IMF STAFF POSITION NOTE

January 28, 2009
SPN/09/01

Gauging Risks for Deflation

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INTERNATIONAL MONETARY FUND

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January 28, 2009

Contents Page

EXECUTIVE SUMMARY 3

I. Costs of Deflation and Historical Experience 4
A. Costs 4
B. Historical Experience 5

II. Gauging Risks of Deflation 6
A. A Deflation Vulnerability Indicator 6
B. Prospects for Inflation Expectations 9

III. Risk Assessments Based on the Global Projection Model 15

IV. Potential Policy Responses 18
A. Financial Sector Policies 19
B. Monetary Policy Actions 19
C. Monetary Policy Communication and Framework Changes 20
D. Fiscal Policy and Interactions with Monetary Policy 21
E. Exchange Rate Movements 22

V. Some Lessons For Today from Japan's Experience with Deflation 22

References 24

Tables
1. Deflation Vulnerability Indicator: Questions and Answers, 2008Q4/2009Q4 7
2. Deflation Vulnerability Assessment Criteria 9
3. Deflation Vulnerability in the Global Economy, 1998, 2003, 2008, 2009 11
4. Simple Measures of Inflation Persistence 13
5. Inflation Persistence at Low Inflation 13

[1]Were are very grateful to Angela Espiritu, Patrick Hettinger, and Susanna Mursula for outstanding research assistance and to Olivier Blanchard, Kevin Clinton, Charles Collyns, Antonio Fatás, Charles Freedman, Marianne Johnson, Kenneth Kang, Petya Koeva, Manmohan Kumar and many other IMF colleagues for their comments and suggestions. David Einhorn provided excellent editorial assistance. The views expressed in this paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

Figures

1. Deflation Vulnerability Indicator and House Prices, 1994–2009 8
2. Cross-Country Distribution of Inflation, 2008Q3–2009Q4 10
3. Forecasting Inflation Expectations in 2009Q4 15
4. Global Projection Model-Based Projections for G-3 Economies, 2007–11 17
5. Zero Interest Rate Floor Hits 18

Appendix I. Global Projection Model (GPM) 27

EXECUTIVE SUMMARY

The worldwide financial crisis, falling asset values, and an associated collapse in business and consumer confidence, have once again raised the specter of deflation. Governments and central banks have responded to the problems of financial institutions by introducing measures to deal with both liquidity and solvency problems. At the same time, central banks have cut their policy rates to counter the increased credit risk premiums and many governments are implementing fiscal stimulus to support aggregate demand.

Nonetheless, prospects for global growth have deteriorated rapidly. In advanced economies, output is forecast to contract in 2009 for the first year since World War II.[2] In emerging economies, growth is expected to slow sharply. A central problem facing policymakers is how deep and prolonged the recession will be. Deflationary pressures might intensify the recession, as policy interest rates get close to the zero floor.

Against this backdrop, this paper discusses deflation risks and policy options. The key findings are the following:

- *Past episodes of deflation in the wake of asset price collapses and banking crises have been associated with weak economic performance. Slumping collateral values have exacerbated the credit crunch, and monetary policy has lost effectiveness in stabilizing output.*
- *An index of deflation vulnerability developed by Kumar and others (2003) covering countries accounting for roughly 80 percent of world output suggests that deflationary tendencies in the global economy are now somewhat higher than during the 2002–03 deflation scare. A key difference between then and now is the weakness in many housing markets, and the financial crisis. Neither are fully captured by the vulnerability indicator. Considering this, risks for sustained deflation are appreciably greater than in 2002–03, particularly in several G-7 economies. Nonetheless, the most likely outcome is that sustained deflation will be avoided, as was the case in 2002–03.*
- *A model-based analysis for the G-3 economies (United States, euro area, and Japan) also suggests that, on the assumption that the financial distress is gradually resolved, the most likely outcome is that the global economy will stay clear of sustained deflation. However, if financial sector problems are not remedied or further shocks add to current stresses, there is a significant probability of more negative deflationary outcomes, with a deeper and more prolonged recession.*
- *Policymakers should err on the side of acting too soon rather than too late in countering deflationary shocks. Very low inflation and inflation expectations can create a problem for monetary policy even before a sustained deflation sets in. Key considerations are that the lower inflation and inflation expectations are, the smaller the scope for central banks to stimulate activity with interest rate cuts; notwithstanding the recent experience of relatively high global inflation, slumping aggregate demand can quickly lead to expectations of falling prices in large parts of*

[2]See IMF, 2009a.

the world because in these parts inflation expectations are not very persistent; and monetary policy takes one to two years to exert its full effect on activity.

This paper concludes with a discussion of policy strategies. It underscores the crucial role of financial sector policies in remedying deflationary pressures directly and indirectly, by enhancing the effectiveness of monetary and fiscal policies. Monetary policy can help in some areas, but supportive fiscal policies are likely to be needed to prevent a deflationary episode becoming entrenched. Monetary policy measures include operating in a broad range of financial markets to relieve credit rationing, and to lower risk spreads and term premiums. Finally, to reinforce long-run inflation expectations, central bank communications should emphasize the commitment to return inflation to objectives with all due speed.

I. Costs of Deflation and Historical Experience

1. Deflation is typically defined as a sustained drop in the general price level. A temporary fall in the price level, for example, driven by oil prices, does not qualify. Deflation has often, but not always, been associated with poor economic performance.[3]

A. Costs

2. Deflation is usually costly when it comes as a surprise, which is typically the case following asset price collapses. Collateral unexpectedly loses value, while agents' debt burden remains unchanged in nominal terms. Banks reevaluate their loan portfolios and cut back their exposures. This, in turn, causes bankruptcies and additional financial stress that lower demand and asset prices further.[4]

3. The role of nominal rigidities in this spiral, which is likely to be particularly severe in highly leveraged economies, is complex. As aggregate demand and prices slump, real wages rise if nominal wages are rigid downwards. [5] This would set off another a wave of job cuts, further declines in demand and asset prices, bankruptcies, and so forth. However, Keynes (1936), Tobin (1975), and others argue that nominal rigidities might help prevent deflation. DeLong and Summers (1986) show that by inhibiting expectations of sustained price declines, sticky wages may forestall the increases in ex-ante real interest rates that can lead to a deflationary spiral. Thus, they argue that such steps as the introduction of a legal minimum

[3]Steady deflation at a rate equal to the equilibrium real rate of interest could have a beneficial aspect, as the equilibrium nominal rate would then be zero. Thus, the opportunity cost of holding money balances would be equal to the essentially zero cost of producing them (Friedman, 1969). However, since income, consumption, and other taxes are distortionary, positive inflation rates—i.e., positive tax rates on holding money balances—might nonetheless be desirable (Ramsey taxation). However, except in situations of extreme price changes, both arguments carry little weight, because the deadweight losses from the implied taxes on money balances are very low.

[4]See Bernanke (1983); see Mendoza (2008) for a related version of the debt-deflation mechanism in the context of sudden stops in international capital flows.

[5]The evidence on nominal wage rigidity is mixed: for the United States, see McLaughlin (1994), Akerlof and others (1996), Card and Hyslop (1996), and Kahn (1997); for the United Kingdom, see Smith (2000, 2002) and Nickell and Quintini (2000). For a comparison between the United States, the United Kingdom, and Germany, see Decressin and Decressin (2002). Regarding the consumer price index, Altissimo and others (2006) show that in the euro area at the micro level around 40 percent of price changes are price reductions, except in services, for which the number is 20 percent. The average price decrease is slightly larger than 10 percent.

wage, unemployment benefits, and support for the poor have contributed to the decline in the cyclical volatility of output. By the same token, it is often argued that euro-area economies, because of their larger welfare programs and more regulated labor markets, offer greater protection against deflation.

4. Once deflation becomes reflected in agents' expectations, it can significantly impair the effectiveness of monetary policy. When the short-term interest rate reaches zero, the central bank can no longer ease policy by lowering the usual rate target. Instead, real interest rates would rise as deflation becomes more severe. For this reason, even low persistent rates of inflation (say, less than 1 percent) can be problematic. The empirical importance of the zero bound can be debated. Summers (1991) argues that real interest rates were negative during roughly one-third of the years since World War II, and that had there been price stability, output would have often fallen short of potential. But King (1999) argues that ex-ante real interest rates were much higher than Summers's ex-post measures. King's argument underscores that a crucial objective for monetary policy during a downturn must be to avoid expectations of deflation.

B. Historical Experience

5. Deflation was not a rare phenomenon before World War II, and the growth record during periods of deflation was not always bad. Bordo (2004) points to two episodes in the United States: 1921–29, when prices fell by about 1 to 2 percent per year, amid strong economic growth, interrupted by two mild recessions; and 1873–96, which saw sustained price declines of about 2 percent per year and solid growth. These periods illustrate that sustained deflation may not necessarily pose a problem. The reason may well be that during these prosperous years the real return on capital, and hence the equilibrium real interest rate, was quite high, driven by strong productivity growth.

6. However, sustained deflation makes an economy vulnerable to a sudden weakening in aggregate demand. Thus, Summers (1991) argues that real GDP growth in periods of falling prices has been less strong than in periods of rising prices, particularly in the United States. The worst cases were those where deflation came unexpectedly. The Great Depression, notably the 1929–33 period, featured overly tight monetary policy, which combined with an asset price collapse and banking panics, resulted in a debt-deflation spiral (Fischer, 1933). This was marked by widespread bankruptcies, a breakdown of financial intermediation and the monetary transmission mechanism, and sustained high unemployment. Bordo (2004) calculates that, over this period in the United States, annual output declined by 7.6 percent and prices at a rate of 6.8 percent per year. The Japan deflation episode of the 1990s and the U.S. episode of 1837–43 also featured financial crises and a subpar output growth performance.

7. The current setting in much of the industrialized world has common features with those deflation episodes that were accompanied by substantial output losses. In the United States, following a prolonged increase in house prices and leverage, the turning of the housing cycle is triggering bank failures and a severe weakening in net household wealth. These are leading to cutbacks in credit, which are causing reduced spending and job losses, which in turn exacerbate the collapse of asset prices. The process has spiraled out, from residential real estate to the rest of the economy, and from advanced to emerging economies.

8. However, important differences in comparison with the 19th and early 20th centuries make prolonged deflation less likely. Today, there are well established social safety nets, deposit insurance, and frameworks for banking crisis resolution. The debt-deflation mechanism, and the role of macroeconomic policies in averting deflation, are now better understood. Furthermore, core inflation rates remain above 1.5 percent in most countries, whereas the 19th and early 20th centuries were, overall, a period of price level decline. Nonetheless, the experience of Japan indicates that advanced economies, per se, cannot be considered immune to costly deflation.

II. Gauging Risks of Deflation

9. This section gauges the risks of deflation from two different angles: a deflation vulnerability indicator, which draws information from a broad range of macroeconomic variables; and an analysis of downward sensitivity of inflation expectations.

A. A Deflation Vulnerability Indicator

10. Kumar and others (2003) develop an indicator of deflation vulnerability, which they apply to a set of countries accounting for over 80 percent of world GDP (purchasing power parity, PPP, basis). Based on the historical experience, this index seeks to capture malign deflation. Accordingly, the index covers a range of indicators: various price indices; GDP growth and the output gap; the real exchange rate; equity prices; credit growth; and monetary aggregates. The higher the indicator, the more likely it is that an economy will suffer a prolonged period falling prices. A high index value also signals a potentially harmful interaction of variables, e.g., price declines with a binding zero interest floor.

11. For each country, the indicator is created from responses to the questions shown below (Table 1). If the answer is affirmative, it is denoted by 1, otherwise by 0. The numerical responses for each country are then aggregated. Specifically, the financial and credit indicators are weighted according to their relative importance in the economy.[6] Country indices are then aggregated with PPP GDP weights (see IMF, 2008, p. 253).

12. The index suggests that in 2008Q4, deflation risks for the world are somewhat higher than at the time of the 2002–03 deflation scare (Figure 1). In 2008, however, the index increased much more rapidly than in 2002–03. This underscores that the present disinflation and possible deflation have a large unexpected component, which is deleterious for growth.

13. Kumar and others (2003) also classify country observations into four risk assessment categories, according to whether they faced "minimal," "low," "moderate," or "high" risk of deflation (Table 2). An index value below 0.2 is considered to point to "minimal" risks for

[6]They receive a weight of 3, 2, or 1 in countries with relatively large, average, or small financial sectors (see Kumar and others, 2003). For a country where both indicators receive a weight of 3, the sum of the answers to the 11 questions is divided by 15, rather than by 11 for a country for which both indicators receive a weight of 1.

Table 1. Deflation Vulnerability Indicator: Questions and Answers, 2008Q4/2009Q4

Question	Average of Answers	
	2008Q4 Estimate	2009Q4 Projection
Is CPI inflation < 0.5?	0.03	0.22
Is GDP inflation < 0.5?	0.11	0.28
Is core CPI inflation < 0.5?	0.03	...
Output gap widened more than -2 percent in past four Q?	0.83	0.03
Is the latest output gap lower than -2 percent?	0.75	0.69
Is growth in last three years < 2/3 growth in previous ten years?	0.28	0.75
Has the equity index declined by more than 30 percent in the past three years?	0.47	...
Has the real exchange rate appreciated more than 4 percent over the past year?	0.17	...
Is Q4/Q4 credit growth < Q4/Q4 nominal GDP growth?	0.17	...
Has cumulative credit growth been less than 10 percent over the past three years?	0.08	...
Is broad money growing slower than base money < 2 percent for last 2 years?	0.11	...

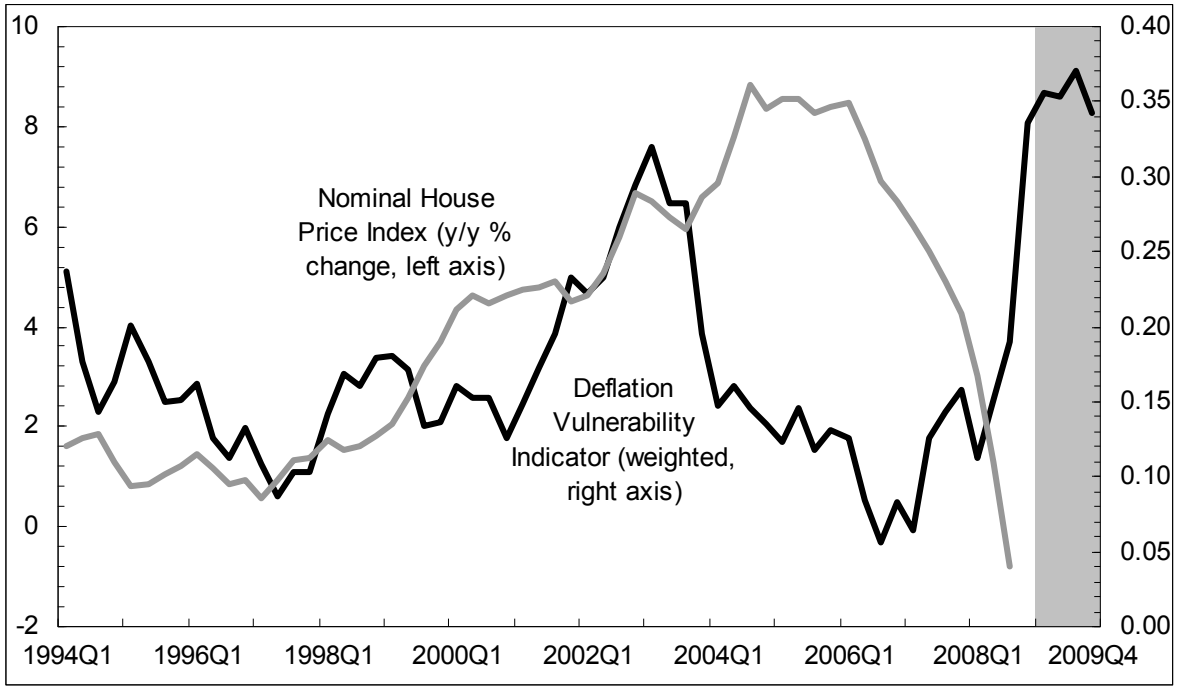
Source: IMF staff estimates based on the methodology developed by Kumar and others (2003). The average of answers is simply the addition of countries' "yes" responses in the particular period, which are denoted by 1, divided by the number of countries, which is 36.

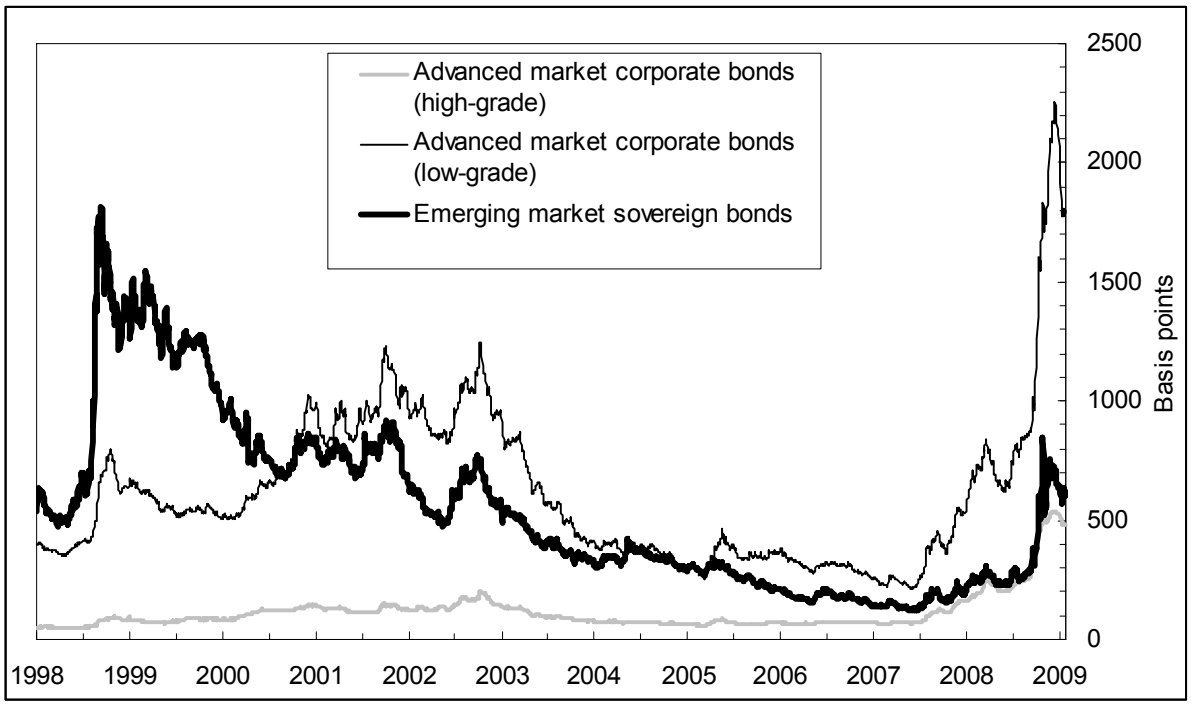
deflation, while a value above 0.5 indicates "high" risk. Low and moderate risk categories lie in between. According to these criteria, risks for global deflation have recently moved from "minimal" to "moderate," as the index has moved above 0.3 in the course of 2008. What precisely does this mean? Table 2 gauges the relation between the vulnerability indicator and prospects for prices. Thus, for each risk category, the table shows the proportion of country observations that featured a lower price level two years after the country entered that particular risk category. After entering the "moderate" risk assessment category, almost 14 percent of all such observations feature price declines for two years. After entering the "minimal" risk category, the proportion is less than 1 percent. These were countries that experienced high output growth, unlike those that were in the moderate or high risk categories, suggesting that price declines might have been driven by high productivity growth.

14. For 2008–09, the deflation indicator is pulled up by negative output gaps and low asset prices. Temporary forces that have kept credit growth up—reintermediation and the drawdown of precommitted credit lines—are likely to wane. Headline inflation in many countries is projected to decline toward, or under, 1 percent (Figure 2). In view of likely upward biases in measurement of the consumer price index (CPI), this implies virtual price stability.[7] In any event, prices for many items would be falling, so that their producers may be facing relatively high real interest rates, despite record low nominal rates.

[7]For the United States, the biases are put at about 1 percentage point, based on work by the Boskin Commission and subsequent updates (see Gordon, 2006). A comprehensive Boskin-type assessment does not exist for Japan or the euro area. For Japan, Broda and Weinstein (2007) see an upward bias of 2 percentage points. For the euro area, studies typically identify upward biases that are smaller than 1 percentage point. An exception is Wynne (2005), who argues that the euro-area Harmonised Index of Consumer Prices (HICP) underestimates true inflation by 1 to 1.5 percentage point. However, he reaches this conclusion based on survey data covering inflation perceptions, which have been relatively high ever since the euro changeover. This approach has been questioned (Rodriguez-Palenzuela, 2006). Upward biases are also argued to be present in many other CPI indicators (BIS, 2006).

Figure 1. Deflation Vulnerability Indicator, House Prices, and Bond Spreads 1994–2009





Sources: Kumar and others (2003), authors' calculations, and OECD. Housing price data are a PPPGDP-weighted aggregate of those of OECD countries and come from the OECD. The deflation vulnerability indicator covers a broader list of countries (see Table 3). For the calculation of spreads, see IMF (2008), p. 12.

Table 2. Deflation Vulnerability Assessment Criteria

		Vulnerability	Inflation <= 0		Real GDP Growth
		t	*t* + 8 quarters		*t*
			N	Share	Median
Minimal	<= 0.2	Minimal	13	1.0%	7.7
Low	0.2 < x <= 0.3	Low	5	2.2%	6.8
Moderate	0.3 < x <= 0.5	Moderate	39	14.2%	1.0
High	> 0.5	High	16	25.4%	1.2

Sources: Kumar and others (2003); and authors' calculations.

15. Looking at individual countries, 13 display "moderate" risk of deflation based on 2009 projections, among them Germany, Italy, and France (Table 3). The United States is on the border to high risk. Only Japan exhibits clearly high risk, according to the indicator. However, risks of a debt-deflation spiral in Japan are lower than 10 years ago, owing to improved balance sheets of the banks and the nonfinancial corporate sector.

16. An important caveat to this analysis is that the deflation indicator may underestimate the risks today relative to those for earlier episodes, as it does not consider house prices (Figure 1). In 2002/03, housing markets were very strong, with low interest rates boosting prices and construction, helping pull the global economy out of its weak patch. Also, the indicator does not do full justice to the credit crisis because it does not consider quantitative indicators of financial conditions other than bank credit, which is being buoyed by temporary forces. Spreads on bonds, for example, are much wider today than during 2002–03 in advanced economies and have reached levels similar to those prevailing in 2002–03 in emerging economies.

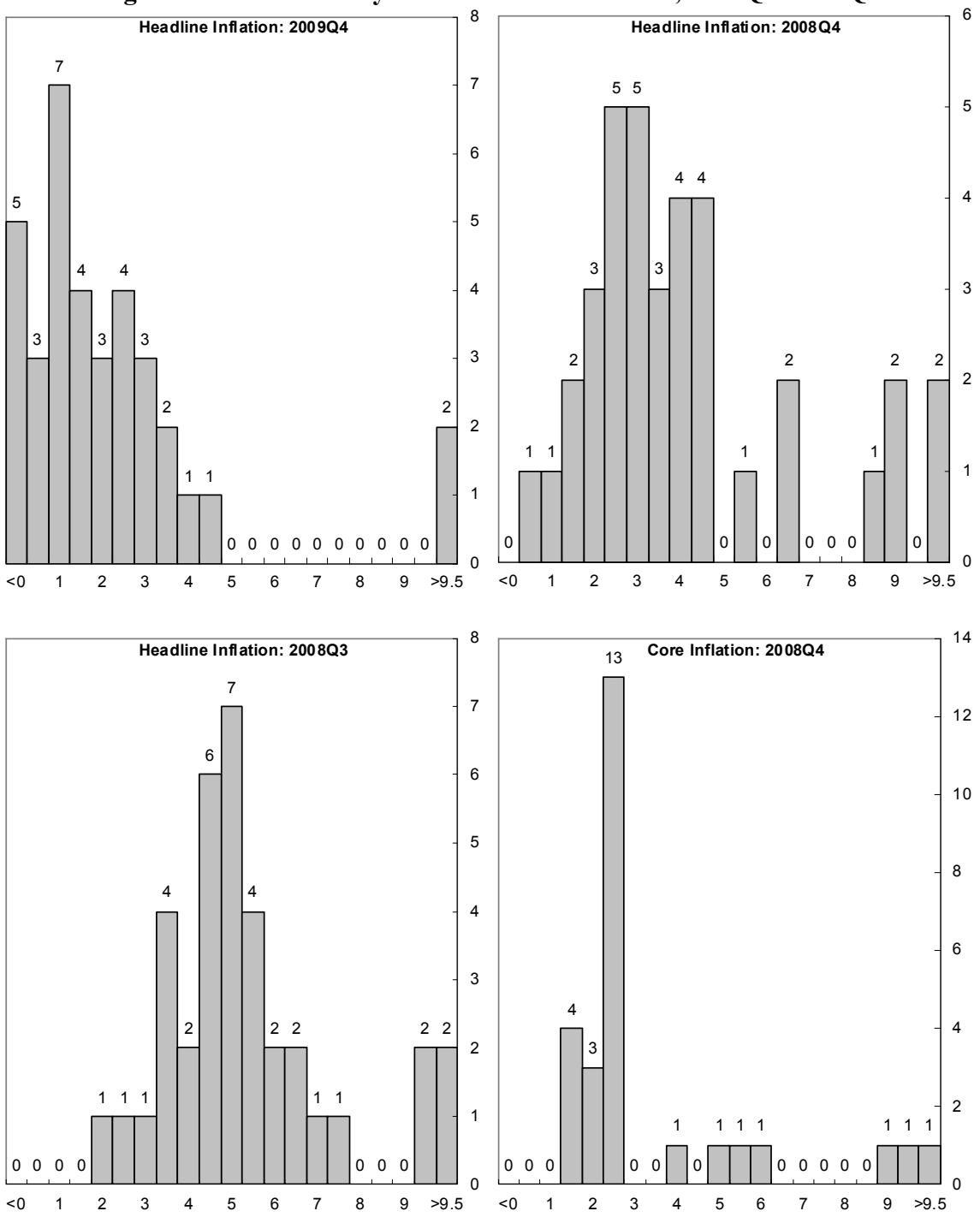
B. Prospects for Inflation Expectations

17. A key reason why deflation is a matter of concern is that inflation expectations can fall to low levels or become negative, thereby undermining the effectiveness of nominal interest rate cuts. Hence, an interesting question to investigate is how much protection—e.g., nominal or other rigidities—might offer from inflation expectations moving to low levels or turning negative. A very simple way to shed some light on this is to gauge the persistence of inflation expectations and actual inflation. Accordingly, the following regression is run:[8]

$$\pi_{it} = \alpha_i + \beta_i \pi_{it-1} + \varepsilon_{it} \qquad (1)$$

[8]This is a standard way to gauge the persistence of inflation at the macroeconomic level. See, for example, Gadzinski and Orlandi (2004) and the results reported in Altissimo and others (2006). However, these papers do not consider persistence in inflation expectations.

Figure 2. Cross-Country Distribution of Inflation, 2008Q3–2009Q4



Source: IMF, Global Data Source database.

Table 3. Deflation Vulnerability in the Global Economy, 1998, 2003, 2008, 2009

2009Q4		2008Q4		2003Q1		1998Q4	
Country	Index	Country	Index	Country	Index	Country	Index
Japan	0.71	Japan	0.64	Hongkong	0.86	Thailand	0.55
United States	0.53	Taiwan POC	0.53	Japan	0.86	Japan	0.50
Taiwan POC	0.47	United States	0.47	Taiwan POC	0.80	Switzerland	0.50
Norway	0.46	Ireland	0.46	Singapore	0.64	China	0.43
Sweden	0.46	Norway	0.46	Luxembourg	0.63	Malaysia	0.42
Finland	0.43	Switzerland	0.43	Portugal	0.56	Chile	0.38
Switzerland	0.43	Thailand	0.42	Finland	0.55	Singapore	0.38
Belgium	0.42	Italy	0.38	Germany	0.54	Korea	0.36
Germany	0.38	Sweden	0.38	Canada	0.53	Hongkong	0.31
Italy	0.38	China	0.36	Brazil	0.50	New Zealand	0.31
France	0.36	Finland	0.36	France	0.50	Brazil	0.27
Luxembourg	0.33	France	0.36	Switzerland	0.50	Russia	0.25
Thailand	0.33	Belgium	0.33	Malaysia	0.46	Sweden	0.25
Ireland	0.31	Luxembourg	0.33	Poland	0.38	France	0.21
Malaysia	0.31	New Zealand	0.31	Sweden	0.38	Luxembourg	0.20
Greece	0.29	Greece	0.29	Greece	0.33	Denmark	0.15
Austria	0.27	Korea	0.29	Ireland	0.33	Germany	0.15
China	0.27	Austria	0.27	Netherlands	0.33	Greece	0.15
Russia	0.27	United Kingdom	0.27	Denmark	0.31	Canada	0.13
Denmark	0.23	Denmark	0.23	Norway	0.31	Austria	0.10
Netherlands	0.23	Germany	0.23	South Africa	0.31	India	0.10
Portugal	0.23	Netherlands	0.23	Belgium	0.30	Poland	0.10
South Africa	0.23	Hongkong	0.21	Mexico	0.27	Belgium	0.09
Hongkong	0.21	Singapore	0.21	United States	0.27	Taiwan POC	0.09
Singapore	0.21	Canada	0.20	Thailand	0.25	South Africa	0.08
Australia	0.20	Mexico	0.18	Italy	0.23	Finland	0.08
Canada	0.20	Russia	0.18	Austria	0.22	Norway	0.08
Mexico	0.18	Malaysia	0.15	Spain	0.21	Australia	0.07
New Zealand	0.15	Poland	0.15	United Kingdom	0.20	Ireland	0.00
Korea	0.14	Portugal	0.15	China	0.18	Italy	0.00
Spain	0.14	Spain	0.14	New Zealand	0.18	Mexico	0.00
United Kingdom	0.13	Australia	0.13	Korea	0.14	Netherlands	0.00
Poland	0.08	India	0.09	India	0.09	Portugal	0.00
Brazil	0.00	Brazil	0.00	Chile	0.08	Spain	0.00
Chile	0.00	Chile	0.00	Australia	0.07	United Kingdom	0.00
India	0.00	South Africa	0.00	Russia	0.00	United States	0.00
Mean							
Simple	0.28		0.27		0.37		0.19
GDP weighted	0.34		0.33		0.32		0.18

where π_i denotes the headline inflation, core inflation, one year-ahead consensus forecast inflation, and break-even inflation rates.[9] The samples generally start in 1994Q1 or later. Aside from data availability, the reason is that there are many breaks in the mean inflation rate during the post-World War II period: the first is typically in the early 1970s; the second

[9]The break-even inflation rates are calculated based on the difference between the nominal yield on a fixed-rate government bond and the real yield on an inflation-linked government bond of similar maturity. Break-even rates are 20 years for Canada, 10 years for Australia, France, Japan, the United Kingdom, and the United States, nine years for Italy, and four years for Sweden.

in the mid-1980s; and the third in the early 1990s.[10] The equation is run country by country as well as in a panel with fixed effects (Table 4).[11]

18. The results suggest that core inflation tends to be more persistent than the headline and consensus forecast inflation. Break-even inflation expectations are the least persistent but this is likely to partly reflect financial market developments, notably liquidity and inflation-risk premia as well as other noisy components. Thus, as far as expectations are concerned, the subsequent analysis focuses on consensus inflation expectations. Based on the PPP GDP-weighted average of individual country coefficients—which, from an economic point of view, is the preferred way of gauging average persistence when there are good reasons for variations across countries[12]—the half-lives are about three quarters for consensus headline inflation expectations and six quarters for core inflation. In other words, following a shock it takes about three to six quarters for the various inflation rates to travel half way back to their pre-shock levels.

19. Inflation persistence varies widely across countries. The β coefficients are generally within the range of 0.75 to 0.95, implying a half life for inflation shocks of between 2 and 13 quarters. The differences among the G-3—United States, euro area, and Japan—are, however, small: half-lives for actual and expected inflation are typically between three and four quarters for all three.[13]

20. Also, inflation persistence appears lower at low inflation rates. The regression (1) is rerun with a dummy variable that takes the value of 1 for country-quarters with inflation below or equal to 1 percent and that is interacted with the intercept and slope coefficients. During such episodes, shocks to core inflation and consensus inflation expectations have half lives of only one to two quarters (Table 5), according to the PPP-weighted averages of the various country coefficients.[14] Furthermore, the difference in persistence between core and consensus expected inflation disappears. These findings are not surprising. Countries with lower inflation rates typically have more credible central banks; and greater central bank credibility facilitates returning inflation to target following shocks.

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[10]For a broader discussion of gauging persistence and the role of breaks in mean inflation (or, regime shifts), see, for example, Altissimo and others, 2006.

[11]In principle, the lagged dependent variable on the right-hand side would call for instrumental variables estimation to avoid biased parameter estimates in the panel specification (Hsiao, 1986). However, the time series dimension of the data—around 60 data points—is much larger than the cross section and thus any bias is likely to be very small. In that case, ordinary least squares is more efficient.

[12]See Pesaran and Smith (1995). From an econometric point of view, it would be preferable to aggregate the individual coefficients with the inverse of standard errors as weights.

[13]This is broadly in line with the findings for headline and core inflation of Gadzinski and Orlandi (2004) and the evidence on aggregate inflation dynamics discussed in Altissimo and others (2006). At the micro level, however, Altissmo and others (2006) find that prices changes in the euro area are less frequent (every four to five quarters) than in the United States (every two quarters). The reasons for the less-frequent adjustments are unclear.

[14]The PPP-weighted average is preferred to the pooled estimate, which is also shown in the table, for econometric (see Pesaran and Smith, 1995) and economic reasons (giving smaller countries less weight).

Table 4. Simple Measures of Inflation Persistence

	Lagged				
	Headline	Core	Consensus Forecast	Break-Even	Average
HKG	0.95	0.95	0.94	.	0.95
ISR	0.92	0.93	0.96	.	0.94
SLV	0.91	0.94	0.91	.	0.92
SGP	0.95	0.99	0.78	.	0.91
GBR	0.91	0.93	0.83	0.93	0.90
GRC	0.91	0.86	0.93	.	0.90
NLD	0.91	0.92	0.86	.	0.90
TWN	0.76	0.95	0.93	.	0.88
FIN	0.90	0.91	0.83	.	0.88
ITA	0.91	0.93	0.93	0.74	0.88
PRT	0.83	0.87	0.89	.	0.86
KOR	0.80	0.86	0.92	.	0.86
AUS	0.85	0.87	0.78	0.94	0.86
AUT	0.84	0.84	0.89	.	0.86
DNK	0.81	0.89	0.87	.	0.86
IRE	0.88	0.93	0.71	.	0.84
ESP	0.80	0.84	0.85	.	0.83
BEL	0.83	0.80	0.86	.	0.83
NZL	0.84	0.86	0.78	.	0.83
SWE	0.71	0.83	0.88	0.88	0.82
FRA	0.79	0.91	0.89	0.68	0.81
JPN	0.80	0.90	0.89	0.60	0.80
NOR	0.66	0.90	0.81	.	0.79
USA	0.65	0.89	0.77	0.78	0.77
DEU	0.75	0.82	0.75	.	0.77
CHE	0.74	0.68	0.87	.	0.77
CAN	0.68	0.77	0.55	0.64	0.66
Panel	**0.90**	**0.92**	**0.92**	**0.88**	**0.91**
Weighted Average	**0.76**	**0.89**	**0.81**	**0.78**	**0.82**

Sources: World Economic Outlook database; and authors' calculations.

Table 5. Inflation Persistence at Low Inflation

	Lagged Inflation	<= 1%	R2
Headline	0.88	-0.23	0.91
	(0.01)	(0.04) .	
Core	0.92	-0.16	0.92
	(0.01)	(0.03) .	
Consensus Forecast	0.92	-0.14	0.95
	(0.01)	(0.03) .	
Break-Even	0.88	0.02	0.90
	(0.03)	(0.06) .	
Weighted Average			
Headline	0.72	-0.23	
Core	0.88	-0.22	
Consensus Forecast	0.81	-0.16	
Break-Even	0.76	0.01	

Source: World Economic Outlook database; and authors' calculations.

21. At the current juncture, which comes on the heels of a period of inflationary shocks and inflation above central bank targets in many countries, economies with less persistent inflation and expectations may be more vulnerable to experiencing a spell of deflation in response to the unexpected slump in aggregate demand. The reason is that the effects of the past inflationary shocks in these countries die out more quickly. Economies with higher numbers for the deflation vulnerability indicators and relatively less persistent inflation include Japan (JPN), United States (USA), Norway (NOR), Sweden (SWE), Switzerland (CHE), Belgium (BEL), Germany (DEU), and France (FRA). These feature inflation half-lives of two to four quarters. By the same token, assuming that the inflation process and expectations formation mechanisms as estimated for 1994–2008 in Tables 4 and 5 do not change during a spell of deflation, which is a risk, the economies with less persistent inflation and expectations may find it easier than the other economies to exit deflation once this has taken a hold.

22. Reaching a more solid verdict on the likelihood of a spell of expectations for deflation requires a simple model of inflation expectations and forecasts. Accordingly, the next step is to relate inflation expectations to other variables, namely the output gap (y), the unemployment rate (u), headline inflation (π), and the oil price, all entered into the equation with lags $L = 0,...,3$.[15] The focus here is on the consensus expectations (π^e), given that their coverage is much broader and that they are less affected by specific financial market developments:

$$\pi_{it}^{e} = \alpha_i + \beta_i^1 \pi_{it-1}^{e} + \beta_i^2(L)u_{it} + \beta_i^3(L)y_{it} + \beta_i^4(L)\pi_{it} + \beta_i^5(L)\pi oil_t + \varepsilon_{it} \qquad (2)$$

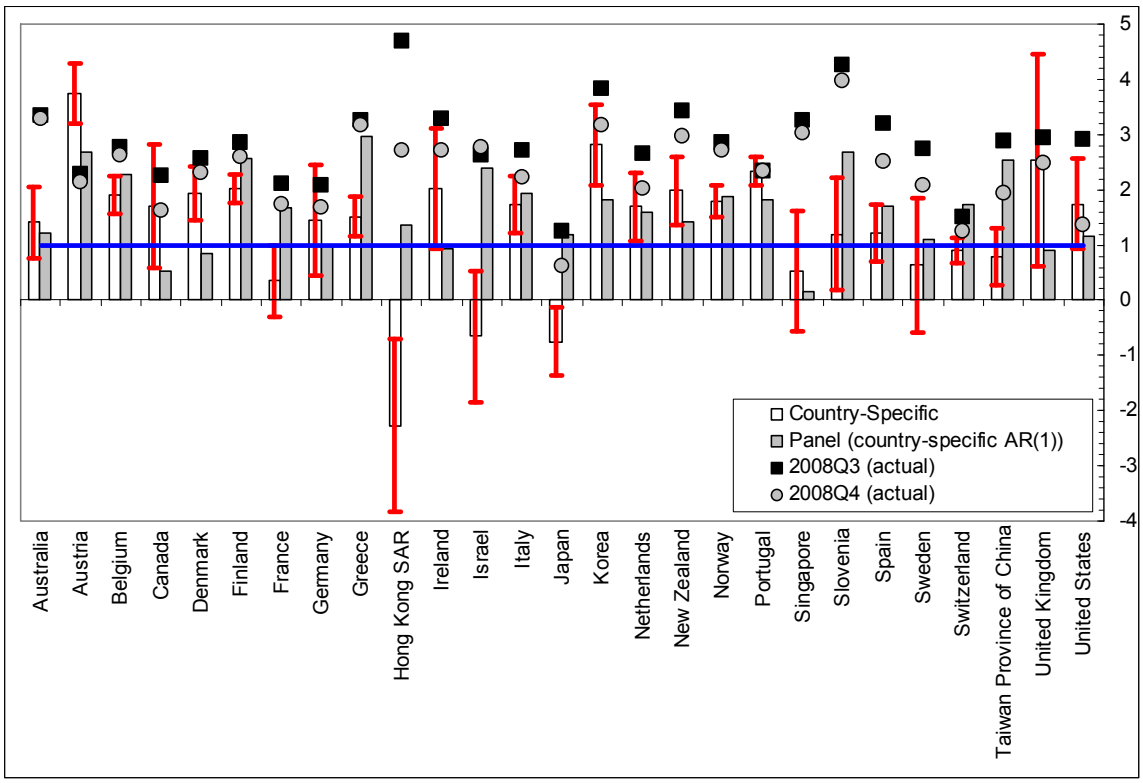
This equation is estimated separately for each country i as well as in a panel (allowing for country-specific coefficients on the lag of expected inflation), with a full set of interactive dummies for inflation smaller or equal to 1 percent. Then a forecast for one-year ahead expectations in 2009Q4 is produced, based on country economist projections for the unemployment rate, output gap, headline inflation, and assuming oil prices evolve in line with January 2009 futures markets.[16]

23. The results suggest that inflation expectations will decline in almost all countries, by ½ to 2 percentage points (Figure 3), depending on the forecasting equation. As a result, many countries would see inflation expectations close to, or below, 1 percent in at least one projection. The probability for expectations of appreciable deflation, however, is low for most countries, even if some countries are expected to see temporary price level declines (see Figure 2 and Figure 4). This might reflect various factors, including agents' assessments of the role of price rigidities and central banks' efforts to return inflation to targets.

[15]An alternative would be to substitute core inflation for headline inflation. However, country economists at the IMF do not produce forecasts for core inflation and the ultimate purpose of the exercise is to produce forecasts for expected inflation based on economists' projections for output, unemployment, headline inflation, and on the assumption of constant oil prices.

[16]The oil price is entered in U.S. dollars per barrel. The assumed price based on futures markets is $50 in 2009 and $60 in 2010, down from $97 in 2008.

Figure 3. Forecasting Inflation Expectations in 2009Q4



Sources: World Economic Outlook database; and authors' calculations.

24. In summary, despite the recent period of relatively high global inflation, inflation persistence might not offer enough protection from appreciable falls in inflation expectations given the size of the demand shock. This is so notably for the United States, major euro-area countries, and Japan. Thus, policymakers should probably err on the side of acting too soon rather than too late in countering the deflationary shocks.

III. Risk Assessments Based on the Global Projection Model

25. This section proposes to analyze deflation vulnerability with the help of the IMF staff's Global Projection Model (GPM), which explicitly considers the implications of the zero interest floor (ZIF) for monetary policy. [17] The most intractable deflation problem occurs when policy interest rates reach the ZIF for a prolonged period of time because if a zero interest rate fails to close the output gap, downward pressure on prices is reinforced. Unless other policies are implemented to raise aggregate demand, this could result in a downward deflationary spiral. The model incorporates three country models, for the United States, the euro area, and Japan (the G-3); and it covers output and unemployment, the rate

[17]The remainder of this paper draws heavily on Freedman and others (2008), Carabenciov and others (forthcoming) and Clinton and others (2008). Appendix A provides a summary of the Global Projection Model. Note that while the model is not useful for studying the longer-term implications of different types of fiscal policies, its structure is flexible enough to analyze the demand implications of temporary fiscal impulses.

of inflation, the exchange rate, and, with a modified Taylor rule, the monetary policy interest rate.

26. Figure 4 shows the current *World Economic Outlook* (WEO) baseline outlook (black line) and GPM-based fan charts for the G-3 economies (see also IMF, 2009a).[18] It shows panels for output growth, the output gap, the rate of inflation, and the price level. Figure 5 shows the proportion of outcomes in which the policy interest rate hits the zero interest rate floor (ZIFHITS) in each quarter, as well as the proportion of simulations in which the model is unable to solve (denoted as "failures"). The economic interpretation of the latter is an intractable disequilibrium situation. That is, downward pressures on the price level create increases in the real interest rate, which result in reduced aggregate demand, a larger negative output gap, intensified deflationary pressures, etc. There is no equilibrium at which the economy can settle without additional policy initiatives to raise aggregate demand. The key features of the WEO baseline projections are the following:

- The WEO baseline projection for the G-3 shows year-on-year negative output growth troughing at about –3 percent and lasting five quarters. Positive growth resumes gradually, not moving above potential growth until the beginning of 2010.

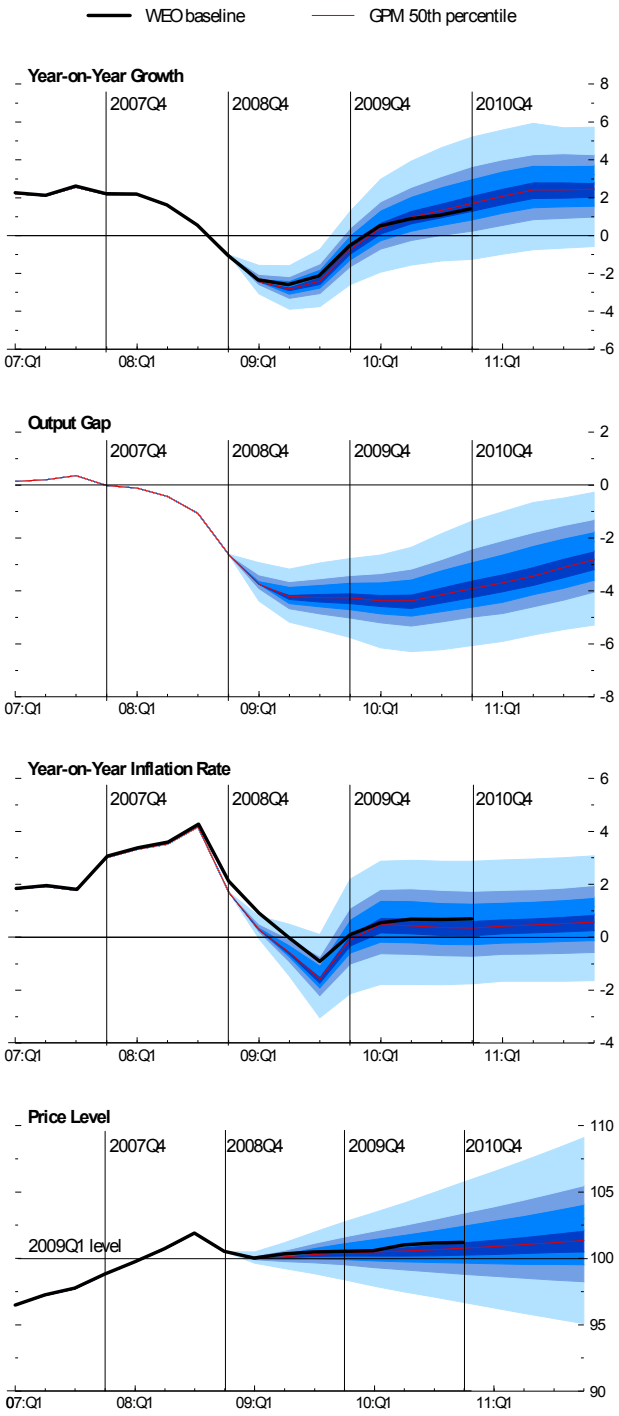
- The year-on-year rate of inflation in the WEO baseline projection becomes negative in 2009Q3, and then moves back into positive territory. It is driven by the combination of the recent sharp decline in oil prices and the weakness in the G-3 economies. The price level shows the same results but in a more striking fashion, with actual declines in 2008Q4 and 2009Q1.

The key features of the GPM fan charts are the following:

- The median of the GPM-based fan charts for G-3 growth (red solid line that separates the upper and lower 50 percent parts of the distribution) are very similar to the WEO baseline, but there are significant differences for inflation. As a result of significant negative output gaps, the median of the GPM fan charts shows more deflation initially and then inflation returning more gradually to its equilibrium value as the economy recovers. More importantly, the GPM-based fan charts indicate a significant material risk that economic developments could be significantly worse—for example, negative growth lasting one more year, into 2010. Notice that in the model economic agents see that the decline in the level of oil prices is temporary—they do not extrapolate it to the future.

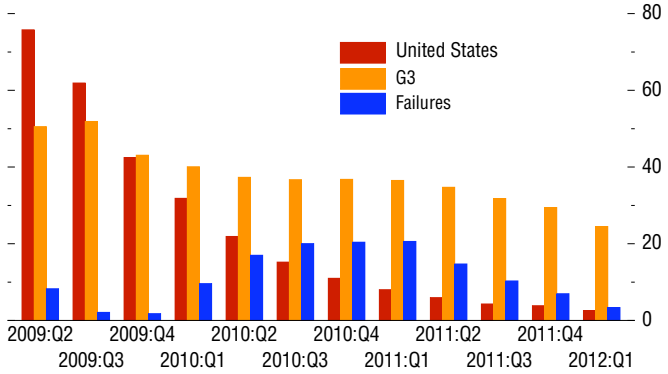
[18]The WEO baseline is aggregated from the forecasts of country desk economists. While the GPM is used to help coordinate and impose some consistency on the WEO updating process, its structure is not imposed fully on a technical level. Consequently, the WEO baseline does not necessarily have to be located in the center of the GPM fan charts and the latter should be considered as an independent assessment of the risks. See Clinton and others (2008).

Figure 4. Global Projection Model-Based Projections for G-3 Economies, 2007–11



Source: IMF staff estimates.

Figure 5. Zero Interest Rate Floor Hits (periods)



- Importantly, over 11 percent of the model runs over the next three years failed to solve: these simulations, which assume announced fiscal policies, have an ever-increasing deflationary spiral with rising real interest rates that prevent the economy from recovering. Figure 5 also shows the proportion of outcomes where economies hit the ZIF. According to these estimates, in the short run the constraint is expected to bind for the United States. However, an aggressive and early easing in the stance of U.S. monetary policy in 2008 suggests that the constraint is expected to become less severe as the economy recovers, and inflation gradually rises to levels consistent with the Fed's objective. For Japan, the constraint continues to bind a significant proportion of the time in 2010 because of lower inflation objectives and a lower equilibrium real interest rate. For the euro area, the likelihood that the ZIF becomes binding rises through 2010, as monetary easing and fiscal stimulus in 2008 and 2009 are less aggressive than in United States. However, the likelihood is not forecast to reach the high short-run levels of the United States.

To sum up, the WEO baseline projection, in itself, does not contain an unduly serious deflation problem. However, the GPM-based fan charts reveal a significant probability of much more negative deflationary outcomes, and hence a deeper and more prolonged recession in the G3.

IV. Potential Policy Responses

27. What can be done by policy to reduce the likelihood of sustained deflation? The macroeconomic policy remedies are agressive monetary easing, including through nonconventional methods, and fiscal expansion. However, these policies are important but only temporary palliatives to a financial sector problem that also undermines their efficacy. Hence, a comprehensive and coordinated response to the financial sector turmoil is of overarching importance. This is also what is suggested by the example of Japan, the only advanced economy to have suffered deflation in the recent past (see Section V).

28. Monetary policy can help in some areas, and fiscal policy—mindful of the need to address long-term fiscal sustainability challenges, which are being amplified by the need to repair bank balance sheets—can also contribute to avoiding some of the weakness in the baseline forecast and in the distributions below that forecast. And the interaction of

supportive monetary and fiscal policies can be particularly helpful in preventing the worst effects of deflationary pressures.

A. Financial Sector Policies

29. Some progress is being made with respect to unclogging financial markets. Central banks and governments are acting on multiple fronts. They are providing ample liquidity to financial institutions; directly intervening in securities markets, for example, with the purchase of commercial paper; supporting renewed bank bond issuance with public guarantees; broadening the coverage of deposit insurance schemes; and recapitalizing banks that have suffered large losses but are considered viable over the medium run.[19] Accordingly, financial strains have retreated form their recent peaks. Nonetheless, they remain at exceptionally elevated levels, as policymakers have not yet achieved a gradual and orderly deleveraging and downsizing in financial systems that minimizes the deleterious effects on employment and output.

30. Specifically, what is missing is a comprehensive and coordinated approach to relieving financial stress that achieves greater clarity about the state of bank balance sheets. Thus far the policy efforts have addressed the immediate threats to financial stability but, for financial institutions, have not done so in a comprehensive way. Accordingly, they have done little to resolve the uncertainty about the long-term solvency of financial institutions. The process of loan loss recognition and restructuring of bad loans is still incomplete. Therefore, financial sector policies should focus on advancing this process by forcing credible and coordinated loan loss recognition and by providing public support to the viable financial institutions. Such policies should be supported by measures to safeguard public resources, resolve insolvent banks, and set up public agencies to dispose of the bad debts acquired by the government.

31. Importantly, immediate policies and actions need to be consistent with long-run objectives for restructuring financial sectors. They need to be implemented in a coordinated manner, supported with regulatory and supervisory reforms; otherwise they risk creating new distortions across countries, markets, or types of financial institutions.

B. Monetary Policy Actions

32. In the shorter run, central banks (along with governments) have a number of options available to them to try to stimulate demand in their economies, even if their interest rates are already close to zero. However, some of these need to be deployed cautiously and central banks will need to communicate clearly how unconventional measures relate to achieving their monetary policy objectives. The options include the following:

- While policy interest rates have been reduced significantly, there is still some room for further reduction in some countries.

[19]See IMF (2009b) for a more comprehensive analysis of financial sector challenges presently facing policymakers.

- The spreads between rates on commercial versus government ("riskless") rates remain exceptionally wide. The policy initiatives to mitigate this have included central banks accepting riskier assets as collateral. More may have to be done in this regard to reduce the spread that financial institutions have to pay and, consequently, the rates that borrowers have to pay. However, this can only be a temporary palliative pending resolution of the liquidity and solvency concerns that drive the spreads.

- By purchasing medium- and longer-term government bonds for their balance sheet, central banks can also try to reduce interest rates at longer horizons (e.g., Bernanke, 2002). Some economists have argued that quantitative easing will have the same kind of effect on medium-term interest rates, while others have been even more optimistic about the benefits of quantitative easing operating through nontraditional channels. The latter remains an open question (see Section V).

- Central banks and governments could lend directly to businesses by purchasing commercial paper and indirectly to households by purchasing mortgage-backed securities. The Fed, for example, has already taken this road. However, this approach carries its own risks in that it involves governments and central banks in credit decisions, and results in their taking on large credit risks.[20] One alternative is to use moral suasion to persuade major banks, particularly those in which governments have invested, to increase their lending. But this also raises problems of further increases in loan losses in the future and the need for further recapitalization of such institutions. Perhaps the optimal way of dealing with this issue is for governments (rather than central banks) to take on some extra risk and exposure, and to take actions to strengthen the economy so that banks will return to their normal lending patterns after some period of time.

C. Monetary Policy Communication and Framework Changes

33. Central banks may take actions and use communications to convince markets that their low interest rate policy will be pursued as long as the economy remains weak. The benefit of such an approach is that medium- and longer-term interest rates may fall, in line with expectations of future policy rates. Central banks that publish the policy interest rate underlying their forecast (currently only the Reserve Bank New Zealand, the Norges Bank, the Riksbank, and the Czech National Bank) would show such intentions explicitly. Central banks that do not publish their forecast policy interest rate can use language to make the same point—or begin publishing forecasts.

34. A more fundamental framework change would be moving from "inflation" to "price-level-path targeting" or "average-inflation targeting (AIT)" as an alternative to inflation targeting. By focusing on the price level path or the average rate of inflation from the beginning of the targeting period, central banks may be able to have a greater effect on inflation expectations (and thus real interest rates) than with pure inflation targeting (see Clinton and others, forthcoming). The basic idea is that as inflation undershoots, central banks would make up for it in the future with a looser stance for monetary policy. This being

[20]For the European Central Bank it also raises the issue of how to spread purchases across the assets of its member countries.

known by market participants, they would adjust their expectations for inflation to a larger extent than under a standard inflation-targeting regime, where bygones are treated as bygones. However, this can raise issues following periods of high inflation that would call for periods of deflation. Also, changing a monetary policy regime in the middle of a crisis carries some risks, placing a premium on strong communication.

35. One of the crucial questions with respect to the validity of this argument is whether an AIT framework can be made credible. If interest rates are already at the ZIF, would the public believe that the central bank could engineer a rate of inflation above 2 percent over a near- to medium-term horizon? As discussed above, in part this would depend on the ability of the central bank to bring down medium-term interest rates by committing itself to holding the short-term policy rate at or near zero until it is clear that an economic recovery is taking hold.

36. By contrast, a commitment by the fiscal authorities to run an expansionary fiscal policy (to be discussed shortly) would increase the likelihood that economic agents would find the central bank commitment more credible, without having a similar potentially destabilizing effect on future financial stability.

D. Fiscal Policy and Interactions with Monetary Policy

37. Freedman and others (2008) argue that expansionary fiscal policy can have a significant positive impact on the economy.[21] They conclude that even temporary—e.g., two-year—expansionary fiscal actions can be effective. This would require that monetary policy remain accommodative, which, under the circumstances, would be in line with the central bank's own inflation objective. Also, the effects of the fiscal expansion may be magnified in a multi-country exercise. Moreover, the type of fiscal instrument used to bring about the increased fiscal deficit can have a significant influence on the size of the fiscal multiplier. Importantly, expansionary fiscal policy could increase the credibility of the commitment of the central bank to temporarily increasing the rate of inflation above the longer-term target rate.

38. In short, while in normal times monetary policy and fiscal policy need not necessarily be coordinated, in circumstances of deep and prolonged recession and serious risks of potential deflation, the two policies can be mutually supportive and help to offset downward pressures on demand and prices. However, in deploying fiscal policy governments will need to bear long-term fiscal sustainability challenges in mind.[22] In many advanced economies, these are major and relate to the pressure that aging populations put on spending for public pensions and health care. Large public expenditures for rebuilding bank balance sheets will add to these challenges. Accordingly, governments will have to make clear how they intend to address them, lest their actions at some stage risk putting noticeable upward pressure on long-term interest rates.

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[21]More detailed results will be provided in Freedman and others (forthcoming).

[22]Also, governments may want to issue index-linked government bonds without a deflation floor, so as to limit the rise in the real burden of the debt while inflation stays negative.

E. Exchange Rate Movements

39. Attempts on the part of some countries to engineer a depreciation or devaluation in the exchange rate in order to provide stimulus to aggregate demand for the goods and services produced in their country might work for small open economies. However, in the context of a global recession in the industrialized economies, an attempt by one of the major countries to use exchange rate policy as a way of offsetting its recession would likely run into accusations of "beggar thy neighbor" policies and possible lead to competition to weaken exchange rates on the part of their large trading partners. Worse, there would be a risk of competitive protectionist actions of the sort that was so detrimental in the early 1930s.

V. Some Lessons for Today from Japan's Experience with Deflation

40. The most recent case of deflation in a major country involved Japan. Its experience with unconventional monetary policy measures has been mixed. In 2001, the Bank of Japan (BoJ) put in place a quantitative easing framework, with banks' current account balances held at the BoJ becoming the operating target. The program included stepped-up purchases of government bonds. In 2002 the BoJ started buying asset-backed commercial paper, asset-backed securities, and equities directly from banks. These measures were supported with a public commitment to keep rates near zero until the actual and forecast CPI firmly returned into positive territory—a zero interest rate policy. Additionally, the Ministry of Finance undertook large-scale foreign exchange interventions in 2003 and early 2004.

41. Some observers have argued that the actions related to quantitative easing were useful (e.g., Kobayashi and others, 2006; and Honda and others, 2006), but others challenge this view. For example, Kumar and others (2003) conclude there is little evidence that quantitative easing was effective. Others reached broadly similar conclusions based on later data (e.g., Deutsche Bank, 2008). Baba and others (2005) stress the limited effects on lending and output of the many measures, notwithstanding appreciable changes in the yield curve. They attribute this to the reduced net worth of both lenders and borrowers as well as the associated negative financial-accelerator effects that offset the effect of low interest rates.

42. The present setting differs from that in Japan in important respects. In particular, the financial stress is much more extensive. Whereas in Japan the crisis was concentrated among the banks, current stress encompasses a wide range of institutions, and securities and derivatives markets. This justifies intervening directly in securities markets, as well as working on raising liquidity in banks. Another crucial difference is that countries today cannot benefit from exchange rate depreciations as Japan did, because many are facing the same slump in demand.

43. The example of Japan holds many useful lessons for today. It suggests that quantitative easing needs to go hand-in-hand with financial sector restructuring. If pursued alone, it may weaken incentives for restructuring within the financial sector, which is essential for healthy lending activity in the long run. Specifically, in addition to the recapitalization efforts that are currently under way, it will therefore be crucial for governments to promote the removal of toxic assets, with a view to fostering a transparent

clean-up of bank balance sheets.[23] Moreover, there is a consensus emerging that more fiscal stimulus may be required in the short run to support demand and prevent a prolonged contraction in economic activity. This, however, should rely mainly on temporary measures and be formulated within medium-term fiscal frameworks that ensure that the rapid build-up in public debt as a result of stimulus and bank balance sheet support can be reversed. This is essential to ensure that fiscal sustainability can be attained in the phase of growing demographic pressure.

[23]In Japan this also involved cleaning up nonfinancial corporate balance sheets, which were weak because of excess capacity in a number of sectors.

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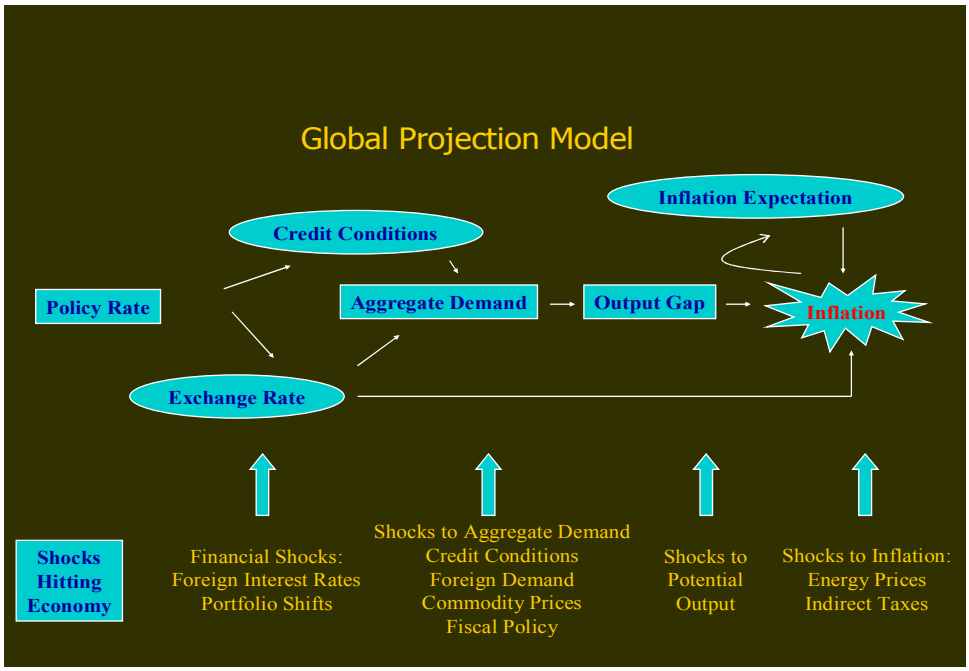
Appendix I. Global Projection Model (GPM)



GPM is well suited to analysis of the practical problem at hand. We employ a Bayesian system estimation technique. This efficiently combines information in the current data set with prior information about coefficients, based on economic theory and existing empirical knowledge, and on properties implied by the model as whole. In contrast, pure a priori calibration may lack empirical plausibility, while data-driven estimation procedures may yield anomalous results, especially when the relevant data series are short.

GPM builds from the standard modern monetary policy model, with equations determining:

- the output gap;
- the inflation rate (an inflation-expectations augmented Phillips curve);
- the exchange rate, and
- the interest rate (a monetary policy rule).

The model adds several features to earlier versions of the standard model. Thus, expectations are based on both lags and leads, representing backward- and forward-looking elements. And it includes important nonlinearities, including the zero bound on interest rates. Moreover, GPM offers various options for monetary policy rules, which may be estimated from the data, or determined by an optimization process, or set to represent counterfactual options.

Output is represented by real GDP; the output gap is the difference between actual and potential.[24] The inflation rate is modeled as the annualized quarterly change in the CPI, but for reporting purposes we follow the normal year-over-year convention. The US exchange rate is euro or yen per dollar (an increase corresponding to US dollar appreciation); the real

[24]All variables except interest rates are in natural logarithms. For all intents and purposes, this means that, e.g., the output gap is measured as a proportion of potential GDP.

exchange rate adjusts for differential changes in CPIs (an increase implying an increase in the relative price of US goods). It is convenient to express all variables as deviations from long-run equilibrium, i.e. in gap form.

The United States sector includes endogenous credit conditions. We construct an index of bank lending tightening (BLT) in the United States from the Federal Reserve Board's Senior Loan Officer Survey. The index subtracts the percentage of "eased" responses against the percentage of "tightened." A BLT in excess of 50 percent means an unusually sharp tightening. This index predicts the US business cycle over the last decade with high precision.[25]

The policy rule for the short-term interest rate is based on a forward-looking Taylor rule in which the policy rate depends on the central bank's forecast of inflation (3 quarters ahead), on the output gap, and on the lagged policy rate.

The Bayesian method provides an estimate of the posterior distribution of the variance-covariance matrix of disturbance terms, as well as of the system parameters. We work with the mode of the posterior distribution and condition all the remaining experiments on this point estimate. Unobservable historical variables, such as potential output, are estimated using a linear Kalman filter, conditioned on the posterior mode.

Simulations to construct the confidence intervals in the baseline forecast, and to derive the results for the policy rule experiments, are done on the assumption that shocks are unanticipated. In each period, the solution is derived on the assumption that all the future shocks will be zero. Thus, in the model simulations, we suppose that the shocks that we simulate surprise economic agents, and we neglect the potential behavioral implications of uncertainty about the future.

Variable definitions for country j

$\overline{Y}_{j,t}$: potential output

$i_{j,t}$: nominal interest rate

$R_{j,t}$: real interest rate

$\overline{R}_{j,t}$: equilibrium real interest rate

$\pi_{j,t}$: annualized quarterly inflation

$\pi 4_{j,t}$: year-on-year inflation

$Z_{j,t}$: real exchange rate

$\overline{Z}_{j,t}$: equilibrium real exchange rate

$Z^{e}_{j,t}$: expected exchange rate of next period

$BLT_{US,t}$: credit tightness

$RPOIL_{US,t}$: log of the real equilibrium price of oil

[25]See Carabenciov and others (2008). In 2008Q4 the index reached an unprecedented 80 percent.

$RPOIL_{US,t}$: log of the real price of oil

Behavioral Equations

Output gap equation of country j:

$$y_{j,t} = \beta_{j,1} y_{j,t-1} + \beta_{j,2} y_{j,t+1} - \beta_{j,3} r_{j,t-1} + \beta_{j,4} \sum_k \omega_{j,k,4} z_{j,k,t-1}$$
$$+ \beta_{j,5} \sum_k \omega_{j,k,5} y_{k,t-1+} \theta_j \eta_{j,t} + \varepsilon^y_{j,t}$$

This equation determines the output gap as a function of

- its own lead and lagged values,
- the real interest rate gap
- bank lending tightening (BLT, US equation only)
- output gaps in its trading partners
- the real exchange rate gap, and
- a disturbance term

The lag from the output gap itself captures both intrinsic delays due to adjustment costs, and the adaptive component of expectations, or habit persistence. The lead corresponds to forward-looking investment and consumption behavior, in anticipation of expected future output and income. Normal cyclical variations in the availability of credit are accounted for implicitly by the interest rate and other variables in the equation. However, shocks to lending practices will have an independent impact, which is not so captured. Their effect is represented by the term $\eta_{US,t}$, which is defined to be a distributed lag of the non-systematic component of the variable BLT. We measure these shocks as the residuals of a simple estimated equation where BLT depends on the expected value of the output gap 4 quarters in the future.

Inflation equation for country j:

$$\pi_{j,t} = \lambda_{j,1} \pi 4_{j,t+4} + (1 - \lambda_{j,1}) \pi 4_{j,t-1} + \lambda_{j,2} y_{j,t-1} + \lambda_{j,3} \sum_k \omega_{j,k,3} \Delta Z_{j,k,t}$$
$$+ \upsilon_{j,1} \pi^{RPOIL}_{j,t} + \upsilon_{j,2} \pi^{RPOIL}_{j,t-1} - \varepsilon^{\pi}_{j,t}$$

This augmented Phillips curve has inflation as a function of

- inflation expectations—a weighted average of past and model-consistent future inflation rates
- the lagged output gap
- the change in the real exchange rate
- the current and lagged increase in the real price of oil, and
- a disturbance term

The model-consistent aspect relates to price setting based on predictions of future inflation.

When monetary policy adheres to a stable policy rule, expectations eventually converge on the inflation path targeted by the central bank.

The greater the weight on the forward-looking component ($\lambda_{j,1}$), the more rapid is the convergence to the policy target. The backward-looking component, in contrast, reflects adaptive behavior, which slows the adjustment.

The coefficient on the lagged output gap embodies the familiar short-run output-inflation tradeoff. This is the crucial link between the real sector of the economy and the price level.

The coefficients on the changes in the real exchange rate and in the real price of oil reflect the pass-through to the CPI of changes in import and oil prices.

The parameter estimates for the inflation equation are reported in Table A1. They suggest that there has a been a significant decline in the weight on lagged inflation relative to earlier sample periods where monetary policy was less successful in providing an anchor for inflation and inflation expectations.

Table A1. Inflation Equation Estimated Coefficients

Output gap

	US	euro area	Japan
Future Inflation ($\lambda_{j,1}$)	0.73	0.69	0.65
Past Inflation (1- $\lambda_{j,1}$)	0.27	0.31	0.35
Lagged Output gap ($\lambda_{j,2}$)	0.17	0.21	0.17
Real Exchange Rate Changes ($\lambda_{j,3}$)	0.06	0.10	0.08

Policy interest rate equation for country j:

$$i_{j,t} = \gamma_{j,1} i_{j,t-1} + (1-\gamma_{j,1})[\bar{r}_{j,t} + \pi 4_{j,t+3}] + \gamma_{j,2}[\pi 4_{j,t+3} - \pi^*_j] + \gamma_{j,3} y_{j,t} + \varepsilon^i_{j,t}$$

This Taylor-type rule determines a key, policy-determined, short-term interest rate (Federal Funds rate for the United States, 30-day interbank rates for the euro area and Japan). The own lag provides smoothed policy responses, in line with the incremental movements typical of central bank decisions.[26] In a steady state, with inflation on target, and the price level on track, the central bank sets the actual nominal interest rate, $i_{j,t}$ at the long-run equilibrium level (equal to the equilibrium real rate plus the rate of inflation). Otherwise, it opens a corrective interest rate gap. A key difference relative to the Taylor rule is that expected Y-o-

[26]Woodford (2003) provides a theoretical rationale for the smoothed interest rate response. In essence, smoothing increases the impact of changes in short-term rates on longer-term rates, because it gives the changes some persistence.

Y inflation rate 3 quarters ahead enters the equatiuon instead of a contemporaneous measure of Y-o-Y inflation. As is the case with the Taylor rule the policy rule also responds to output gaps, which can have important effects on the path of future inflation and reducing variability in the real economy. A disturbance term allows for interest rate actions (possible policy errors) not indicated by the equation. The equation is constrained to respect the zero lower bound to the interest rate.

Exchange rate equation:

$$4\left(Z^{e}_{j,t+1} - Z_{j,t}\right) = \left(R_{j,t} - R_{us,t}\right) - \left(\overline{R}_{j,t} - \overline{R}_{us,t}\right) + \varepsilon^{Z^{e}-Z}_{j,t}$$

This equation embodies a modified uncovered interest parity (UIP) condition. But whereas simple UIP would imply equality of all exchange-rate adjusted short-term interest rates, this equation allows cross-country differences in equilibrium real interest rates ($\overline{R}_{j,t} - \overline{R}_{us,t}$), even in the long-run. That is, each currency has a risk premium, which may be positive or negative—or zero in the case that simple UIP does hold. The expectations process for the real exchange rate has lagged and model-consistent (forward-looking) components—see Carabenciov and others (2008).

Variance and covariance of disturbances

Shocks to the variables are not independent. The present version of GPM contains 3 cross-equation correlations, between:

- potential output and inflation disturbances—negative covariance representing supply shocks—e.g. a positive shock to potential output reduces the current inflation rate;

- potential output growth and output gap disturbances—positive covariance representing the expected income effect of a change in growth, which has an immediate effect on spending and output, implying excess demand in the short run;

- potential output growth and BLT disturbances in the United States—a negative covariance representing asset market/output market interactions—e.g. higher growth of potential eases bank credit (because higher growth implies higher asset values and returns); in the short run an anticipatory increase in spending would produce a positive output gap.

Underlying Equilibrium Values and Stochastic Processes

Underlying real equilibrium values, which determine the long-run paths of real variables, are not directly observable, but within the context of the model, the Bayesian technique allows us to estimate these values, given the stochastic process for each variable.

Potential output

Potential output follows a stochastic trend with disturbances which may affect its level permanently, and its growth rate over a finite period. In addition, increases in the

international price of oil have a negative effect on potential output. Disturbances may affect the level of potential output, but its growth rate over time will eventually return to its steady-state growth rate.

Real equilibrium interest rate and exchange rate:

Shocks may cause both short- and long-run changes in the equilibrium values of the interest rate and the exchange rate. The equilibrium real exchange rate follows a random walk.

Oil price:

The log of the real equilibrium price of oil (in inflation-adjusted US dollars), is modeled as a stochastic trend where the current price gradually adjusts to a long-term equilibrium that contains a unit root. In model simulations, the nominal price of oil in the United States rises with the US inflation rate, and in other countries with the rate of exchange against the US dollar. Changes in the price of oil will have two effects in the model. First, permanent increases in the real price of oil will result in a permanent decline in potential output. Second, higher oil prices raise inflation and require an increase in real interest rates, which will result in weaker demand conditions.