.35
	4	1.89	0.05	0.28	0.67	1.07	1.40	0.36	0.24
	8	1.76	0.06	0.35	0.58	1.11	0.21	0.68	0.11

Table 2: Continued

		1977–94				1995–2007			
			Fraction of forecast error variance due to				Fraction of forecast error variance due to		
Country	Horizon	Forecast error standard deviation	International	Spillovers	Own shock	Forecast error standard deviation	International	Spillovers	Own shock
Denmark	1	2.40	0.17	0.00	0.83	2.81	0.05	0.00	0.95
	2	1.99	0.18	0.06	0.76	1.92	0.03	0.37	0.60
	4	1.90	0.18	0.10	0.71	1.56	0.04	0.55	0.41
	8	1.39	0.16	0.21	0.63	1.22	0.10	0.61	0.30
Finland	1	3.95	0.04	0.00	0.96	1.33	0.28	0.00	0.72
	2	2.93	0.04	0.20	0.46	1.09	0.26	0.29	0.45
	4	2.61	0.04	0.22	0.74	1.13	0.24	0.48	0.28
	8	2.52	0.03	0.38	0.59	1.47	0.15	0.67	0.17
France	1	1.24	0.53	0.00	0.47	0.97	0.30	0.00	0.70
	2	1.03	0.42	0.20	0.38	0.72	0.25	0.18	0.56
	4	0.97	0.38	0.34	0.28	0.66	0.13	0.53	0.34
	8	0.80	0.30	0.53	0.18	0.71	0.08	0.72	0.20
Germany	1	2.79	0.34	0.00	0.66	1.29	0.02	0.00	0.98
	2	2.09	0.32	0.25	0.43	1.23	0.04	0.39	0.57
	4	1.51	0.34	0.36	0.29	1.35	0.02	0.71	0.26
	8	1.22	0.35	0.41	0.24	1.43	0.02	0.81	0.17
Iceland	1	1.03	0.00	0.00	1.00	6.34	0.30	0.00	0.70
	2	1.45	0.00	0.03	0.96	4.26	0.17	0.42	0.41
	4	1.95	0.01	0.14	0.85	2.75	0.13	0.54	0.33
	8	2.23	0.02	0.35	0.63	2.00	0.10	0.66	0.25

Table 2: Continued

		1977–94				1995–2007			
			Fraction of forecast error variance due to				Fraction of forecast error variance due to		
Country	Horizon	Forecast error standard deviation	International	Spillovers	Own shock	Forecast error standard deviation	International	Spillovers	Own shock
Ireland	1	0.86	0.15	0.00	0.85	4.68	0.06	0.00	0.94
	2	1.18	0.15	0.04	0.81	3.17	0.03	0.24	0.72
	4	1.61	0.16	0.13	0.71	2.62	0.02	0.47	0.51
	8	1.56	0.15	0.26	0.59	2.53	0.01	0.71	0.28
Italy	1	1.87	0.11	0.00	0.89	1.17	0.03	0.00	0.97
	2	1.61	0.15	0.09	0.76	1.04	0.05	0.37	0.59
	4	1.31	0.21	0.22	0.56	0.92	0.02	0.65	0.33
	8	1.07	0.18	0.39	0.43	0.84	0.09	0.78	0.13
Japan	1	2.25	0.02	0.00	0.97	1.59	0.13	0.00	0.87
	2	1.60	0.03	0.25	0.73	2.08	0.14	0.46	0.39
	4	1.36	0.05	0.34	0.60	2.27	0.16	0.62	0.22
	8	1.37	0.08	0.47	0.45	2.48	0.20	0.63	0.17
Korea	1	3.88	0.09	0.00	0.91	2.54	0.37	0.00	0.63
	2	3.05	0.06	0.16	0.78	2.52	0.33	0.29	0.37
	4	2.41	0.07	0.28	0.65	2.72	0.34	0.41	0.25
	8	1.98	0.06	0.40	0.54	2.52	0.38	0.43	0.18
Mexico	1	3.22	0.11	0.00	0.89	2.83	0.18	0.00	0.82
	2	2.52	0.08	0.19	0.72	2.45	0.14	0.33	0.53
	4	2.34	0.11	0.33	0.56	2.14	0.09	0.61	0.30
	8	2.18	0.11	0.50	0.38	1.88	0.06	0.80	0.14

Table 2: Continued

		1977–94				1995–2007			
			Fraction of forecast error variance due to				Fraction of forecast error variance due to		
Country	Horizon	Forecast error standard deviation	International	Spillovers	Own shock	Forecast error standard deviation	International	Spillovers	Own shock
Netherlands	1	3.72	0.40	0.00	0.60	1.21	0.08	0.00	0.92
	2	2.64	0.38	0.18	0.43	1.09	0.03	0.20	0.77
	4	1.98	0.35	0.31	0.34	1.07	0.02	0.43	0.55
	8	1.51	0.31	0.40	0.28	1.35	0.02	0.52	0.46
Norway	1	4.04	0.22	0.00	0.78	2.06	0.54	0.00	0.46
	2	2.64	0.21	0.19	0.60	2.19	0.23	0.66	0.10
	4	1.92	0.19	0.24	0.57	1.49	0.26	0.64	0.10
	8	1.57	0.15	0.32	0.52	1.07	0.17	0.74	0.09
Spain	1	2.65	0.36	0.00	0.64	0.74	0.14	0.00	0.86
	2	1.87	0.35	0.11	0.54	0.65	0.11	0.20	0.70
	4	1.76	0.35	0.12	0.53	0.67	0.06	0.47	0.47
	8	1.63	0.32	0.18	0.50	0.83	0.04	0.69	0.27
Sweden	1	3.50	0.02	0.00	0.98	0.94	0.13	0.00	0.87
	2	2.64	0.08	0.19	0.73	0.97	0.20	0.25	0.54
	4	2.02	0.12	0.33	0.55	1.10	0.26	0.33	0.41
	8	1.81	0.08	0.57	0.35	1.07	0.27	0.52	0.21
Switzerland	1	1.74	0.35	0.00	0.65	1.38	0.20	0.00	0.80
	2	1.49	0.26	0.19	0.55	1.47	0.15	0.35	0.49
	4	1.40	0.24	0.34	0.42	1.57	0.07	0.62	0.31
	8	1.26	0.18	0.48	0.34	1.33	0.03	0.75	0.22

Table 2: Continued

		1977–94				1995–2007			
			Fraction of forecast error variance due to				Fraction of forecast error variance due to		
Country	Horizon	Forecast error standard deviation	International	Spillovers	Own shock	Forecast error standard deviation	International	Spillovers	Own shock
Turkey	1	5.80	0.06	0.00	0.94	4.71	0.24	0.00	0.76
	2	4.46	0.03	0.18	0.79	5.07	0.23	0.44	0.33
	4	3.42	0.04	0.27	0.69	5.03	0.18	0.67	0.14
	8	2.33	0.07	0.33	0.60	4.36	0.18	0.76	0.05
United Kingdom	1	2.44	0.09	0.00	0.91	0.72	0.26	0.00	0.74
	2	1.88	0.08	0.31	0.61	0.66	0.20	0.18	0.62
	4	1.58	0.11	0.37	0.52	0.68	0.14	0.42	0.44
	8	1.39	0.12	0.43	0.46	0.72	0.08	0.68	0.24
United States	1	2.86	0.20	0.00	0.80	1.11	0.19	0.00	0.81
	2	2.34	0.17	0.11	0.72	1.05	0.24	0.36	0.41
	4	1.93	0.17	0.25	0.58	0.99	0.16	0.58	0.27
	8	1.52	0.19	0.34	0.46	1.06	0.09	0.76	0.15

Note : This table shows the standard deviation and three-way decomposition of variance of filtered annual GDP growth at quarterly observations. The standard deviations are in percentage points at annual rate [(400/h) times the forecast error, where h is the forecast horizon]. These results are based on the two-factor structural VAR model using the detrended growth.

different countries, with international shocks contributing less in some and domestic shocks contributing less in others.

It is worth noting that a larger sample of countries tends to give larger shares of spillovers at any given point in time. Working with the larger sample is appropriate in our view since it captures the substantive idea that the economic boundaries of the world are bigger and the world is more interconnected. The bigger the sample, the more complex the interactions, implying that shocks are not necessarily transmitted all at once, and importantly, may be transmitted via other third countries. When estimation is restricted to the G-7 sample but for our extended time period, the result implies more common shocks and fewer spillovers than the results presented above for the full sample of countries. However, this appearance of a greater common international shock with the focus on the G-7 countries is misleading. When the other countries are not included in the sample, the spillovers from them are largely perceived as a common shock to the G-7 countries. To the extent that the other countries have grown in economic importance – particularly in their role in the vertical integration process – the spillover component will continue to be missed if the focus is on the G-7 economies.

IV. More Spillovers or a Faster Response to Foreign Impulses?

If the share of spillovers has increased, the final question is as follows: was there an increase in country-specific shocks that contributed to the spillovers or did the sensitivity to foreign shocks increase?

We proceed as follows. Let V_p denote the variance of the four-quarter ahead forecast errors in a given country, calculated using the VAR, in a period p where $p = 1$ or 2 corresponding to 1977–94 or 1995–2007. The variance decomposition attributes a portion of V_p to each of the 24 shocks in the model (the international shock, domestic shock and 22 sources of spillover shocks). We can write $V_p = V_{p,1} + \cdots + V_{p,j} + \cdots V_{p,24}$, where $V_{p,j}$, the variance in period p attributed to shock j. Thus the change in the variance between the two periods is $V_2 - V_1 = (V_{2,1} - V_{1,1}) + \cdots + (V_{2,j} - V_{1,j}) + (V_{2,24} - V_{1,24})$.

As Stock and Watson (2005) note, in an identified structural VAR, the variance component $V_{p,j}$ can be rewritten as $a_{pj}\sigma^2_{pj}$, where a_{pj} is a term dependent on the squared cumulative impulse response to shock j in period p and σ^2_{pj} is the variance of shock j in period p. Thus, the change in contribution of the jth shocks can be decomposed as

$$V_{2j} - V_{1j} = \left(\frac{a_{1j} + a_{2j}}{2}\right)\left(\sigma^2_{2j} - \sigma^2_{1j}\right) + \left(\frac{\sigma^2_{1j} + \sigma^2_{2j}}{2}\right)\left(a_{2j} - a_{1j}\right).$$

That is, the change in the variance can be decomposed into the contribution from the change in the shock variance plus the contribution from the change in the impulse response. To ensure an identified VAR, we assume, as in Stock and Watson (2005), that the factor loadings are uncorrelated and that the second factor has no impact effect on the United States. This, in turn, yields plausible factors.

The results in Table 3 suggest the following principal findings. Virtually everywhere, the shock variance itself declined over time (20 out of 22 countries). The decline in this shock variance also reflected a decline in spillover shocks. In contrast, the response to shocks increased virtually everywhere (15 out of 22 countries). The response to spillover shocks increased more broadly (17 out of 22 countries). And where the aggregate response coefficient increased, the main contributor to that increased response was typically the response to spillover shocks. Thus, for example, in Germany and Japan, the aggregate change in the response coefficient would have been negative if not for the coefficient on spillovers.[7]

To provide a quantitative sense of these changes, we ask the following question: what would volatility in the second period have been if the shocks were of the same size as in the first period but the response was as in the second period? In other words, we use the transmission mechanism of the second period and the shocks from the earlier part of the sample to calculate the counterfactual. The calculations are based on the standard deviation of annual GDP-filtered growth computed using the two-factor structural VAR. The counterfactual in Figure 2 shows that volatility would have been substantially higher in all countries.

V. Interpreting the Results

What accounts for the increased role of spillovers and their speed? In this section, we offer a tentative explanation. Though the nature of globalization in recent decades has been multifaceted, encompassing trade and finance, one particular development seems to fit the timing of increased spillover shares as well the speed of spillovers. The rise in global trade intensity has been increasingly characterized by vertical specialization, with a central role for emerging markets. Vertical specialization occurs when countries engage primarily in a particular stage of a product's processing. Thus the material for a garment may

[7]Thus, while Forbes and Chinn (2004) document spillovers in financial markets from major industrialized to emerging markets, our results could imply that the industrialized countries were also the recipients of spillovers.

Table 3: Then and Now – Were the Shocks Larger or the Transmission Different?

	Variances			Contribution of change in shock Variance				Contribution of change in impulse response function			
	1977–94 Column 1	1995–2007 Column 2	Change Column 3	Total Column 4	International Column 5	Spillovers Column 6	Own Column 7	Total Column 8	International Column 9	Spillovers Column 10	Own Column 11
Australia	3.96	1.24	−2.72	−3.99	0.06	−1.74	−2.31	1.27	0.26	1.25	−0.24
	(0.76)	(0.22)	(0.79)	(0.92)	(0.16)	(0.78)	(0.48)	(1.01)	(0.32)	(0.90)	(0.35)
Austria	1.92	0.39	−1.54	−2.18	−0.06	−0.5	−1.62	0.65	−0.54	0.18	1.01
	(0.39)	(0.06)	(0.40)	(0.60)	(0.11)	(0.45)	(0.37)	(0.67)	(0.24)	(0.50)	(0.31)
Belgium	0.82	0.73	−0.09	−0.54	−0.02	−1.07	0.55	0.45	−0.41	1.37	−0.51
	(0.16)	(0.11)	(0.19)	(0.37)	(0.10)	(0.33)	(0.12)	(0.44)	(0.18)	(0.38)	(0.10)
Canada	3.56	1.14	−2.43	−3.75	−0.01	−1.44	−2.29	1.32	0.27	0.87	0.18
	(0.68)	(0.21)	(0.72)	(0.85)	(0.19)	(0.65)	(0.48)	(0.95)	(0.38)	(0.74)	(0.38)
Denmark	3.59	2.43	−1.16	−1.43	0.10	−2.45	0.91	0.27	−0.67	3.41	−2.47
	(0.71)	(0.41)	(0.82)	(1.38)	(0.24)	(1.29)	(0.45)	(1.69)	(0.50)	(1.49)	(0.46)
Finland	6.83	1.27	−5.56	−3.98	−0.01	0.25	−4.23	−1.58	0.00	−1.15	−0.43
	(1.25)	(0.20)	(1.27)	(1.81)	(0.21)	(1.58)	(0.80)	(1.88)	(0.50)	(1.72)	(0.53)
France	0.94	0.44	−0.51	−0.39	0.00	−0.37	−0.02	−0.12	−0.30	0.28	−0.10
	(0.17)	(0.07)	(0.19)	(0.31)	(0.08)	(0.29)	(0.07)	(0.36)	(0.16)	(0.32)	(0.05)
Germany	2.29	1.83	−0.46	−3.05	−0.05	−2.25	−0.75	2.58	−0.70	2.72	0.57
	(0.44)	(0.30)	(0.54)	(1.19)	(0.21)	(1.14)	(0.24)	(1.43)	(0.38)	(1.30)	(0.20)
Iceland	3.80	7.59	3.79	32.92	0.08	−9.15	41.99	−29.13	0.90	12.73	−42.75
	(0.67)	(1.23)	(1.40)	(9.36)	(0.46)	(3.84)	(8.47)	(9.67)	(0.80)	(4.52)	(8.24)

Table 3: Continued

	Variances			Contribution of change in shock Variance				Contribution of change in impulse response function			
	1977–94 Column 1	1995–2007 Column 2	Change Column 3	Total Column 4	International Column 5	Spillovers Column 6	Own Column 7	Total Column 8	International Column 9	Spillovers Column 10	Own Column 11
Ireland	2.58	6.85	4.27	22.61	−0.01	−8.37	30.99	−18.34	−0.27	11.23	−29.30
	(0.46)	(1.21)	(1.28)	(6.23)	(0.40)	(3.25)	(5.32)	(6.41)	(0.78)	(3.80)	(4.99)
Italy	1.71	0.85	−0.86	−1.53	−0.04	−1.02	−0.47	0.67	−0.31	1.19	−0.21
	(0.33)	(0.14)	(0.36)	(0.64)	(0.11)	(0.61)	(0.15)	(0.76)	(0.22)	(0.69)	(0.13)
Japan	1.84	5.14	3.29	−5.51	0.13	−4.64	−1.00	8.80	0.58	7.19	1.03
	(0.30)	(0.93)	(0.98)	(2.69)	(0.47)	(2.58)	(0.33)	(3.32)	(0.88)	(3.05)	(0.33)
Korea	5.80	7.40	1.60	−9.88	0.30	−6.67	−3.50	11.47	1.79	8.13	1.55
	(1.14)	(1.40)	(1.81)	(3.26)	(0.79)	(2.87)	(0.94)	(4.17)	(1.55)	(3.37)	(0.82)
Mexico	5.49	4.58	−0.91	−4.51	−0.08	−3.72	−0.71	3.60	−0.08	4.69	−1.01
	(0.94)	(0.78)	(1.23)	(3.65)	(0.38)	(3.58)	(0.48)	(4.15)	(0.77)	(3.99)	(0.41)
Netherlands	3.91	1.14	−2.77	−3.36	−0.15	−1.05	−2.16	0.59	−1.21	0.33	1.47
	(0.75)	(0.20)	(0.78)	(0.99)	(0.25)	(0.76)	(0.61)	(1.20)	(0.47)	(0.90)	(0.52)
Norway	3.70	2.21	−1.49	−4.13	−0.07	−2.55	−1.51	2.64	−0.05	3.07	−0.38
	(0.71)	(0.36)	(0.80)	(1.43)	(0.27)	(1.35)	(0.33)	(1.66)	(0.49)	(1.54)	(0.20)
Spain	3.11	0.45	−2.66	−1.34	0.15	0.16	−1.64	−1.32	−1.22	−0.31	0.21
	(0.61)	(0.07)	(0.61)	(0.80)	(0.21)	(0.64)	(0.45)	(0.90)	(0.48)	(0.71)	(0.24)
Sweden	4.09	1.20	−2.89	−2.18	0.04	2.47	−4.68	−0.71	−0.20	−3.44	2.93
	(0.73)	(0.21)	(0.76)	(1.84)	(0.20)	(1.55)	(0.91)	(1.86)	(0.43)	(1.66)	(0.76)
Switzerland	1.97	2.45	0.48	−3.48	−0.03	−3.25	−0.21	3.97	−0.28	4.10	0.14

Table 3: Continued

	Variances			Contribution of change in shock Variance				Contribution of change in impulse response function			
	1977–94 Column 1	1995–2007 Column 2	Change Column 3	Total Column 4	International Column 5	Spillovers Column 6	Own Column 7	Total Column 8	International Column 9	Spillovers Column 10	Own Column 11
	(0.36)	(0.42)	(0.55)	(1.31)	(0.23)	(1.27)	(0.23)	(1.57)	(0.46)	(1.46)	(0.18)
Turkey	11.72	25.34	13.62	−39.84	−0.27	−36.06	−3.51	53.46	4.51	49.89	−0.94
	(2.26)	(4.48)	(5.06)	(13.09)	(1.94)	(12.79)	(1.40)	(16.13)	(3.78)	(15.17)	(1.31)
United Kingdom	2.50	0.46	−2.05	−2.56	0.06	−0.67	−1.95	0.51	−0.26	−0.07	0.85
	(0.44)	(0.08)	(0.45)	(0.55)	(0.10)	(0.35)	(0.42)	(0.59)	(0.24)	(0.40)	(0.34)
United States	3.72	0.99	−2.73	−1.71	0.19	−0.26	−1.64	−1.02	−0.67	−0.09	−0.25
	(0.74)	(0.16)	(0.76)	(1.09)	(0.24)	(0.98)	(0.40)	(1.30)	(0.49)	(1.13)	(0.26)
G-7	2.76	1.65	−1.11	−2.49	0.11	−1.30	−1.30	1.31	−0.35	1.52	0.15
All others	4.57	4.76	0.19	−7.17	0.02	−5.36	−1.82	7.36	0.30	6.93	0.13

Note: Decomposition of changes in the variance of four-quarter-ahead FSVAR forecast errors into changing impulses and changing propagation.
The first three columns give variance of band pass (BP) filtered GDP (in percentage points) by subsamples, using the estimated FSVAR (identified as described in Section II and following Stock and Watson 2005). The remaining columns decompose this difference into changes in the variance of the shocks, and changes in the impulse response function. The sum of the international, 'spillovers' and 'own' column equals the 'total' column. In parentheses, we report estimated standard errors.
(2) − (1) = (3).
(3) = (4) + (8).
(4) = (5) + (6) + (7) (8) = (9) + (10) + (11).

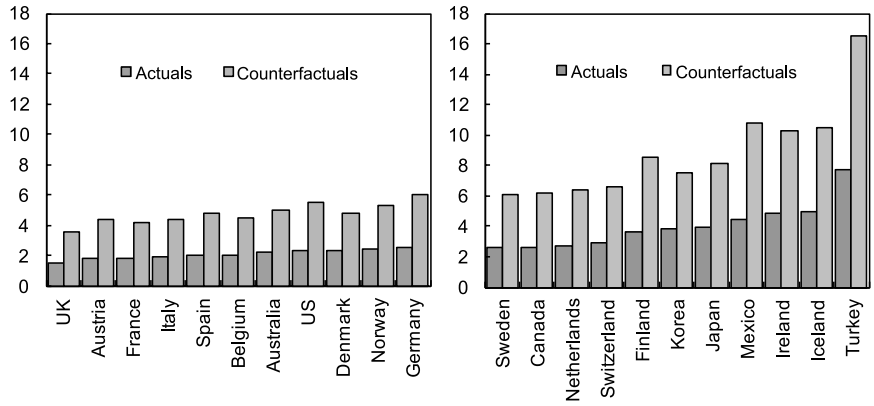

Figure 2: Actual and counterfactual volatility for 1995–2007 (standard deviation of annual growth)

Note: At quarterly level, computed using a two-factor structural VAR. Actual volatility refers to the standard deviation of annual growth of filtered growth computed using estimated parameters for 1995–2007, and variances of shocks (common and own) for period 1995–2007. Counterfactual volatility refers to the standard deviation computed using estimated parameters for 1995–2007, but the variances of shocks for 1977–94.

be cut in the United States, the cut pieces may be sewed in Jamaica and the final packaging done in Europe for customers on that continent. More elaborate vertical specialization may occur in the assembly of electronics products and automobiles.

Vertical specialization increases the trade content of production while increasing global interconnectedness (Yi 2003). Because of the interconnections, Yi (2003) argues that vertical specialization responds non-linearly to lower tariffs and other reductions in trade costs and, as such, can account for a substantial fraction of the increase in the trade share of global production. The non-linearities inherent in vertical specialization imply that it is a natural mechanism of sizeable and speedy spillovers.

A few studies document the rise in vertical specialization over the time span of interest to us. Breda et al. (2008) estimate vertical specialization – measured as the import content of exports – for several European countries from 1995 to 2000. They reach an important conclusion (p. 10): 'Our evidence supports a significant increase between 1995 and 2000 in the vertical specialization of the countries considered, fairly comparable in terms of magnitude with that detected over a 20-year period by Hummels et al. (2001)'. In Europe, the production of transport equipment emerged as the most vertically specialized sector and Germany as the

country most rapidly increasing its vertical specialization.[8] The timing of this sharp rise in vertical specialization documented by Breda et al. (2008) coincides with the increased share of spillovers in country volatility, as estimated in this paper.

The timing is also consistent with a more prominent role played by emerging economies in the global vertical specialization process. Anticipating the North American Free Trade Agreement (NAFTA), which came into force in 1994, an increasing share of sales of Mexican affiliates was to parent companies in the United States, reaching one-third of all sales by 2000. Noting this development, Burstein et al. (2008) also find that the comovement of Mexican and United States business cycles increased along with the vertical integration. This period also saw the emergence of China as a global source of manufactured products. Koopman et al. (2008) find that imports accounted for about half of Chinese exports between 1997 and 2006, this high ratio reflecting the importance of 'processing' exports.[9] And, at the same time, the formerly planned economies of Eastern Europe emerged as suppliers within Europe – in Sinn's (2006) language, the 'work benches' of Germany moved to Eastern Europe.

Thus, the evidence is that there was a general acceleration of vertical specialization in the early- to mid-1990s aided by the greater role of lower wage emerging economies that formed key links in global supply chains. With vertically specialized trade closely tied to production decisions, this timing is consistent with the increased importance of spillovers of shocks to GDP growth. As a further exercise we examined whether the increased share of spillovers in an individual country's volatility was also related to its increased vertical specialization. The results are supportive, though by no means conclusive. The left panel of Figure 3 plots the increase in the share of spillovers against the increase in vertical specialization between 1995 and 2000 for all countries for which the OECD reports the vertical specialization measure. There is a positive relationship between vertical specialization and spillovers. It is, however, a suggestive but not a tight relationship, with a *t*-statistic of 1.56. The United Kingdom and Denmark reduced their vertical specialization and experienced relatively small increases in their share of spillovers; at the other end, Spain and Korea experienced sizeable increases on both dimensions. In contrast, the United States and Finland experienced large increases in their spillover share without a correspondingly large increase in

[8] Sinn (2006) also notes Germany's propensity to engage in vertical specialization during the same period: the import share of German exports increased from 27% in 1991 to 39% in 2002. Sinn, however, regards this trend as an unwelcome development, characterizing Germany as increasingly a 'the bazaar economy'. Manufacturing goods on their way from Slovakia to America pass, he says, through German statistics.

[9] Absence of comparable data precluded inclusion of China in this analysis.

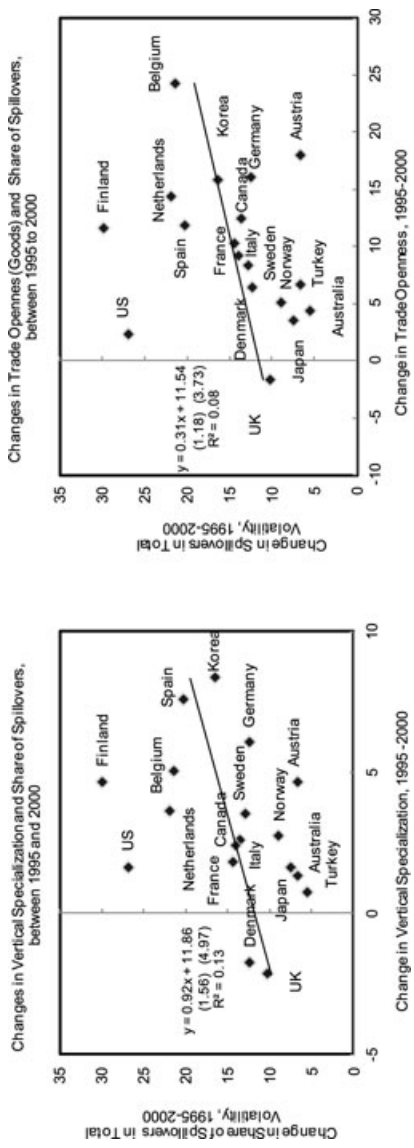

Figure 3: Role of trade globalization in the change of spillovers

Note: (1) Sample includes only 18 countries, as data for vertical specialization are not available for 1995 for Iceland, Ireland, Mexico and Switzerland, and 2000 for Iceland and Mexico. Regression estimated with Ordinary Least Squares. *t*-Statistics of coefficients are shown in parentheses. (2) Trade openness measured as the sum of exports and imports over the GDP, expressed in nominal terms, US dollars. To ensure comparability, the left- and right-hand-side panels have the same countries.
Source: OECD, WEO and IMF staff calculations.

vertical specialization. In the right panel of Figure 3, we plot the increase in the share of spillovers against the increase in trade/GDP ratios of the same countries. This line also slopes upwards, which is not surprising since the increase in trade shares and increase in vertical specialization are highly correlated. However, the generally weaker relationship between trade intensity and spillovers (in terms of the *t*-statistic and *R*-squared) suggests that it is the vertical specialization component of trade intensity that matters for spillovers.

Finally, while increased vertical specialization and a more prominent role of spillovers occurred during a relatively benign global economic period (punctuated by brief crises), the virulent downturn that started in the spring of 2008 is consistent with the analysis laid out in this section. The precipitous fall in global production was associated with an even more precipitous decline in global trade. While many explanations have been offered for this fall in trade, a plausible explanation has been the importance of vertical specialization, which can unwind in a non-linear manner (Levchenko et al. 2009; Yi 2009). As Yi (2009) emphasizes, a feature of vertical specialization is the speed at which it acts. Thus, while vertical specialization acted to support production and trade during the long period of globally coordinated expansion, the same mechanism acted more malignantly to reinforce the crisis. Bems et al. (2010, 2011) point the finger at these cross-border supply relationships for more than 70% of the collapse in world trade during the recent crisis, creating a pace of decline greater than during the Great Depression.[10]

An earlier phase – the 1960s and 1970s – identified by Stock and Watson (2005) as a period of common and spillover shocks, differed in character. They find that their estimated common global factors are most closely correlated with shocks to oil prices and other industrial materials. To the extent that these shocks affected individual countries with somewhat different timings, their methodology would also interpret the dynamics as spillovers. The contrast with the recent period is clear: the more integrated global economy creates spillovers through strong production and trade linkages.

VI. Conclusions

The Great Moderation was a well-established trend with causes that, in turn, were durable. Volatility declined because of improved policy management and innovations in the private sector. But at the same time, the global economy was

[10]Financial shocks had direct spillover effects through the global interconnections of banks (Eichengreen et al. 2009) and vertical specialization acted to transmit the shocks to the global 'real' economy.

integrating. This other trend, we find, laid the basis for a countervailing effect: the possibility of rapid international transmission of a country's volatility was a latent source of volatility amplification. In a benign pre-crisis global environment, the international transmission mechanism also worked in a benign manner. However, the sense of panic in the past few years was due not just to large common shocks – impinging on the financial sectors and the real economies of several countries – but also due to the rapid pace with which the crisis crossed borders.

A case could be made that the very achievement of the Great Moderation has resulted in greater global fragility. Stability allowed the expansion of vertical specialization across borders, a specialization that demanded a high degree of reliability of transactions across borders. Vertical specialization raised global production possibilities and economic welfare. Once the crisis started, however, these cross-border supply relationships were key to the collapse in world trade.

The policy response demanded by these developments presents a challenge. Strong interconnections and, especially, their high speed are now part of the global economic and financial fabric. The need, therefore, for international policy coordination is evident. This need was manifest during the recent crisis and the urgency of the moment dictated coordination (to varying degrees) of short-term monetary and fiscal policies. This was not a choice: all countries had to play their part to achieve the required scale of response (Eichengreen and O'Rourke 2010). That same urgency also led to the recognition that coordination cannot just be a reaction to emergencies but needs to be forward looking and proactive. And here is where the challenges have arisen. The closest the world has to a policy coordination framework is in the G-20 forum. Angeloni and Pisani-Ferry (2011, p. 2) write that once the existential risks of the crisis receded, the G-20 'started to engage in the more routine task of crisis prevention, mainly through attempts at economic policy coordination. Here its performance has been less than convincing and criticism of its effectiveness has increased'. In particular, there is no appetite within this forum for binding agreements and consequently it must work mainly through peer influence. This outcome should not be a surprise since the range of issues requiring attention is broad and the perspectives on them vary.

Either because the strength of spillovers is not adequately recognized or because nations are unwilling to cede sovereignty, the desired coordination of pre-emptive action 'looks unlikely at present' (Angeloni and Pisani-Ferry 2011, p. 6). The best, therefore, that can be achieved in today's setting is an appeal to a country's self-interest with the expectation that a significant subset of domestically valuable measures will also have globally beneficial outcomes. Hence, we are back full circle, as Obstfeld and Rogoff (2002) pointed out a while ago.

Ultimately, more domestic action to prevent and contain crises is crucial. This will require pre-emptive restraint of the development of asset price and credit booms, and the simultaneous creation of shock absorbers (larger public and private financial buffers, including through contingent instruments). Each of these actions is controversial and has costs in terms of foregone growth or fiscal claims. But more vigorous self-interested protection against low-probability events may be the only bulwark against the next crisis criss-crossing borders with ruinous consequences.

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Appendix

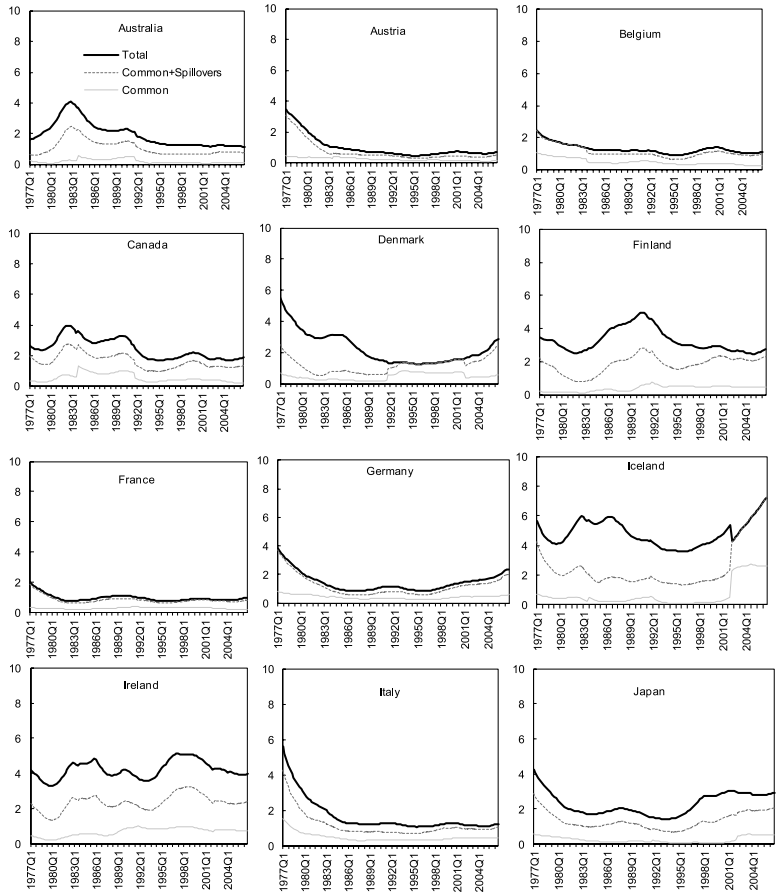

Figure A1: GDP growth volatility and its decomposition by country

Note: Measured as time-varying variance decomposition from a two-factor structural VAR, based on Stock and Watson (2005). Total (top line) is the total variance, the sum of variances of common, spillovers and own idiosyncratic shocks. Common shocks are assumed to affect all countries simultaneously, and their variance is represented here as the bottom line. Spillovers are idiosyncratic shocks in one country assuming to affect other countries after one lag. They are represented here as the difference between the middle and bottom lines. Own idiosyncratic shocks are represented here as the difference between the top and middle lines.

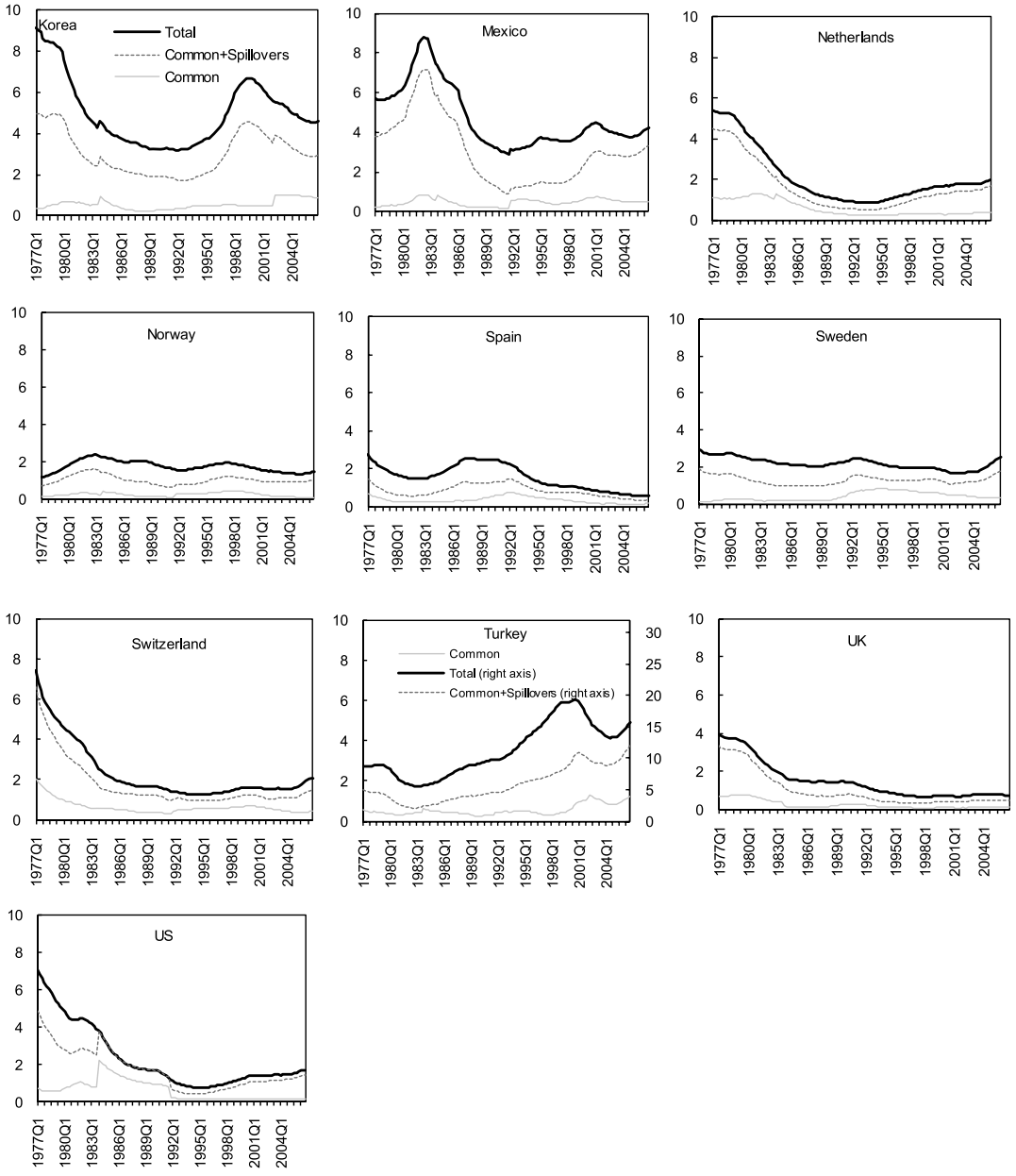

Figure A1: *Continued*