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Output and Unemployment Dynamics during the Great Recession: A Panel Unobserved Components Analysis

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Abstract

This paper analyzes the sources of output and unemployment dynamics in the world economy during the Great Recession. This analysis is based on a panel unobserved components model of the world economy, disaggregated into its fifteen largest national economies. We find that excess supply pressure was primarily transmitted from the output market to the labor market by economy specific combinations of negative domestic or foreign output demand shocks, mitigated to varying degrees by countercyclical labor market policies or institutions.

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I. INTRODUCTION

As the world economy recovers from the Great Recession, policymakers in many economies face the challenge of reducing unemployment from unacceptably high levels, and relatively slow recoveries in many of these economies has compounded this challenge. Understanding the sources of these labor market imbalances is prerequisite to designing effective policy measures to address them.

During the Great Recession, output and unemployment dynamics varied considerably across economies. In Spain, which experienced a drop in domestic demand, output fell by 3.7 percent while the unemployment rate rose by 10.7 percent. In Germany, which experienced a drop in foreign demand, output fell by 6.7 percent yet the unemployment rate actually fell by 0.1 percent. These examples suggest that the accumulation of imbalances in the output and labor markets depended on the nature of the shocks responsible for causing them, the policy measures implemented to address them, and the institutions operating in these markets.

This paper analyzes the sources of output and unemployment dynamics in the world economy during the Great Recession. This analysis is based on a panel unobserved components model of the world economy, disaggregated into its fifteen largest national economies. This structural macroeconometric model features extensive linkages between the real and financial sectors, both within and across economies. The major advanced and emerging economies under consideration are Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Mexico, Russia, Spain, the United Kingdom, and the United States. We measure the evolution of output and labor market imbalances in these economies by estimating their output and unemployment rate gaps. We then identify the structural determinants of output growth and the unemployment rate with historical decompositions. In doing so, we estimate the contributions of a variety of temporary shocks to the cyclical dynamics of these variables, distinguishing between those originating domestically versus abroad, while controlling for the effects of permanent shocks on their trend paths.

During the Great Recession, we find that excess supply pressure was primarily transmitted from the output market to the labor market by economy specific combinations of negative domestic or foreign output demand shocks, mitigated to varying degrees by countercyclical labor market policies or institutions, and exceptional monetary policy loosening. This general structural econometric result encompasses much economy specific heterogeneity with respect to the relative contributions of different shocks, policies and institutions. It complements the reduced form econometric results of Balakrishnan, Das and Kannan (2010), who analyze the determinants of unemployment dynamics in advanced economies from a longer term historical perspective, distilling lessons from previous business cycles for the current juncture.

The organization of this paper is as follows. The next section describes a structural macroeconometric model of the world economy. Estimation of this model is the subject of section three. Inference within the framework of the estimated model on the sources of output and unemployment dynamics is conducted in section four. Conclusions are offered in section five.

II. The Panel Unobserved Components Model

Our panel unobserved components model of the world economy consists of multiple structural unobserved components models of large open economies connected by trade and financial linkages. Within each economy, cyclical components are modeled as a multivariate linear rational expectations model of the monetary transmission mechanism derived from postulated behavioral relationships, to which a multivariate linear rational expectations model of the labor market is appended. These behavioral relationships approximately nest those associated with a variety of alternative structural macroeconomic models derived from microeconomic foundations, conferring robustness to model misspecification. In the interest of parsimony, cross economy equality restrictions are imposed on the structural parameters of these behavioral relationships, the response coefficients of which vary across economies with their structural characteristics. Trend components are modeled as independent random walks, conferring robustness to intermittent structural breaks.

The monetary transmission mechanism in each economy operates via interest rate and exchange rate channels, both of which link the short term nominal interest rate, which serves as the instrument of monetary policy, to consumption price inflation and the output gap, which are generally target variables. Under the interest rate channel, monetary policy affects the output gap and by implication inflation by inducing intertemporal substitution in domestic demand in response to changes in the long term real interest rate. Under the exchange rate channel, monetary policy both directly affects inflation, and indirectly affects the output gap and by implication inflation via intratemporal substitution between domestic and foreign demand, by inducing changes in the real effective exchange rate. A financial accelerator mechanism linked to the real value of an internationally diversified equity portfolio amplifies and propagates both of these channels.

Labor market dynamics are linked to output market dynamics in each economy by labor supply and demand relationships governing the joint evolution of the real wage and the unemployment rate gap. Cyclical imbalances in the output market are transmitted to the labor market, but not in the opposite direction. This block exogeneity restriction identifies labor supply and demand shocks as partial contributors to labor market imbalances, given output market imbalances.

In what follows, $\hat{x}_{i,t}$ denotes the cyclical component of variable $x_{i,t}$, while $\bar{x}_{i,t}$ denotes the trend component of variable $x_{i,t}$. Cyclical and trend components are additively separable, that is $x_{i,t} = \hat{x}_{i,t} + \bar{x}_{i,t}$. Furthermore, $\mathrm{E}_t\, x_{i,t+s}$ denotes the rational expectation of variable $x_{i,t+s}$

associated with economy i, conditional on information available at time t. Finally, $x_{i,t}^{f}$ denotes the trade weighted average of variable $x_{i,t}$ across the trading partners of economy i, $x_{i,t}^{p}$ denotes the portfolio weighted average of domestic currency denominated variable $x_{i,t}$ across the investment destinations of economy i, and x_{t}^{w} denotes the output weighted average of variable $x_{i,t}$ across all economies.

A. Cyclical Components

The cyclical component of output price inflation $\hat{\pi}_{i,t}^{Y}$ depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical component of output according to domestic supply relationship,

$$\hat{\pi}_{i,t}^{Y} = \phi_{1,1}\hat{\pi}_{i,t-1}^{Y} + \phi_{1,2}\,\mathrm{E}_t\,\hat{\pi}_{i,t+1}^{Y} + \theta_{1,1}\hat{Y}_{i,t} + \theta_{1,2}\sum_{z}\frac{X_i^{COM^z}}{Y_i}\phi_1(L)\Delta\ln(\hat{S}_{i,t}^{USA}\hat{P}_t^{COM^z}) + \varepsilon_{i,t}^{\hat{P}^Y}, \quad (1)$$

where domestic supply shock $\varepsilon_{i,t}^{\hat{P}^Y} \sim \text{iid } \mathcal{N}(0,\sigma_{\hat{P}^Y,i}^2)$. The cyclical component of output price inflation also depends on contemporaneous, past, and expected future changes in the cyclical components of the domestic currency denominated prices of energy and nonenergy commodity exports, where polynomial in the lag operator $\phi_1(L) = 1 - \phi_{1,1}L - \phi_{1,2}\,\mathrm{E}_t\,L^{-1}$. The response coefficients of this relationship vary across economies with their commodity export intensity, measured by the ratio of energy or nonenergy commodity exports to output $\frac{X_i^{COM^z}}{Y_i}$.

The cyclical component of consumption price inflation $\hat{\pi}_{i,t}^{C}$ depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical component of output according to supply relationship,

$$\begin{aligned}\hat{\pi}_{i,t}^{C} &= \phi_{1,1}\hat{\pi}_{i,t-1}^{C} + \phi_{1,2}\,\mathrm{E}_t\,\hat{\pi}_{i,t+1}^{C} + \theta_{1,1}\hat{Y}_{i,t} \\ &\quad + \theta_{2,1}\frac{M_i}{Y_i}\phi_1(L)\Delta\ln\hat{Q}_{i,t} + \theta_{2,2}\sum_{z}\frac{M_i^{COM^z}}{Y_i}\phi_1(L)\Delta\ln(\hat{S}_{i,t}^{USA}\hat{P}_t^{COM^z}) + \varepsilon_{i,t}^{\hat{P}^Y} + \phi_1(L)\varepsilon_{i,t}^{\hat{P}^M},\end{aligned} \quad (2)$$

where foreign supply shock $\varepsilon_{i,t}^{\hat{P}^M} \sim \text{iid } \mathcal{N}(0,\sigma_{\hat{P}^M,i}^2)$. The cyclical component of consumption price inflation also depends on contemporaneous, past, and expected future changes in the cyclical components of the real effective exchange rate and the domestic currency denominated prices of energy and nonenergy commodity imports. The response coefficients of this relationship vary across economies with their commodity import intensity, measured by the ratio of energy or nonenergy commodity imports to output $\frac{M_i^{COM^z}}{Y_i}$.

The cyclical component of output $\ln\hat{Y}_{i,t}$ follows a stationary first order autoregressive process driven by a monetary conditions index according to demand relationship,

$$\ln \hat{Y}_{i,t} = \phi_{3,1} \ln \hat{Y}_{i,t-1} + \theta_{3,1} \left(1 - \frac{M_i}{Y_i}\right) \left(\hat{r}^L_{i,t} + \theta_{3,2} \ln \frac{\hat{P}^{STK,p}_{i,t}}{\hat{P}^C_{i,t}}\right)$$
$$+\theta_{4,1} \frac{X_i}{Y_i} \phi_3(L) \ln \hat{D}^f_{i,t} + \theta_{4,2} \frac{X_i + M_i}{Y_i} \phi_3(L) \ln \hat{Q}_{i,t} + \left(1 - \frac{M_i}{Y_i}\right) \nu^{\hat{D}}_{i,t} + \frac{X_i}{Y_i} \phi_3(L) \nu^{\hat{X}}_{i,t}, \tag{3}$$

where foreign demand shock $\nu^{\hat{X}}_{i,t} = \rho_{\hat{X}} \nu^{\hat{X}}_{i,t-1} + \varepsilon^{\hat{X}}_{i,t}$ with $\varepsilon^{\hat{X}}_{i,t} \sim \text{iid } \mathcal{N}(0, \sigma^2_{\hat{X},i})$. Reflecting the existence of international trade and financial linkages, this monetary conditions index is defined as a linear combination of a financial conditions index and the contemporaneous and past cyclical components of the real effective exchange rate.[1] The cyclical component of output also depends on the contemporaneous and past cyclical components of foreign demand, where polynomial in the lag operator $\phi_3(L) = 1 - \phi_{3,1} L$. The response coefficients of this relationship vary across economies with their trade openness, measured by the ratio of exports to output $\frac{X_i}{Y_i}$ or imports to output $\frac{M_i}{Y_i}$.

The cyclical component of domestic demand $\ln \hat{D}_{i,t}$ follows a stationary first order autoregressive process driven by a financial conditions index according to domestic demand relationship,

$$\ln \hat{D}_{i,t} = \phi_{3,1} \ln \hat{D}_{i,t-1} + \theta_{3,1} \left(\hat{r}^L_{i,t} + \theta_{3,2} \ln \frac{\hat{P}^{STK,p}_{i,t}}{\hat{P}^C_{i,t}}\right) + \nu^{\hat{D}}_{i,t}, \tag{4}$$

where domestic demand shock $\nu^{\hat{D}}_{i,t} = \rho_{\hat{D}} \nu^{\hat{D}}_{i,t-1} + \varepsilon^{\hat{D}}_{i,t}$ with $\varepsilon^{\hat{D}}_{i,t} \sim \text{iid } \mathcal{N}(0, \sigma^2_{\hat{D},i})$. This financial conditions index is defined as a linear combination of the contemporaneous cyclical components of the long term real interest rate and the real value of an internationally diversified equity portfolio.

The cyclical component of the nominal wage $\ln \hat{W}_{i,t}$, deflated by the price of consumption, depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical component of the unemployment rate according to labor supply relationship,

$$\ln \frac{\hat{W}_{i,t}}{\hat{P}^C_{i,t}} = \phi_{5,1} \ln \frac{\hat{W}_{i,t-1}}{\hat{P}^C_{i,t-1}} + \phi_{5,2} \, \mathrm{E}_t \ln \frac{\hat{W}_{i,t+1}}{\hat{P}^C_{i,t+1}} + \theta_{5,1} \hat{u}_{i,t} + \theta_{5,2} \phi_5(L) \hat{\pi}^C_{i,t} + \varepsilon^{\hat{W}}_{i,t}, \tag{5}$$

where labor supply shock $\varepsilon^{\hat{W}}_{i,t} \sim \text{iid } \mathcal{N}(0, \sigma^2_{\hat{W},i})$. The cyclical component of the consumption based real wage also depends on contemporaneous, past, and expected future changes in the cyclical component of consumption price inflation, where polynomial in the lag operator $\phi_5(L) = 1 - \phi_{5,1} L - \phi_{5,2} \, \mathrm{E}_t L^{-1}$.

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[1]This monetary conditions index $\hat{I}^{MCI}_{i,t}$ is defined as $\hat{I}^{MCI}_{i,t} = \hat{I}^{FCI}_{i,t} + \frac{\theta_{4,2}}{\theta_{3,1}} \frac{X_i + M_i}{Y_i} \left(1 - \frac{M_i}{Y_i}\right)^{-1} \phi_3(L) \ln \hat{Q}_{i,t}$, where financial conditions index $\hat{I}^{FCI}_{i,t}$ satisfies $\hat{I}^{FCI}_{i,t} = \hat{r}^L_{i,t} + \theta_{3,2} \ln \frac{\hat{P}^{STK,p}_{i,t}}{\hat{P}^C_{i,t}}$.

The cyclical component of the unemployment rate $\hat{u}_{i,t}$ follows a stationary first order autoregressive process driven by the contemporaneous cyclical components of output and the output based real wage according to labor demand relationship,

$$\hat{u}_{i,t} = \phi_{6,1}\hat{u}_{i,t-1} + \theta_{6,1}\ln\hat{Y}_{i,t} + \theta_{6,2}\ln\frac{\hat{W}_{i,t}}{\hat{P}^{Y}_{i,t}} + \varepsilon^{\hat{L}}_{i,t}, \tag{6}$$

where labor demand shock $\nu^{\hat{L}}_{i,t} = \rho_{\hat{L}}\nu^{\hat{L}}_{i,t-1} + \varepsilon^{\hat{L}}_{i,t}$ with $\varepsilon^{\hat{L}}_{i,t} \sim \text{iid } \mathcal{N}(0,\sigma^2_{\hat{L},i})$.

The cyclical component of the short term nominal interest rate $\hat{i}^{S}_{i,t}$ depends on a weighted average of its past and desired cyclical components according to monetary policy rule,

$$\hat{i}^{S}_{i,t} = \phi_{7,1}\hat{i}^{S}_{i,t-1} + (1-\phi_{7,1})\left[I_i(\theta_{7,1}\hat{\pi}^{C}_{i,t} + \theta_{7,2}\ln\hat{Y}_{i,t}) + (1-I_i)\theta_{7,3}\ln\hat{S}^{USA}_{i,t}\right] + \varepsilon^{\hat{i}^S}_{i,t}, \tag{7}$$

where monetary policy shock $\varepsilon^{\hat{i}^S}_{i,t} \sim \text{iid } \mathcal{N}(0,\sigma^2_{\hat{i}^S,i})$. Under a flexible inflation targeting regime $I_i = 1$ and the desired cyclical component of the short term nominal interest rate responds to the contemporaneous cyclical components of consumption price inflation and output, while under a fixed exchange rate regime $I_i = 0$ and it responds to the contemporaneous cyclical component of the nominal bilateral exchange rate. For economies belonging to a currency union, the target variables entering into their common monetary policy rule are expressed as output weighted averages across union members. The cyclical component of the short term real interest rate $\hat{r}^{S}_{i,t}$ satisfies $\hat{r}^{S}_{i,t} = \hat{i}^{S}_{i,t} - \text{E}_t\,\hat{\pi}^{C}_{i,t+1}$.

The cyclical component of the long term real interest rate $\hat{r}^{L}_{i,t}$ depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical component of the short term real interest rate according to term structure relationship,

$$\hat{r}^{L}_{i,t} = \phi_{8,1}\hat{r}^{L}_{i,t-1} + \phi_{8,2}\,\text{E}_t\,\hat{r}^{L}_{i,t+1} + \theta_{8,1}\hat{r}^{S}_{i,t} + \varepsilon^{\hat{i}^L}_{i,t}, \tag{8}$$

where liquidity risk premium shock $\varepsilon^{\hat{i}^L}_{i,t} \sim \text{iid } \mathcal{N}(0,\sigma^2_{\hat{i}^L,i})$. The cyclical component of the long term nominal interest rate $\hat{i}^{L}_{i,t}$ satisfies $\hat{r}^{L}_{i,t} = \hat{i}^{L}_{i,t} - \text{E}_t\,\hat{\pi}^{C}_{i,t+1}$.

The cyclical component of the price of equity $\ln\hat{P}^{STK}_{i,t}$, deflated by the price of consumption, depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical components of output and the short term real interest rate,

$$\ln\frac{\hat{P}^{STK}_{i,t}}{\hat{P}^{C}_{i,t}} = \phi_{9,1}\ln\frac{\hat{P}^{STK}_{i,t-1}}{\hat{P}^{C}_{i,t-1}} + \phi_{9,2}\,\text{E}_t\ln\frac{\hat{P}^{STK}_{i,t+1}}{\hat{P}^{C}_{i,t+1}} + \theta_{9,1}\ln\hat{Y}_{i,t} + \theta_{9,2}\hat{r}^{S}_{i,t} + \varepsilon^{\hat{P}^{STK}}_{i,t}, \tag{9}$$

where equity risk premium shock $\varepsilon^{\hat{P}^{STK}}_{i,t} \sim \text{iid } \mathcal{N}(0,\sigma^2_{\hat{P}^{STK},i})$.

The cyclical component of the real bilateral exchange rate $\ln \hat{Q}_{i,t}^{USA}$ depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical component of the short term real interest rate differential,

$$\ln \hat{Q}_{i,t}^{USA} = \phi_{10,1} \ln \hat{Q}_{i,t-1}^{USA} + \phi_{10,2} \,\mathrm{E}_t \ln \hat{Q}_{i,t+1}^{USA} + \theta_{10,j} (\hat{r}_{i,t}^{S} - \hat{r}_{USA,t}^{S}) + \varepsilon_{i,t}^{\hat{S}}, \tag{10}$$

where exchange rate risk premium shock $\varepsilon_{i,t}^{\hat{S}} \sim \text{iid } \mathcal{N}(0, \sigma_{\hat{S},i}^2)$. The sensitivity of the real bilateral exchange rate to changes in the short term real interest rate differential depends on capital controls, with $j = 1$ in their absence and $j = 2$ in their presence. The cyclical component of the nominal bilateral exchange rate $\ln \hat{S}_{i,t}^{USA}$ satisfies $\ln \hat{Q}_{i,t}^{USA} = \ln \hat{S}_{i,t}^{USA} + \ln \hat{P}_{USA,t}^{C} - \ln \hat{P}_{i,t}^{C}$.[2]

The cyclical component of the change in the price of energy or nonenergy commodities $\ln \hat{P}_t^{COM^z}$ depends on a linear combination of its past and expected future cyclical components driven by the contemporaneous cyclical component of world output,

$$\Delta \ln \hat{P}_t^{COM^z} = \phi_{11,1} \Delta \ln \hat{P}_{t-1}^{COM^z} + \phi_{11,2} \,\mathrm{E}_t \Delta \ln \hat{P}_{t+1}^{COM^z} + \theta_{11,j} \ln \hat{Y}_t^{w} + \varepsilon_t^{\hat{P}^{COM^z}}, \tag{11}$$

where commodity price shock $\varepsilon_t^{\hat{P}^{COM^z}} \sim \text{iid } \mathcal{N}(0, \sigma_{\hat{P}^{COM},z}^2)$. The sensitivity of the change in the price of commodities to changes in world output depends on their type $z \in \{e, n\}$, with $j = 1$ for energy commodities and $j = 2$ for nonenergy commodities. As an identifying restriction, all innovations are assumed to be independent, which combined with our distributional assumptions implies multivariate normality.

B. Trend Components

The growth rates of the trend components of the price of output $\ln \bar{P}_{i,t}^{Y}$, the price of consumption $\ln \bar{P}_{i,t}^{C}$, output $\ln \bar{Y}_{i,t}$, domestic demand $\ln \bar{D}_{i,t}$, the price of equity $\ln \bar{P}_{i,t}^{STK}$, and the price of energy or nonenergy commodities $\ln \bar{P}_t^{COM^z}$ follow random walks:

$$\Delta \ln \bar{P}_{i,t}^{Y} = \Delta \ln \bar{P}_{i,t-1}^{Y} + \varepsilon_{i,t}^{\bar{P}^Y},\ \varepsilon_{i,t}^{\bar{P}^Y} \sim \text{iid } \mathcal{N}(0, \sigma_{\bar{P}^Y,i}^2), \tag{12}$$

$$\Delta \ln \bar{P}_{i,t}^{C} = \Delta \ln \bar{P}_{i,t-1}^{C} + \varepsilon_{i,t}^{\bar{P}^C},\ \varepsilon_{i,t}^{\bar{P}^C} \sim \text{iid } \mathcal{N}(0, \sigma_{\bar{P}^C,i}^2), \tag{13}$$

$$\Delta \ln \bar{Y}_{i,t} = \Delta \ln \bar{Y}_{i,t-1} + \varepsilon_{i,t}^{\bar{Y}},\ \varepsilon_{i,t}^{\bar{Y}} \sim \text{iid } \mathcal{N}(0, \sigma_{\bar{Y},i}^2), \tag{14}$$

$$\Delta \ln \bar{D}_{i,t} = \Delta \ln \bar{D}_{i,t-1} + \varepsilon_{i,t}^{\bar{D}},\ \varepsilon_{i,t}^{\bar{D}} \sim \text{iid } \mathcal{N}(0, \sigma_{\bar{D},i}^2), \tag{15}$$

[2] It can be shown that the cyclical component of the nominal effective exchange rate $\ln \hat{S}_{i,t}$ satisfies $\ln \hat{S}_{i,t} = \ln \hat{S}_{i,t}^{USA} - \sum_{j=1}^{N} w_{i,j} \ln \hat{S}_{j,t}^{USA}$, while the cyclical component of the real effective exchange rate $\ln \hat{Q}_{i,t}$ satisfies $\ln \hat{Q}_{i,t} = \ln \hat{Q}_{i,t}^{USA} - \sum_{j=1}^{N} w_{i,j} \ln \hat{Q}_{j,t}^{USA}$, where $w_{i,j}$ denotes the bilateral trade weight for economy i with respect to economy j, and N denotes the number of economies. Note that $\ln \hat{Q}_{i,t} = \ln \hat{S}_{i,t} + \ln \hat{P}_{i,t}^{C,f} - \ln \hat{P}_{i,t}^{C}$.

$$\Delta \ln \overline{P}_{i,t}^{STK} = \Delta \ln \overline{P}_{i,t-1}^{STK} + \varepsilon_{i,t}^{\overline{P}^{STK}},\ \varepsilon_{i,t}^{\overline{P}^{STK}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{P}^{STK},i}^{2}), \tag{16}$$

$$\Delta \ln \overline{P}_{t}^{COM^{z}} = \Delta \ln \overline{P}_{t-1}^{COM^{z}} + \varepsilon_{t}^{\overline{P}^{COM^{z}}},\ \varepsilon_{t}^{\overline{P}^{COM^{z}}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{P}^{COM^{z}}}^{2}). \tag{17}$$

The trend components of the growth rate of the nominal wage $\ln \overline{W}_{i,t}$ and unemployment rate $\overline{u}_{i,t}$ also follow random walks:

$$\Delta \ln \overline{W}_{i,t} = \Delta \ln \overline{W}_{i,t-1} + \varepsilon_{i,t}^{\overline{W}},\ \varepsilon_{i,t}^{\overline{W}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{W},i}^{2}), \tag{18}$$

$$\overline{u}_{i,t} = \overline{u}_{i,t-1} + \varepsilon_{i,t}^{\overline{u}},\ \varepsilon_{i,t}^{\overline{u}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{u},i}^{2}). \tag{19}$$

The trend components of the short term nominal interest rate $\overline{i}_{i,t}^{S}$, long term nominal interest rate $\overline{i}_{i,t}^{L}$, and growth rate of the nominal bilateral exchange rate $\ln \overline{S}_{i,t}^{USA}$ also follow random walks:

$$\overline{i}_{i,t}^{S} = \overline{i}_{i,t-1}^{S} + \varepsilon_{i,t}^{\overline{i}^{S}},\ \varepsilon_{i,t}^{\overline{i}^{S}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{i}^{S},i}^{2}), \tag{20}$$

$$\overline{i}_{i,t}^{L} = \overline{i}_{i,t-1}^{L} + \varepsilon_{i,t}^{\overline{i}^{L}},\ \varepsilon_{i,t}^{\overline{i}^{L}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{i}^{L},i}^{2}), \tag{21}$$

$$\Delta \ln \overline{S}_{i,t}^{USA} = \Delta \ln \overline{S}_{i,t-1}^{USA} + \varepsilon_{i,t}^{\overline{S}},\ \varepsilon_{i,t}^{\overline{S}} \sim \text{iid } \mathcal{N}(0, \sigma_{\overline{S},i}^{2}). \tag{22}$$

The trend component of the short term real interest rate $\overline{r}_{i,t}^{S}$ satisfies $\overline{r}_{i,t}^{S} = \overline{i}_{i,t}^{S} - \mathrm{E}_t\, \overline{\pi}_{i,t+1}^{C}$, the trend component of the long term real interest rate $\overline{r}_{i,t}^{L}$ satisfies $\overline{r}_{i,t}^{L} = \overline{i}_{i,t}^{L} - \mathrm{E}_t\, \overline{\pi}_{i,t+1}^{C}$, and the trend component of the real bilateral exchange rate $\ln \overline{Q}_{i,t}^{USA}$ satisfies $\ln \overline{Q}_{i,t}^{USA} = \ln \overline{S}_{i,t}^{USA} + \ln \overline{P}_{USA,t}^{C} - \ln \overline{P}_{i,t}^{C}$. As an identifying restriction, all innovations are assumed to be independent.

III. Estimation

The traditional econometric interpretation of this panel unobserved components model of the world economy regards it as a representation of the joint probability distribution of the data. We employ a Bayesian estimation procedure which respects this traditional econometric interpretation.

A. Estimation Procedure

The parameters and unobserved components of our panel unobserved components model are jointly estimated with a Bayesian procedure, conditional on prior information concerning the values of structural parameters, and judgment concerning the paths of trend components. Inference on the parameters is based on an asymptotic normal approximation to the posterior distribution around its mode, which is calculated by numerically maximizing the logarithm of the posterior density kernel. Following Engle and Watson (1981), we employ an estimator of the Hessian which depends only on first derivatives and is negative semidefinite.

Evaluation of the logarithm of the posterior density kernel involves first solving for the unique stationary solution to the multivariate linear rational expectations model governing the evolution of cyclical components with the algorithm due to Klein (2000). The resultant first order vector autoregressive model is then combined with a dynamic factor model governing the evolution of trend components to form a linear state space model expressing the levels of all observed nonpredetermined endogenous variables as a function of an unobserved state vector, which in turn evolves according to a first order vector autoregressive process. This linear state space model is then augmented with a set of stochastic restrictions on selected unobserved state variables summarizing judgment concerning the paths of the trend components of all observed nonpredetermined endogenous variables. The logarithm of the predictive density function is then evaluated, conditional on the parameters associated with this linear state space model, with the filter presented in Vitek (2009), which adapts the filter due to Kalman (1960) to incorporate judgment. Finally, the logarithm of this conditional density function is combined with the logarithm of a multivariate normal density function summarizing prior information concerning the values of parameters. For a detailed discussion of this estimation procedure, please refer to Vitek (2009).

B. Estimation Results

Joint estimation of the parameters and unobserved components of our panel unobserved components model is based on the levels of a total of one hundred forty six endogenous variables observed for fifteen economies over the period 1999Q1 through 2009Q4. The economies under consideration are Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Mexico, Russia, Spain, the United Kingdom, and the United States. The observed endogenous variables under consideration are the price of output, the price of consumption, the quantity of output, the quantity of domestic demand, the nominal wage, the unemployment rate, the short term nominal interest rate, the long term nominal interest rate, the price of equity, the nominal bilateral exchange rate, and the prices of energy and nonenergy commodities. For a detailed description of this data set, please refer to Appendix A.

Parameters

The set of parameters associated with our panel unobserved components model is partitioned into two subsets. Those parameters associated with the conditional mean function are estimated conditional on informative independent priors, while those parameters associated exclusively with the conditional variance function are estimated conditional on diffuse priors.

The marginal prior distributions of those parameters associated with the conditional mean function are centered within the range of estimates reported in the existing empirical literature, where available. The conduct of monetary policy is represented by a flexible inflation targeting regime in all economies except for China, where it is represented by a fixed exchange rate regime. Capital controls apply in China, India and Russia. Great ratios and bilateral trade and equity portfolio weights entering into the conditional mean function are calibrated to match their observed values in 2005. All world output shares and bilateral trade and equity portfolio weights are normalized to sum to one.

Judgment concerning the paths of trend components is generated by passing the levels of all observed endogenous variables through the filter described in Hodrick and Prescott (1997). Stochastic restrictions on the trend components of all observed endogenous variables are derived from these preliminary estimates, with a time varying innovation covariance matrix set equal to that obtained from unrestricted estimation. Initial conditions for the cyclical components of exogenous variables are given by their unconditional means and variances, while the initial values of all other state variables are treated as parameters, and are calibrated to match functions of initial realizations of the levels of observed endogenous variables, or preliminary estimates of their trend components calculated with the filter due to Hodrick and Prescott (1997).

The posterior mode is calculated by numerically maximizing the logarithm of the posterior density kernel with a modified steepest ascent algorithm. Parameter estimation results pertaining to the period 1999Q3 through 2009Q4 are reported in Table 1 of Appendix B. The sufficient condition for the existence of a unique stationary rational expectations equilibrium due to Klein (2000) is satisfied in a neighborhood around the posterior mode, while our estimator of the Hessian is not nearly singular at the posterior mode, suggesting that the linear state space representation of our panel unobserved components model is locally identified.

The posterior modes of most structural parameters are close to their prior means, reflecting the imposition of tight priors to preserve empirically plausible impulse response dynamics. The estimated variances of shocks driving variation in cyclical components are all well within the range of estimates reported in the existing empirical literature, after accounting for data rescaling. The estimated variances of shocks driving variation in trend components vary considerably across economies and observed endogenous variables.

Unobserved Components

The output gap is a measure of cyclical output market imbalances, with positive values indicating excess demand pressure, and vice versa. In parallel, the unemployment rate gap is a measure of cyclical labor market imbalances, with positive values indicating excess supply pressure, and vice versa. Estimates of these measures of output and labor market imbalances are plotted for the economies under consideration in Figure 1.

The output gap and the unemployment rate gap tend to be negatively correlated, an empirical regularity associated with Okun (1970). During the estimation sample period under consideration, we estimate that the correlation between these measures of output and labor market imbalances averaged −0.77 for advanced economies, and −0.40 for emerging economies. During the Great Recession, identified as that economy specific period in which the output gap fell from peak to trough, these correlations increased to −0.93 for advanced economies, and to −0.52 for emerging economies. These exceptionally high correlations indicate that the simultaneous accumulation of excess supply pressure in the output and labor markets primarily reflected their responses to common shocks.

In the wake of the Great Recession, output and labor market imbalances vary considerably across the economies under consideration. Our terminal estimates of the output gap range between −1.6 and −6.8 percent for advanced economies, and between 0.5 and −9.2 percent for emerging economies. These output gap estimates are generally negative and large, but have been shrinking rapidly in several emerging economies. Our terminal estimates of the unemployment rate gap range between −0.5 and 6.3 percent for advanced economies, and between −1.3 and 1.4 percent for emerging economies. The high dispersion of these unemployment rate gap estimates, relative to the corresponding output gap estimates, motivates our analysis of their structural determinants.

IV. Inference

We measure the contributions of a variety of temporary shocks to the cyclical dynamics of output growth and the unemployment rate with historical decompositions, distinguishing between those originating domestically versus abroad, while controlling for the effects of permanent shocks on their trend paths. Estimated historical decompositions of output growth and the unemployment rate are plotted for the economies under consideration in Figure 2 and Figure 3, respectively.

Estimated historical decompositions of output growth in the world economy attribute business cycle dynamics around relatively stable potential output growth rates primarily to economy specific combinations of domestic and foreign demand shocks. Business cycle fluctuations in relatively closed economies such as the United States have been primarily driven by domestic demand shocks, whereas fluctuations in relatively open economies such as China and Germany have been primarily driven by foreign demand shocks. Potential output growth rates have generally stabilized at relatively high levels in emerging economies, but have tended to exhibit gradual declines from relatively low levels in advanced economies.

During the build up to the Great Recession, positive domestic demand shocks contributed to the accumulation of excess demand pressure throughout the world economy, often amplified by foreign demand shocks or world risk premium shocks. During the precipitous synchronized global contraction which ensued, economy specific combinations of negative domestic and foreign demand shocks rapidly eliminated this excess demand pressure, supplanting it with excess supply pressure to varying degrees. A notable exception is China, where small positive domestic demand shocks were dominated by large negative foreign demand shocks. This rapid accumulation of excess supply pressure was exacerbated by an abrupt tightening of monetary conditions in many economies driven by risk premia reversals, in spite of exceptional monetary policy loosening. These risk premia reversals were most pronounced in the United States, where exceptional monetary policy loosening was most aggressive.

Estimated historical decompositions of the unemployment rate attribute fluctuations at business cycle frequencies around less volatile natural rates of unemployment primarily to economy specific combinations of domestic and foreign output demand shocks, together with domestic labor demand shocks. Note that labor supply and demand shocks capture labor market dynamics not derived from output market dynamics, possibly reflecting labor market policies or institutions. The contributions of domestic and foreign output demand shocks to the unemployment rate have generally mirrored those to output growth, reflecting the fact that the demand for labor is derived from the demand for output. This identifies domestic and foreign output demand shocks as the primary common sources of cyclical fluctuations in the output and labor markets, consistent with Blanchard and Quah (1989). The contributions of domestic labor demand shocks to the unemployment rate have tended to mitigate cyclical fluctuations, indicating countercyclical labor market policies or institutions. A notable exception is Spain, where domestic labor demand shocks have tended to amplify cyclical fluctuations, suggesting procyclical labor market institutions, probably related to the prevalence of temporary employment contracts and wage indexation to consumption price inflation. Natural rates of unemployment have followed diverse economy specific trajectories, possibly reflecting structural change or demographic factors. Hysteresis is a concern in Spain and the United States, where the natural rate of unemployment has been gradually rising.

During the build up to the Great Recession, positive domestic or foreign output demand shocks contributed to the accumulation of excess labor demand pressure in all of the economies under consideration. This excess labor demand pressure was mitigated by negative labor demand shocks, except in Spain where positive labor demand shocks amplified it. During the Great Recession, economy specific combinations of negative domestic or foreign output demand shocks rapidly eliminated this excess labor demand pressure, generally supplanting it with excess labor supply pressure. In those economies which experienced the largest increases in unemployment rate gaps, namely Spain and the United States, the primary contributors were negative domestic demand shocks. Offsetting contributions from labor demand shocks indicate that this transmission of excess supply pressure from the output market to the labor market was mitigated by countercyclical labor market policies or institutions, except in Spain and to a lesser extent the United States, where procyclical labor market institutions may have amplified it. Indeed, these offsetting contributions were relatively large in Germany, Italy and Japan, where short time work programs were implemented. In several economies, exceptional monetary policy loosening also constrained the accumulation of excess supply pressure in the labor market, but to a limited extent. These offsetting contributions were most pronounced in the United Kingdom and the United States.

V. Conclusion

This paper analyzes the sources of output and unemployment dynamics in the world economy during the Great Recession. This analysis is based on a panel unobserved components model of the world economy, disaggregated into its fifteen largest national economies. We find that excess supply pressure was primarily transmitted from the output market to the labor market by economy specific combinations of negative domestic or foreign output demand shocks, mitigated to varying degrees by countercyclical labor market policies or institutions. This general result encompasses much economy specific heterogeneity with respect to the relative contributions of different shocks, policies and institutions.

Appendix A. Description of the Data Set

Estimation is based on quarterly data on several macroeconomic and financial market variables for fifteen economies over the period 1999Q1 through 2009Q4. The economies under consideration are Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Mexico, Russia, Spain, the United Kingdom, and the United States. This data was obtained from the GDS database maintained by the International Monetary Fund where available, and from the MEI database maintained by the Organization for Economic Cooperation and Development or the CEIC database compiled by Internet Securities Incorporated otherwise.

The macroeconomic variables under consideration are the price of output, the price of consumption, the quantity of output, the quantity of domestic demand, the nominal wage, the unemployment rate, and the prices of energy and nonenergy commodities. The price of output is measured by the seasonally adjusted gross domestic product price deflator, while the price of consumption is proxied by the seasonally adjusted consumer price index. The quantity of output is measured by seasonally adjusted real gross domestic product, while the quantity of domestic demand is measured by the sum of seasonally adjusted real consumption and investment expenditures. The nominal wage is proxied by a seasonally adjusted manufacturing wage index, while the unemployment rate is measured by the seasonally adjusted total unemployment rate. The prices of energy and nonenergy commodities are proxied by broad commodity price indexes denominated in United States dollars.

The financial market variables under consideration are the short term nominal interest rate, the long term nominal interest rate, the price of equity, and the nominal bilateral exchange rate. The short term nominal interest rate is measured by the three month treasury bill yield where available, and a three month money market rate otherwise, expressed as a period average. The long term nominal interest rate is measured by the ten year government bond yield where available, and a ten year commercial bank lending or deposit rate otherwise, expressed as a period average. The price of equity is proxied by a broad stock price index denominated in domestic currency units. The nominal bilateral exchange rate is measured by the domestic currency price of one United States dollar expressed as a period average.

Calibration is based on annual data extracted from databases maintained by the International Monetary Fund where available, and from the World Bank Group otherwise. Great ratios are derived from the WEO and WDI databases, bilateral trade weights are derived from the DOTS database, and bilateral equity portfolio weights are derived from the CPIS and WDI databases.

Appendix B. Tables and Figures

Table 1. Parameter Estimation Results

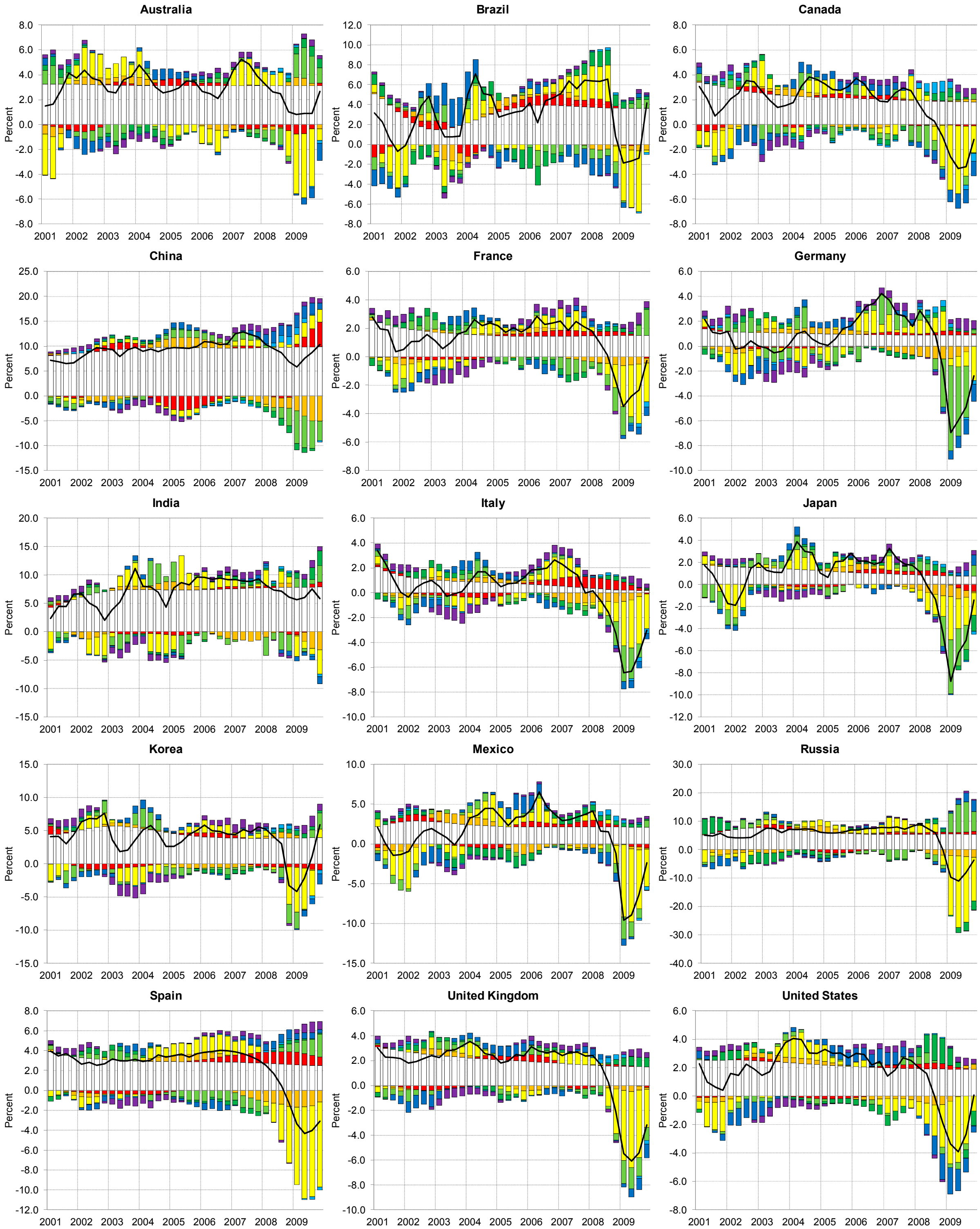
	Prior		Posterior																																	
			World		Australia		Brazil		Canada		China		France		Germany		India		Italy		Japan		Korea		Mexico		Russia		Spain		United Kingdom		United States	
	Mean	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE	Mode	SE
$\phi_{1\,1}$	0.490	4.9e–4	0.490	4.8e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{1\,2}$	0.490	4.9e–4	0.490	4.8e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{1\,1}$	0.010	1.0e–4	0.010	9.9e–5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{1\,2}$	1.000	1.0e–2	0.996	9.2e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{2\,1}$	0.100	1.0e–3	0.100	1.0e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{2\,2}$	1.000	1.0e–2	0.969	9.1e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{3\,1}$	0.490	4.9e–4	0.490	4.9e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{3\,1}$	–0.850	8.5e–3	–0.860	8.2e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{3\,2}$	–0.010	1.0e–4	–0.010	9.9e–5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{4\,1}$	1.000	1.0e–2	1.000	1.0e–2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{4\,2}$	0.050	5.0e–4	0.050	5.0e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{5\,1}$	0.490	4.9e–4	0.490	4.8e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{5\,2}$	0.490	4.9e–4	0.490	4.8e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{5\,1}$	–0.025	2.5e–4	–0.025	2.5e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{5\,2}$	–0.450	4.5e–3	–0.450	4.1e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{6\,1}$	0.490	4.9e–4	0.490	4.9e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{6\,1}$	–0.500	5.0e–3	–0.471	4.7e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{6\,2}$	0.010	1.0e–4	0.010	1.0e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{7\,1}$	0.800	8.0e–4	0.798	7.7e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{7\,1}$	1.500	1.5e–2	...	...	1.535	1.2e–2	1.535	1.2e–2	1.535	1.2e–2	...	...	...	...	1.535	1.2e–2	1.535	1.2e–2	...	...	1.535	1.2e–2	1.535	1.2e–2	1.535	1.2e–2	1.535	1.2e–2	...	...	1.535	1.2e–2	1.535	1.2e–2
$\theta_{7\,2}$	0.125	1.3e–3	...	...	0.124	1.2e–3	0.124	1.2e–3	0.124	1.2e–3	...	...	...	...	0.124	1.2e–3	0.124	1.2e–3	...	...	0.124	1.2e–3	0.124	1.2e–3	0.124	1.2e–3	0.124	1.2e–3	...	...	0.124	1.2e–3	0.124	1.2e–3
$\theta_{7\,3}$	0.250	2.5e–3	...	...	...	...	...	...	...	...	0.250	2.5e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{8\,1}$	0.490	4.9e–4	0.488	4.5e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{8\,2}$	0.490	4.9e–4	0.488	4.2e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{8\,1}$	0.100	1.0e–3	0.089	9.1e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{9\,1}$	0.490	4.9e–4	0.489	4.7e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{9\,2}$	0.490	4.9e–4	0.488	4.5e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{9\,1}$	1.000	1.0e–2	0.986	9.8e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{9\,2}$	–1.000	1.0e–2	–1.001	1.0e–2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{10\,1}$	0.490	4.9e–4	0.490	4.9e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{10\,2}$	0.490	4.9e–4	0.490	4.9e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{10\,1}$	–0.100	1.0e–3	...	...	–0.100	1.0e–3	–0.100	1.0e–3	–0.100	1.0e–3	...	...	...	...	–0.100	1.0e–3	...	...	...	...	–0.100	1.0e–3	–0.100	1.0e–3	–0.100	1.0e–3	...	...	...	...	–0.100	1.0e–3	–0.100	1.0e–3
$\theta_{10\,2}$	–0.025	2.5e–4	...	...	...	...	...	...	...	...	–0.025	2.5e–4	...	...	...	...	–0.025	2.5e–4	...	...	...	...	...	...	...	...	–0.025	2.5e–4	...	...	...	...	...	...
$\phi_{11\,1}$	0.490	4.9e–4	0.489	4.9e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\phi_{11\,2}$	0.490	4.9e–4	0.489	4.9e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{11\,1}$	0.250	2.5e–3	0.250	2.5e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\theta_{11\,2}$	0.100	1.0e–3	0.100	1.0e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\rho_{\hat{v}}$	0.600	6.0e–3	0.606	5.9e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\rho_{\hat{n}}$	0.600	6.0e–3	0.600	5.8e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\rho_{\hat{i}}$	0.600	6.0e–3	0.611	5.9e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\sigma^2_{\hat{p}^Y}$	...	∞	...	...	8.5e–1	1.1e–5	4.0e+0	1.9e–6	4.7e–1	3.1e–5	1.6e+0	3.5e–6	7.8e–2	1.7e–2	2.2e–1	4.7e–2	5.7e–1	1.8e–5	4.8e–1	2.1e–5	3.2e–1	7.0e–2	1.3e+0	6.2e–6	4.2e+0	1.8e–6	1.1e+1	1.0e–6	9.3e–2	2.0e–2	5.9e–1	1.7e–5	5.5e–2	1.2e–2
$\sigma^2_{\hat{p}^M}$	...	∞	...	...	7.4e–1	4.6e–6	2.1e+0	9.4e–7	3.2e–1	7.0e–2	1.9e+0	1.3e–6	6.5e–2	1.4e–2	1.4e–1	3.0e–2	2.2e+0	1.3e–6	2.5e–1	5.3e–2	1.5e–1	3.3e–2	1.4e+0	2.5e–6	1.8e+0	1.2e–6	6.1e+0	1.4e–6	1.2e–1	2.5e–2	3.3e–1	7.2e–2	9.3e–2	2.0e–2
$\sigma^2_{\hat{y}}$	...	∞	...	...	6.8e+0	7.3e–8	1.0e+1	6.4e–8	1.7e+0	4.9e–7	1.8e+0	2.0e–5	1.2e+0	1.6e–5	2.7e+0	3.5e–6	2.9e+1	1.0e–7	1.5e+0	1.9e–5	1.1e+1	8.0e–6	2.1e+0	5.3e–6	1.6e+0	1.4e–7	1.8e+1	4.0e–8	2.3e+0	5.1e–6	8.1e–1	2.1e–5	4.6e+0	2.3e–7
$\sigma^2_{\hat{p}}$	...	∞	...	...	6.7e–1	8.3e–7	1.2e+0	5.3e–7	9.0e–1	5.5e–7	4.3e–1	3.7e–6	2.6e–1	5.7e–2	1.1e+0	1.1e–6	3.9e+0	1.0e–6	3.2e–1	7.0e–2	4.6e–1	1.8e–5	2.1e+0	8.2e–7	2.9e+0	2.1e–7	8.4e+0	4.0e–6	8.6e–1	4.2e–6	4.9e–1	1.4e–5	3.8e–1	6.4e–6
$\sigma^2_{\hat{w}^Y}$	...	∞	...	...	5.0e–1	5.9e–6	9.8e–1	2.9e–6	5.7e–1	5.1e–6	9.3e–1	3.1e–6	2.4e–2	5.2e–3	4.6e–2	1.0e–2	9.9e–2	2.2e–2	1.2e–1	2.6e–2	1.1e+0	2.7e–6	4.6e+0	6.2e–7	3.2e–2	7.0e–3	2.1e+0	1.4e–6	3.9e+0	7.5e–7	7.8e–2	1.7e–2	9.6e–2	2.1e–2
$\sigma^2_{\hat{i}}$	...	∞	...	...	5.5e–2	1.2e–2	6.6e–1	3.2e–7	7.0e–2	1.5e–2	1.2e–1	2.6e–2	4.8e–2	1.1e–2	1.8e–1	4.1e–2	2.6e–1	5.7e–2	1.3e–1	2.9e–2	2.7e–1	5.9e–2	3.0e–1	6.6e–2	5.4e–1	4.2e–7	7.6e–1	1.0e–6	8.4e–2	2.1e–2	1.4e–1	3.0e–2	3.8e–2	8.6e–3
$\sigma^2_{\hat{i}^S}$	...	∞	...	...	2.9e–2	6.3e–3	1.5e–1	3.3e–2	2.1e–2	4.6e–3	1.2e–2	2.6e–3	...	...	1.0e–2	2.2e–3	1.1e–1	2.3e–2	...	...	1.4e–2	3.1e–3	2.7e–2	6.0e–3	9.0e–2	2.0e–2	1.1e+0	2.6e–5	...	...	1.6e–2	3.4e–3	4.0e–2	8.7e–3
$\sigma^2_{\hat{i}^L}$	...	∞	...	...	5.6e–3	1.2e–3	1.3e–2	2.9e–3	3.0e–3	6.6e–4	6.4e–3	1.4e–3	3.0e–3	6.6e–4	2.5e–3	5.4e–4	1.4e–2	3.2e–3	2.0e–3	4.4e–4	2.0e–3	4.4e–4	9.0e–3	2.0e–3	2.7e–2	6.1e–3	5.7e–1	8.1e–5	3.6e–3	7.8e–4	2.5e–3	5.4e–4	6.4e–3	1.4e–3
$\sigma^2_{\hat{p}^{STK}}$	...	∞	...	...	2.4e+1	7.3e–8	9.2e+1	2.4e–8	3.4e+1	4.8e–8	1.3e+2	3.8e–8	5.7e+1	5.5e–8	1.0e+2	3.0e–8	9.7e+1	3.7e–8	4.6e+1	1.3e–7	4.1e+1	6.2e–8	9.6e+1	2.4e–8	6.4e+1	7.0e–8	3.2e+2	7.0e–8	6.0e+1	4.0e–8	2.8e+1	6.7e–8	3.3e+1	5.5e–8
$\sigma^2_{\hat{e}}$	...	∞	...	...	1.3e+1	3.3e–8	2.3e+1	1.9e–8	5.0e+0	1.1e–7	3.7e–1	4.0e–6	...	...	5.9e+0	8.9e–8	2.1e+0	3.3e–7	...	...	7.8e+0	4.5e–8	8.2e+0	1.3e–7	8.9e+0	5.7e–8	7.6e+0	4.2e–8	...	...	5.3e+0	3.1e–7	...	...
$\sigma^2_{\hat{p}^{COM}}$	...	∞	1.7e+2	6.4e–9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\sigma^2_{\hat{p}^{COM}}$	...	∞	2.9e+1	2.0e–8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\sigma^2_{\bar{p}^Y}$	...	∞	...	...	1.4e–5	5.8e–6	1.2e–4	5.0e–5	1.2e–5	8.9e–6	1.3e–4	3.6e–5	1.2e–6	4.6e–7	1.2e–6	2.5e–7	3.8e–5	1.0e–5	3.1e–6	1.2e–6	3.2e–6	9.4e–7	2.2e–5	9.5e–6	3.8e–5	9.4e–6	1.1e–4	1.8e–5	2.2e–5	1.0e–5	1.9e–6	6.4e–7	8.7e–6	3.9e–6
$\sigma^2_{\bar{p}^C}$	...	∞	...	...	5.9e–6	1.6e–6	1.6e–4	5.5e–5	2.2e–6	5.3e–7	6.1e–5	1.6e–5	1.0e–6	8.0e–7	2.9e–6	1.1e–6	9.8e–5	3.8e–5	5.7e–7	1.6e–7	5.7e–6	1.6e–6	1.4e–6	9.6e–7	4.0e–5	1.5e–5	3.1e–4	8.9e–5	3.4e–6	2.6e–6	1.5e–5	3.5e–6	4.6e–6	4.3e–6
$\sigma^2_{\bar{y}}$	...	∞	...	...	3.6e–6	2.3e–6	3.3e–5	1.5e–5	2.4e–5	6.1e–6	4.1e–5	1.1e–5	8.9e–6	2.7e–6	1.4e–5	9.9e–6	9.0e–5	2.2e–5	2.3e–5	6.1e–6	5.2e–5	3.1e–5	2.1e–5	4.0e–6	5.4e–5	6.0e–5	8.6e–5	4.1e–5	3.6e–5	1.4e–5	4.2e–5	1.8e–5	3.1e–5	2.5e–5
$\sigma^2_{\bar{p}}$	...	∞	...	...	3.7e–5	1.9e–5	1.2e–4	4.0e–5	5.1e–5	4.3e–5	1.8e–5	4.8e–6	1.3e–5	8.1e–6	1.8e–5	8.4e–6	1.5e–4	3.8e–5	2.6e–5	7.3e–6	2.6e–5	1.3e–5	4.4e–5	9.3e–6	5.9e–5	7.9e–5	2.4e–4	2.7e–4	1.4e–4	6.7e–5	6.4e–5	2.5e–5	6.7e–5	2.6e–5
$\sigma^2_{\bar{w}^Y}$	...	∞	...	...	5.6e–5	2.7e–5	6.2e–5	3.1e–5	3.9e–5	3.8e–5	6.2e–5	1.4e–5	7.7e–6	1.5e–6	2.3e–6	1.4e–6	7.5e–5	3.6e–5	5.5e–6	1.2e–6	5.9e–5	3.2e–5	4.3e–4	1.6e–4	1.0e–4	2.7e–5	6.9e–4	1.5e–4	7.8e–7	2.5e–7	2.7e–6	7.2e–7	6.4e–6	1.7e–6
$\sigma^2_{\bar{i}}$	...	∞	...	...	4.1e–4	5.3e–5	2.2e–4	1.0e–5	4.2e–4	1.6e–4	3.9e–4	7.5e–5	3.3e–4	8.4e–5	3.4e–3	1.4e–3	1.8e–4	2.3e–5	1.9e–3	2.8e–4	1.4e–4	3.5e–5	2.0e–3	4.7e–4	2.1e–4	2.5e–5	6.1e–3	1.3e–3	2.4e–2	1.1e–2	2.9e–3	1.9e–3	1.6e–3	5.1e–4
$\sigma^2_{\bar{i}^S}$	...	∞	...	...	3.7e–5	2.0e–5	1.9e–4	1.4e–5	3.1e–5	4.0e–6	1.3e–5	5.2e–6	...	...	1.4e–5	3.6e–6	2.5e–4	6.1e–5	...	...	7.0e–6	2.9e–6	1.0e–4	2.1e–5	3.2e–3	7.8e–4	3.1e–2	9.0e–3	...	...	4.8e–5	1.2e–5	1.0e–4	2.0e–5
$\sigma^2_{\bar{i}^L}$	...	∞	...	...	2.7e–6	4.3e–7	3.0e–5	1.9e–6	8.2e–7	2.0e–8	3.1e–5	1.3e–5	8.5e–6	1.1e–6	2.8e–6	2.1e–7	7.0e–4	2.2e–4	2.2e–5	5.8e–6	4.4e–6	1.7e–6	1.4e–4	3.2e–5	3.4e–3	8.0e–4	6.4e–2	1.6e–2	2.1e–5	4.1e–6	2.1e–6	2.2e–7	8.3e–6	7.4e–7
$\sigma^2_{\bar{p}^{STK}}$	...	∞	...	...	2.4e–3	2.0e–3	5.0e–3	3.0e–3	2.8e–3	1.4e–3	1.9e–2	5.5e–3	4.7e–3	2.4e–3	8.3e–3	3.4e–3	9.7e–3	3.9e–3	5.5e–3	3.9e–3	7.8e–3	4.1e–3	3.4e–3	1.4e–3	6.8e–3	3.5e–3	1.2e–2	8.9e–3	5.6e–3	2.1e–3	3.3e–3	1.2e–3	3.5e–3	1.5e–3
$\sigma^2_{\bar{e}}$	...	∞	...	...	1.1e–3	4.8e–4	5.5e–3	1.4e–3	5.8e–4	2.6e–4	1.9e–4	4.2e–5	...	...	6.2e–4	2.2e–4	3.3e–4	1.5e–4	...	...	1.9e–4	5.2e–5	1.4e–3	1.1e–3	1.0e–4	6.7e–5	1.0e–3	4.4e–4	...	...	1.0e–3	7.2e–4	...	...
$\sigma^2_{\bar{p}^{COM}}$	...	∞	2.4e–3	2.4e–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
$\sigma^2_{\bar{p}^{COM}}$	...	∞	1.5e–3	6.7e–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Note: All priors are normally distributed, while all posteriors are asymptotically normally distributed. All observed endogenous variables are rescaled by a factor of 100.

Figure 1. Output Gap versus Unemployment Rate Gap Estimates

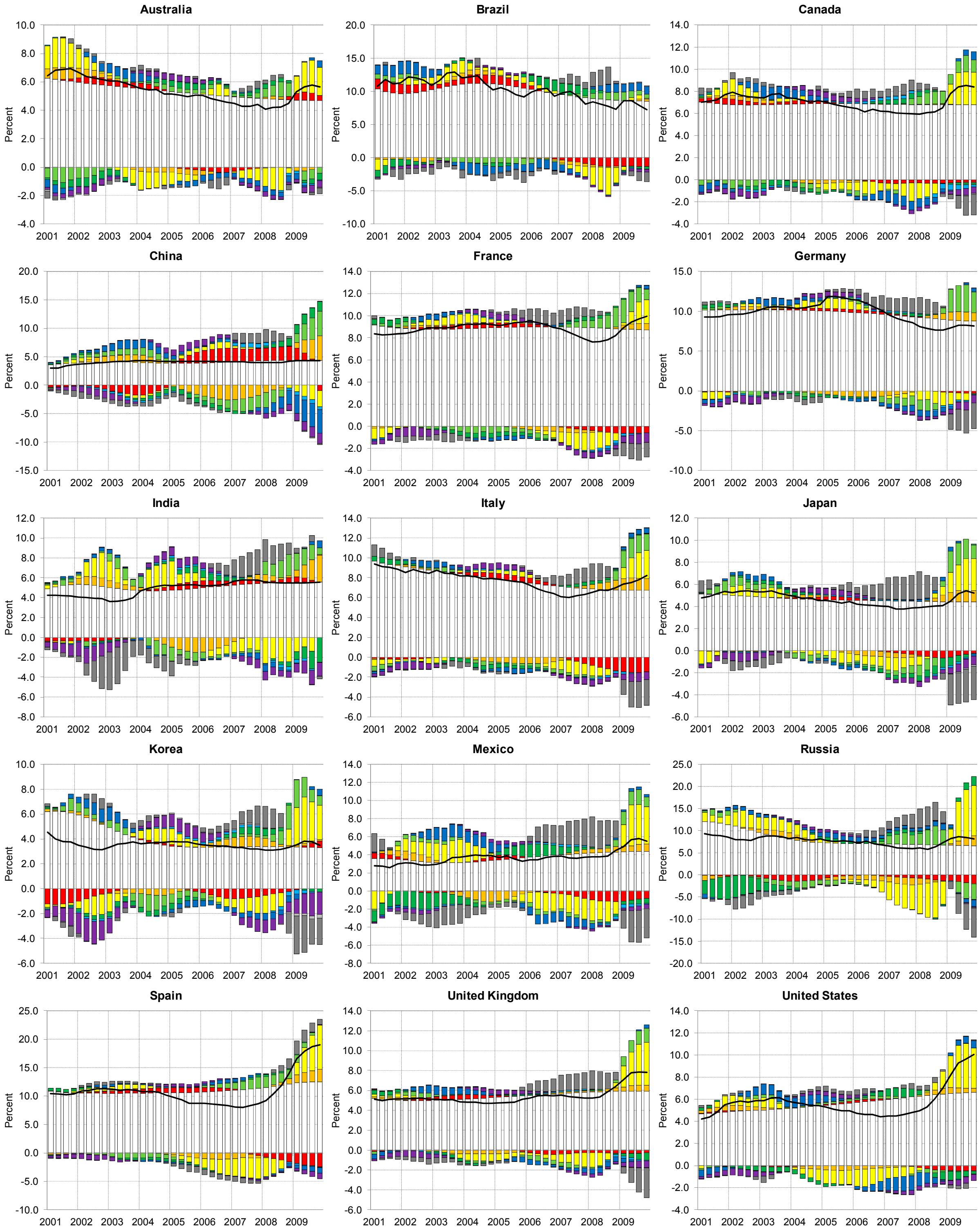
Note: Depicts smoothed estimates of the output gap ■ and the unemployment rate gap ■.

Figure 2. Historical Decompositions of Output Growth



Note: Decomposes observed output growth ■ as measured by the seasonal logarithmic difference of the level of output into the sum of a trend component □ and contributions from domestic output supply ■, foreign output supply ■, domestic output demand ■, foreign output demand ■, domestic monetary policy ■, foreign monetary policy ■, world risk premium ■, and world commodity price ■ shocks.

Figure 3. Historical Decompositions of the Unemployment Rate



Note: Decomposes the observed unemployment rate ■ into the sum of a trend component □ and contributions from domestic output supply ■, foreign output supply ■, domestic output demand ■, foreign output demand ■, domestic labor supply ■, domestic labor demand ■, domestic monetary policy ■, foreign monetary policy ■, world risk premium ■, and world commodity price ■ shocks.

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