Monetary policy rules in economies with traded and non-traded goods

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Abstract
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1 Introduction

At least since the analysis of Keynes (1923), economists have been aware of the extent to which monetary policy has differential effects on the traded and non-traded sectors of an open economy.[1] In recent years, the growing literature on "New Open Economy Macroeconomics" has used micro-founded models to analyze monetary policy and alternative exchange rate regimes.[2] Nevertheless, relatively little attention has been devoted to analyzing the performance of monetary policy rules in economies with imperfect factor mobility across sectors.[3]

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*The views here are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or any other person associated with the Federal Reserve System.

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[1] Recent examples include Carlino and Defina (1998), Lubik (2003), Peersman and Smets (2003), Owyang and Wall (2003). Duarte and Wolman (2002) examine the extent to which shocks to productivity and government spending have differential effects on the tradeable and non-tradeable sectors.

[2] Bowman and Doyle (2002) survey the implications for monetary policy of micro-founded, sticky price open economy models.

[3] For example, Obstfeld and Rogoff (2002) and Canzoneri, Cumby and Diba (2002) analyze monetary policy in open economy models with tradeables and non-tradeables; to facilitate analytic tractibility, these studies use stylized assumptions including one-period-ahead price setting and complete factor mobility across sectors. Benigno (forthcoming) considers monetary policy rules in a model in which all goods are tradeable. In related work, Erceg and Levin (2002) analyze optimal monetary policy in a two-sector closed economy with durable and non-durable goods.

In this paper, we begin by using vector autoregression (VAR) analysis to show that monetary policy innovations have markedly different effects on the traded and nontraded goods sector. In particular, using quarterly data for a set of relatively open economies that includes Australia, Canada, the United Kingdom, and Sweden, we show that a contractionary monetary policy innovation induces output to decline by roughly twice as much in the traded sector as in the nontraded sector.

We proceed to formulate a two country dynamic general equilibrium (DGE) model in which each country produces a traded and nontraded good. Our model includes several salient features. First, we incorporate nominal price rigidities in each sector, and nominal wage rigidity at the aggregate level, so that the monetary policymaker faces a nontrivial stabilization problem. Second, the traded goods sector in our model is much more sensitive to interest rate and exchange rate fluctuations than the nontraded sector. This reflects both the key influence of the exchange rate on the demand for home-produced traded goods, and that capital goods are produced exclusively in the traded sector. Finally, we assume that adjustment costs make it costly to reallocate capital across sectors.

We then consider the implications of alternative simple policy rules for the performance of the economy in response to empirically relevant shocks, including supply shocks, demand shocks, and risk premium shocks to the exchange rate. Our analysis suggests that a rule that places a large weight on a price index that is sensitive to exchange rate fluctuations is likely to induce excessively large deviations in sectoral outputs from the "potential" levels that that would prevail in the absence of nominal rigidities. By contrast, a rule that responds to a weighted average of wage and price inflation, or to the true aggregate output gap, seems to perform much better in minimizing sectoral output deviations from potential. In our ongoing work, we will use second-order perturbation methods to characterize the properties of optimal monetary policy under commitment, and to rank the welfare performance of the simple rules relative to the full commitment optimum.

2 Empirical Evidence

A large literature has utilized identified VARs to measure the response of aggregate output and prices to a monetary policy shock (cf. Sims 1980; Christiano, Eichenbaum, and Evans 1999). Here we follow this approach to investigate the extent to which a shock has differential effects on output in the traded and nontraded sectors of the economy. Accordingly, we construct measures of traded and nontraded output using quarterly GDP by industry data for Australia, Canada, Sweden and the United

Kingdom. For each country, we define traded output as real output in manufacturing, mining, and agriculture, while nontraded output is simply the difference between total GDP and this measure of traded output. Our baseline VAR includes the logarithm of traded output, nontraded output, and the GDP price deflator, and also the level of the short-term policy interest rate.[4] This 4-variable VAR is estimated using ordinary least squares over the 1984:1 to 2002:4 period. We apply a Cholesky decomposition (ordering the variables as listed above) to compute the responses of these variables to a one-standard-deviation innovation in the interest rate. Monte Carlo simulations are used to obtain 95 percent confidence bands for each impulse response function (IRF).

Figure 1 presents responses that are estimated using a pooled sample consisting of the data from all four countries; the responses derived using individual country data are remarkably similar (not shown), notwithstanding larger standard errors. The IRFs from the pooled sample indicate that output in the traded sector contracts much more sharply than output in the nontraded sector in response to the monetary policy innovation. In particular, while nontraded output contracts roughly 0.3 percent in response to a one percentage point rise in the funds rate, output in the traded sector falls nearly 0.8 percent. Interestingly, given an average share of the traded sector in GDP of around 30 percent, the implied response of aggregate output of roughly 0.4-0.5 percent is only slightly higher than has been estimated for major industrial economies using aggregate data.

Given the highly open nature of the economies considered, it is plausible that variation in foreign output plays an important role in determining the behavior of domestic output, prices, and interest rates. Accordingly, we construct a time series measure of foreign output for each of the four countries (weighting the GDP of its seven largest trading partners by its export weights), and add this variable as an exogenous regressor to the VAR described above. As shown in Figure 2, the results using the pooled sample are quite similar to those in Figure 1, although the estimated response of nontraded output is somewhat smaller; thus, the relative response of traded output is comparatively larger than in our baseline specification.

[4] Our analysis abstracts from issues related to the exchange rate response of monetary policy shocks. These are addressed in Kim 1999 and Kim and Roubini 2000.

3 The Model

Our model consists of two countries that may differ in size and their degree of openness, but are otherwise symmetric. Hence, our exposition below focuses on the "home" country. While each country in effect produces only two types of output goods – a traded and nontraded good – we adopt a standard monopolistically competitive framework in each sector to rationalize price stickiness at the sectoral level.

3.1 Firms and Price Setting

There are two productive sectors in the home country, one of which produces traded goods, and the other nontraded goods. We use the subscript D to refer to the sector producing traded goods, and the subscript N to refer to the sector producing nontraded goods. Within each sector, a continuum of monopolistically competitive firms (indexed on the unit interval) fabricate differentiated products $Y_{i,t}(f)$ for $i \in \{D, N\}$ and $f \in [0,1]$. Because households and firms have identical Dixit-Stiglitz preferences over the intermediate goods produced by each sector, it is convenient to assume that a representative aggregator combines the differentiated products of each sector into a single sectoral output index $Y_{i,t}$:

$$Y_{i,t} = \left[\int_0^1 Y_{i,t}(f)^{\frac{1}{1+\theta_p}} \, df \right]^{1+\theta_p} \tag{1}$$

where $\theta_p > 0$. The aggregator chooses the bundle of goods that minimizes the cost of fabricating a given quantity of the sectoral output index $Y_{i,t}$, taking the price $P_{i,t}(f)$ of each good $Y_{i,t}(f)$ as given. The aggregator sells units of each sectoral output index at its unit cost $P_{i,t}$:

$$P_{i,t} = \left[\int_0^1 P_{i,t}(f)^{\frac{-1}{\theta_p}} \, df \right]^{-\theta_p} \tag{2}$$

It is natural to interpret $P_{i,t}$ as the sectoral price index. The aggregator's demand for each good $Y_{i,t}(f)$ –or equivalently, the demand curve facing intermediate goods producer $f \in [0,1]$ in sector $i \in \{N, D\}$ – is given by:

$$Y_{i,t}(f) = \left[\frac{P_{i,t}(f)}{P_{i,t}} \right]^{-\frac{(1+\theta_p)}{\theta_p}} Y_{i,t} \tag{3}$$

for $i \in \{N, D\}$ and $f \in [0,1]$.

Production of Domestic Intermediate Goods Each intermediate goods producer in sector i hires capital services $K_{i,t}(f)$ and a labor index $L_{i,t}(f)$ (defined below) to produce its particular brand. All firms within each sector have the same Cobb-Douglas production function with constant-returns-to-scale, and have an identical level of total factor productivity $z_{i,t}$:

$$Y_{i,t}(f) = K_{i,t}(f)^{\alpha_i} \left(z_{i,t} L_{i,t}(f)\right)^{1-\alpha_i} \tag{4}$$

Firms face perfectly competitive factor markets for hiring capital and the labor. Thus, each firm chooses $K_{i,t}(f)$ and $L_{i,t}(f)$, taking as given both the aggregate wage index W_t and the rental price of capital in its sector $R_{Ki,t}$. While firms in each sector are assumed to face a common wage rate, the rental price of capital diverges across sectors because intersectoral capital reallocation is costly. However, given that firms can costlessly adjust factors of production *within* a sector, the standard static first-order conditions for cost minimization imply that all firms in sector i have the same nominal marginal cost per unit of output $MC_{i,t}$.

We introduce nominal inertia into price-setting by assuming that the monopolistically-competitive intermediate goods producers bear menu costs of adjusting their nominal prices. Given its demand function specified in equation (3), each producer f in sector i chooses its price $P_{i,t}(f)$ in its own currency to maximize an expected discounted profit functional of the form[5]:

$$\widetilde{\mathbb{E}}_t \sum_{j=0}^{1} \psi_{t,t+j}(P_{i,t+j}(f) - MC_{i,t+j})Y_{i,t+j}(f))[1 - \Gamma_{Pi,t+j}(h)] \tag{5}$$

The operator $\widetilde{\mathbb{E}}_t$ represents the conditional expectation based the information available to agents at period t.[6] The firm discounts profits received at date $t+j$ by the state-contingent discount factor $\psi_{t,t+j}$; for notational simplicity, we have suppressed all of the state indices. Let $\xi_{t,t+j}$ denote the price in period t of a claim that pays one dollar if the specified state occurs in period $t+j$; then the corresponding element of $\psi_{t,t+j}$ equals $\xi_{t,t+j}$ divided by the probability that the specified state will occur. The function $\Gamma_{Pi,t}(h)$ may be regarded as reflecting menu costs associated with price adjustment that reduce the effective output level of the firm. Following Laxton and Pesenti (2003), we assume that this menu cost function has the form:

[5]The degree of pass-through from exchange rates into consumer price inflation can influence how desirable it is to place some weight on the exchange rate in a monetary policy rule. For example, see Corsetti and Pesenti 2004 and Bowman and Doyle 2002.

[6]For simplicity, none of the variables is explicitly indexed by the state of nature.

$$\Gamma_{Pi,t}(h) = \frac{v_1}{2}\left(\frac{P_{i,t}(h)}{\pi P_{i,t-1}(h)} - 1\right)^2 + \frac{v_2}{2}\left(\left(\frac{P_{i,t}(h)}{P_{i,t-1}(h)} / \frac{P_{t-1}}{P_{t-2}}\right) - 1\right)^2 \quad (6)$$

The first term in this expression represents convex costs at the firm level of changing prices relative to the steady state inflation rate of the economy, and is standard in the menu cost literature (as in Rotemberg, 1982, and Kim, 2000). The second term specifies an additional cost of price adjustment costs that depends on the aggregate sectoral inflation rate during the previous period. This latter expression is included to allow for structural inflation persistence in the price-setting process.

Production of the Final Consumption Good Households utility depends on consumption of a nontraded good index, consumption of a domestically-produced traded index, and an index of imported goods. For heuristic purposes, it is helpful to regard household preferences as defined over the consumption of a single final consumption good index C_t that is produced in two stages. In the first stage, a representative "traded consumption goods distributor" combines the domestically-produced traded good (index) with the imported good to produce a traded consumption good (C_{Tt}) according to a constant-returns-to-scale CES production function:

$$C_{Tt} = \left((1-\omega_T)^{\frac{\rho_T}{1+\rho_T}} C_{D,t}^{\frac{1}{1+\rho_T}} + \omega_T^{\frac{\rho_T}{1+\rho_T}} (\varphi_{mt} M_{ct})^{\frac{1}{1+\rho_T}}\right)^{1+\rho_T} \quad (7)$$

where C_{Dt} is consumption of the domestically-produced traded good, $M_{C,t}$ is consumption of the imported good, and φ_{mt} reflects costs of adjusting consumer imports. The form of the production function mirrors the preferences of households over consumption of domestically-produced traded goods and imports. Accordingly, the quasi-share parameter $(1-\omega_T)$ may be interpreted as determining household preferences for home relative to foreign traded goods, or equivalently, the degree of home bias in household consumption expenditure on traded goods. The parameter ρ_T determines the substitutibility between home and foreign-produced traded goods in the household utility function (with the intratemporal substitution elasticity equal to $\frac{-(1+\rho_T)}{\rho_T}$). Finally, the adjustment cost term φ_{mt} is assumed to take the quadratic form:

$$\varphi_{mt} = \left[1 - \frac{\varphi_M}{2}\left(\frac{\frac{M_{C,t}}{C_{D,i,t}}}{\frac{M_{C,t-1}}{C_{D,i,t-1}}} - 1\right)^2\right] \quad (8)$$

As in Erceg, Guerrieri, and Gust (2003), our specification implies that adjustment costs depend on the change in the import share rather than on the change in the level of imports. This feature helps account for the empirical pattern that imports tend to adjust rapidly to changes in consumption, but only gradually to changes in relative prices.

The final consumption good can be regarded as produced in a second stage in an analytically symmetric framework. Thus, a representative final consumption goods distributor combines the traded consumption good C_{Tt} produced in the first stage with the nontraded consumption good (index) according to:

$$C_t = \left((1-\omega_N)^{\frac{\rho_N}{1+\rho_N}} C_{T,t}^{\frac{1}{1+\rho_N}} + \omega_N{}^{\frac{\rho_N}{1+\rho_N}} (\varphi_{nt} C_{Nt})^{\frac{1}{1+\rho_N}} \right)^{1+\rho_N} \tag{9}$$

where C_{Nt} is consumption of the nontraded good (index), and φ_{nt} reflects costs of adjusting the ratio of nontraded to traded goods. The quasi-share parameter $(1-\omega_N)$ may be interpreted as determining household preferences for traded relative to nontraded goods, and the adjustment cost term φ_{nt} is assumed to take the quadratic form:

$$\varphi_{nt} = \left[1 - \frac{\varphi_N}{2} \left(\frac{\frac{C_{N,t}}{C_{T,t}}}{\frac{C_{N,t-1}}{C_{T,t-1}}} - 1 \right)^2 \right] \tag{10}$$

3.2 Households and Wage Setting

We assume a continuum of monopolistically competitive households (indexed on the unit interval), each of which supplies a differentiated labor service to the intermediate goods-producers in each sector. All firms, irrespective of sector, are assumed to have the same preferences over the differentiated labor services, and take each household's wage rate as given. Accordingly, given that all firms choose the same composition of labor inputs, it is convenient to assume that a representative labor aggregator (or "employment agency") combines households' labor hours in the same proportions as firms would choose. The aggregate labor index L_t has the Dixit-Stiglitz form:

$$L_t = \left[\int_0^1 (N_t(h))^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w} \tag{11}$$

where $\theta_w > 0$, and $N_t(h)$ is hours worked by a typical member of household h. The aggregator minimizes the cost of producing a given amount of the aggregate labor index (taking as given each household's wage rate $W_t(h)$), and then sells units of the labor index to the intermediate goods producers at their unit cost W_t:

$$W_t = \left[\int_0^1 W_t(h)^{\frac{-1}{\theta_w}} dh \right]^{-\theta_w} \tag{12}$$

It is natural to interpret W_t as the aggregate nominal wage index. The aggregator's demand for the labor services of a typical member of household h is given by:

$$N_t\left(h\right)=\left[\frac{W_t\left(h\right)}{W_t}\right]^{-\frac{1+\theta_w}{\theta_w}}L_t \tag{13}$$

The total quantity of the labor index supplied by the aggregator equals the demand for labor by the intermediate goods-producing firms in each sector:

$$L_t=\int_0^1 L_{Dt}\left(f\right)df+\int_0^1 L_{Nt}\left(f\right)df \tag{14}$$

The Household's Optimization Problem The utility functional of a typical member of household h is:

$$\widetilde{\mathbb{E}}_t\sum_{j=0}^{\infty}\beta^j\{\frac{1}{1-\sigma}\left(C_{t+j}\left(h\right)-\varkappa C_{t+j-1}(h)\right)^{1-\sigma}+ \tag{15}$$

$$\frac{\chi_0}{1-\chi}(1-N_{t+j}\left(h\right))^{1-\chi}+\frac{\mu_0}{1-\mu}\left(\frac{M_{t+j}\left(h\right)}{P_{t+j}}\right)^{1-\mu}\} \tag{16}$$

where the discount factor β satisfies $0<\beta<1$. The dependence of the period utility function on consumption in both the current and previous period allows for the possibility of habit persistence in consumption spending (e.g., Boldrin, Christiano and Fisher). In addition, the period utility function depends on current leisure $1-N_t\left(h\right)$, and current real money balances $\frac{M_t(h)}{P_t}$.

Each household h faces a flow budget constraint in period t that states that its combined expenditure on goods and on the net accumulation of financial assets must equal its disposable income:

$$\begin{gathered}P_{C,t}C_t\left(h\right)+P_{I,t}I_{D,t}\left(h\right)+P_{I,t}I_{N,t}\left(h\right)\\ M_{t+1}\left(h\right)-M_t\left(h\right)+\textstyle\int_s\xi_{t,t+1}B_{D,t+1}(h)-B_{D,t}(h)\\ e_tP^*_{B,t}\Psi_tB_{F,t+1}(h)-e_tB_{F,t}(h)\\ =W_t\left(h\right)N_t\left(h\right)\left[1-\Gamma_{W,t}(h)\right]\\ R_{D,t}K_{D,t}(h)+R_{N,t}K_{N,t}(h)+\Upsilon_t\left(h\right)+TR_t(h)\\ -\tfrac{1}{2}\psi_{DI}P_{I,t}\frac{\left(I_{D,t}(h)-g_zI_{D,t-1}(h)\right)^2}{I_{D,t-1}(h)}-\tfrac{1}{2}\psi_{NI}P_{I,t}\frac{\left(I_{N,t}(h)-g_zI_{N,t-1}(h)\right)^2}{I_{N,t-1}(h)}\end{gathered} \tag{17}$$

Final consumption goods are purchased at a price $P_{C,t}$, and final investment goods at a price $P_{I,t}$. Investment goods purchased for use in sector i augment the capital stock of that sector $K_{i,t+1}(h)$ according to a linear transition law of the form:

$$K_{i,t+1}(h) = (1-\delta_i)K_{i,t}(h) + I_{i,t}(h) \tag{18}$$

Financial asset accumulation of a typical member of household h consists of increases in nominal money holdings $(M_{t+1}(h) - M_t(h))$ and the net acquisition of bonds. We assume that agents within a country can engage in frictionless trading of a complete set of contingent claims. Trade in international assets is restricted to a non-state contingent foreign currency-denominated nominal bond. The term $\int_s \xi_{t,t+1} B_{D,t+1}(h) - B_{D,t}(h)$ represents net purchases of state-contingent domestic bonds. As noted above, $\xi_{t,t+1}$ represents the price of an asset that will pay one unit of domestic currency in a particular state of nature in the subsequent period, while $B_{D,t+1}(h)$ represents the quantity of such claims purchased by a member of household h at time t. Thus, the gross outlay on new state-contingent domestic claims is given by integrating over all states at time $t+1$, while $B_{D,t}(h)$ indicates the value of existing claims given the realized state of nature. The term $e_t P^*_{B,t} \Psi_t B_{F,t+1}(h) - e_t B_{F,t}(h)$ represents the net accumulation of the non-state contingent bond, measured in units of the home currency. The foreign currency price of a bond that pays one unit of the foreign currency in the subsequent period is $P^*_{B,t}$, $B_{F,t+1}(h)$ represents the quantity of such claims purchased at time t, and e_t is the price of a unit of foreign currency in terms of the home currency (so that a rise in e_t corresponds to a depreciation of the home currency). The term Ψ_t is a time-varying financial intermediation cost that affects the effective return on the foreign bond. Following Benigno (2004), we assume that this cost assumes the form

$$\Psi_t = \exp(-\phi_b b_t + u_t) \tag{19}$$

where b_t is the ratio of net foreign assets to nominal GDP in the traded sector, and u_t is a stochastic disturbance that may be interpreted as a shock to the risk premium.

Each member of household h receives gross rental income of $[R_{D,t}K_{D,t}(h) + R_{N,t}K_{N,t}(h)]$ from renting the capital that it has accumulated in the traded and nontraded sectors to firms in the respective sector. Each member also receives an aliquot share $\Upsilon_t(h)$ of the profits of all firms and a lump-sum net transfer of $TR_t(h)$ from the government (which may be negative, and hence a tax). Generalizing the specification of Christiano, Eichenbaum, and Evans (2001) to our multi-sectoral framework, we assume that the household bears costs of changing the level of investment in each sector (beyond the steady state deterministic growth rate of the economy denoted by g_z). Finally, the household earns labor income of $W_t(h)\,N_t(h)\,[1-\Gamma_{W,t}(h)]$, where $\Gamma_{W,t}(h)$ reflects a time-varying menu cost associated with changing the nominal wage rate. The function $\Gamma_{W,t}(h)$ involves a generalized form of menu costs that is similar to the specification for prices considered above:

$$\Gamma_{W,t}(h) = \frac{v_5}{2}\left(\frac{W_t(h)}{\pi g_z W_{t-1}(h)} - 1\right)^2 + \frac{v_6}{2}\left(\left(\frac{W_t(h)}{W_{t-1}(h)}/\frac{W_{t-1}}{W_{t-2}}\right) - 1\right)^2 \tag{20}$$

In every period t, each member of household h maximizes the utility functional (15) with respect to its consumption, sectoral investment levels, (end-of-period) capital stock in each sector, money balances, holdings of contingent claims and foreign bonds, and nominal wage rate, subject to its labor demand function (13), budget constraint (17), and transition equations for capital (18).

3.3 Fiscal Policy

Given our assumption that the government has recourse to lump-sum taxes or transfers, we can impose without loss of generality that the government's budget is balanced in every period. Thus, seignorage revenue is equal to lump-sum transfers plus government purchases on both nontraded goods and on domestically-produced traded goods:

$$M_t - M_{t-1} = \int_0^1 TR_t(h)\,dh + P_{Dt}G_{Dt} + P_{Nt}G_{Nt} \tag{21}$$

where G_{it} indicates real government purchases from sector i. We assume that the government spending in each sector as a fraction of that sector's GDP follows an exogenous stochastic process, so that:

$$\frac{G_{i,t}}{Y_{i,t}} = \omega_{Gi}g_{xi,t} \tag{22}$$

where ω_{Gi} is the steady state share of government spending in the output of sector i, and $g_{xi,t}$ is the shock.

3.4 Monetary Policy

We assume that the central bank follows an interest rate reaction function that can be regarded as a modified form of the Taylor rule (1993). In particular, the short-term nominal interest rate is raised if inflation exceeds its constant target value, or if output *growth* rises above some target value. With some allowance for interest rate smoothing, monetary policy is described by the following interest rate reaction function:

$$i_t = \gamma_i i_{t-1} + \overline{r}(1-\gamma_i) + \gamma_\pi(\pi_{c,t}^{(4)} - \bar{\pi}) + \gamma_y(y_t - y_{t-1} - g_y) + \varepsilon_t \quad (23)$$

where $\pi_{c,t}^{(4)}$ is the four-quarter average inflation rate of the PCE deflator (i.e., $\pi_{c,t}^{(4)} = \frac{1}{4}\sum_{j=0}^{3}\pi_{c,t-j}$), $\overline{r}$ is the steady-state real interest rate, $\bar{\pi}$ is the central bank's constant inflation target, $y_t - y_{t-1}$ is the (annualized) quarterly growth rate of output, g_y is the target value of output, and ε_t is an innovation to the interest rate reaction function. We follow the approach of Orphanides and Wieland (1998) by including real GDP growth rather than the level of the output gap (as in the original formulation of the Taylor Rule).

3.5 Aggregate Resource Constraints and the Foreign Economy

The resource constraint for the domestically-produced traded good (index) is specified as

$$Y_{D,t} = C_{D,t} + I_{D,t} + I_{N,t} + G_{D,t} + X_t \quad (24)$$

where $I_{D,t}$ and $I_{N,t}$ are investment in the traded and nontraded goods sectors, respectively, $G_{D,t}$ is government spending on traded goods, and X_t represents exports. Because the "aggregator" selling the output index $Y_{D,t}$ behaves competitively in both domestic and international product markets, the home currency price of the domestically-produced good is simply $P_{D,t}$, irrespective of whether the good is used in domestic consumption, as new investment (in either sector), or is exported. Thus, the law of one price holds for traded goods. The resource constraint for the nontraded sector is simply:

$$Y_{N,t} = C_{N,t} + G_{N,t} \quad (25)$$

Thus, the competitive aggregator producing the nontraded good index sells it either to households or to the government at the same price P_{Nt}.

We assume that the structure of the foreign economy (the "rest of the world") is isomorphic to that of the home country. Thus, the foreign economy is also comprised of two productive sectors. Because the law of one price holds for foreign traded goods, the import price faced by the home country simply equals the foreign price ($P_{T,t}^*$) translated into home currency terms:

$$P_{Mt} = e_t P_{T,t}^* \quad (26)$$

Thus, our model exhibits "producer currency pricing," so that changes in the nominal exchange rate are immediately and fully passed into import prices. Finally, we assume that the monetary authority in the foreign country follows the same interest rate reaction function as in the home country.

3.6 Exogenous Shocks

As discussed above, the home country faces shocks to the level of productivity in each sector $z_{i,t}$, $i \in \{N, D\}$, the government spending share in each sector $g_{xi,t}$, the monetary policy rule ε_t, and to the exchange rate risk premium u_t. Since the foreign country is also affected by an isomorphic set of shocks, our model includes a total of 11 shocks.

Each of the shocks is assumed to follow a univariate first order autoregression.

4 Solution and Calibration

To be completed.

5 Model Responses under Alternative Simple Rules

Risk Premium Shock Figures 3a and 3b depict model responses to an innovation to the exchange rate risk premium u_t. The persistence of the shock is 0.98, and the innovation is scaled so that it induces about a 5 percent depreciation in the home terms of trade under the baseline monetary policy rule.

It is helpful to begin by considering the effects of the shock in a special case of our model in which prices and wages are completely flexible. Asset market equilibrium requires some combination of a rise in real interest rates and depreciation in the home terms of trade in response to the shock, with the split between the two determined by various structural features of the model. The depreciation in the terms of trade (represented by a rise in Figure 3b) stimulates exports, and accounts for the expansion of traded output. However, to keep aggregate supply and demand in balance, real interest rates rise, crowding out domestic demand. The fall in traded consumption (Figure 3b) that is attributable to higher interest rates and to a higher relative price for imported goods depresses the demand for nontraded goods. The sharp fall in the relative price of nontraded goods (Figure 3b) induces capital and labor to flow from the nontraded to the traded sector (and particularly into export production).

Under the baseline policy rule (dashed blue lines), real interest rates rise noticeably more sharply than would occur in the flexible price/wage equilibrium. This reflects a relatively large (long-run) coefficient of 3 on consumer price inflation in the interest rate reaction function, while the weight on the output gap is only unity (i.e., $\frac{\gamma_\pi}{1-\gamma_i} = 3$; $\frac{\gamma_y}{1-\gamma_i} = 1$). The larger interest rate increase contributes to a more modest depreciation in the terms of trade. Accordingly, given reduced stimulus to exports and a more contractionary impact on interest-sensitive components of domestic demand (especially investment, not shown), the traded sector experiences a less pronounced boom than would occur under flexible prices. Moreover, the smaller exchange rate adjustment means that the relative price of nontraded goods doesn't fall as sharply, and this translates into a larger contraction in the nontraded sector; effectively, rather than the relative price adjustment occurring through the exchange rate, it occurs through a recession.

The other monetary policy rules shown in Figures 3A are derived as targeting rules assuming particular "ad hoc" preferences for the monetary authority (ad hoc in the sense that they are not derived from a social welfare criterion). In the "PCE inflation targeting" case, the policymaker cares only about stabilizing the inflation rate of the consumption deflator; while in the "Inflation/exchange rate" targeting case, the monetary policymaker is assumed to have a period objective function of the form:

$$\pi_{c,t}^2 + 0.5 * e_t^2 \tag{27}$$

Thus, in the latter case the policymaker attaches a direct weight to stabilizing the nominal exchange rate.

It is clear from Figures 3a and 3b that stabilizing the PCE inflation rate requires a much sharper rise in real interest rates than under the baseline policy, contributing to a contraction in the traded sector that is nearly as large as in the nontraded sector. In the case in which the policymaker responds to the exchange rate directly, the contraction in the traded sector becomes even larger, so that the pattern of sectoral output adjustment that occurs in the flexible price equilibrium is reversed.

Figures 4a and 4b show the responses to the same shock under two alternative targeting rules that each come very close to replicating the outcomes under the flexible price equilibrium. One such targeting rule is derived by assuming that the monetary policymaker only cares about stabilizing aggregate output at potential, where potential output is defined as the potential output of each sector weighted by that sector's steady state expenditure share. As in the closed economy multisector model of Erceg and Levin (2003), this policy seems to perform extremely well in keeping sectoral output levels near potential. Due to the difficulty in measuring potential output, it is of interest to consider alternative rules that also perform well in replicating the equilibrium under flexible prices, but which do not require observing potential output. Accordingly, we also consider a "Wage/Price Inflation Targeting rule" that is derived by assuming that the policymaker cares about a weighted average of wage and domestic price inflation (interpreted as the inflation rate of the GDP deflator). Clearly, the responses under this alternative rule are virtually indistinguishable from the case of aggregate output gap targeting, and thus both of these simple rules do well in replicating quantity behavior in the flexible price equilibrium.

Government Spending Shock Figures 5a and 5b depict model responses to an innovation to the government spending share in the traded sector. The persistence of the shock is 0.98, and the innovation is scaled so that it would induce a 1 percent rise in government spending relative to baseline (aggregate) GDP in the absence of any endogenous adjustment.

The effects of the government spending shock in the flexible price equilibrium are broadly familiar from open economy models with one productive sector. Thus, the rise in government spending constricts consumption, induces real interest rates to rise, and the terms of trade to appreciate. Since traded consumption goods become relatively scarce, the price of nontraded goods relative to *domestically-produced* traded goods declines, inducing factor flows to the traded sector (n.b., the price of nontraded goods relative to all traded goods initially rises, due to a fall in import prices).

Turning to the case with nominal rigidities, the rule targeting wage-price inflation continues to do very well in replicating the responses under the flexible price equilibrium. The rule targeting the aggregate output gap also exhibits similar responses (not shown for expositional reasons). By contrast, both the historical rule and the rule targeting PCE inflation induce sectoral output responses that are more expansionary (i.e, less contractionary on the nontraded sector) than in the flexible price case. This reflects that there is little need to raise real interest rates in order to stabilize PCE inflation, since the fall in import prices largely offsets upward pressure on domestic prices. Moreover, given that the nominal exchange rate appreciates in response to this shock, a policymaker concerned with exchange rate stabilization would reduce real interest rates even below the PCE inflation targeting case, implying a larger stimulus to output (not shown).

Productivity Rise in Traded Sector Figures 6a and 6b depict model responses to an innovation to total factor productivity in the traded sector. The persistence of the shock is 0.98, and the innovation is scaled so that total factor productivity in the traded sector initially rises by one percent.

Under flexible prices, the productivity shock to the traded sector would induce traded output to expand. Some depreciation in the home terms of trade augments this expansion by making domestically-produced traded goods cheaper in the foreign country. A rise in the relative price of nontraded goods stimulates labor to move into that sector, which accounts for the modest rise in its output. The real interest rate on domestically-produced goods rises slightly (even though the "consumer" real interest rate falls slightly due to the expectation that the relative price of consumer goods will rise in the future as the productivity shock wears off).

Turning to the baseline model with nominal rigidities, strict targeting of domestic price inflation (i.e., the GDP deflator inflation rate) turns out to be a very stimulative policy. Output in each sector rises much more than would occur under flexible prices. This result is very familiar from closed-economy models, and occurs for the same reason: the domestic price level would fall in response to falling unit labor costs unless policy were sufficiently stimulative. By contrast, PCE inflation targeting turns out to be much less stimulative. Since the terms of trade deterioration puts upward pressure on PCE inflation, stabilizing that measure of inflation requires a tighter policy stance (although such dramatic divergence in results across the alternative inflation measures is largely attributable to our assumption of full exchange rate passthrough). Finally, the wage/price inflation rule also performs reasonably well in this case, inducing responses that are reasonably akin to the case of flexible prices.

6 Welfare Rankings under Alternative Policies

To be completed

7 Conclusions

To be written.

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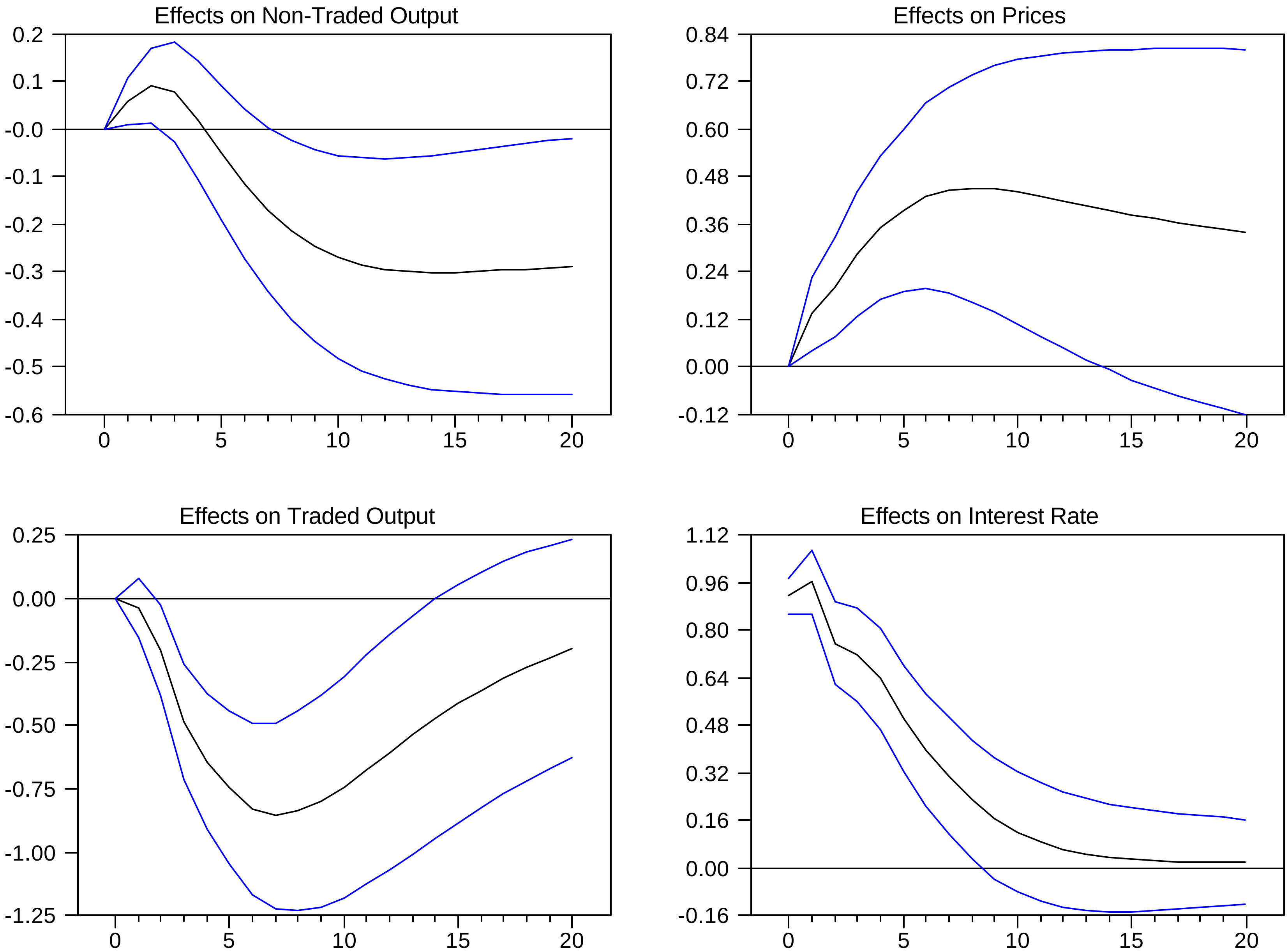
Responses to Interest Rate Shock, Logs, UK SD AL CA >1984



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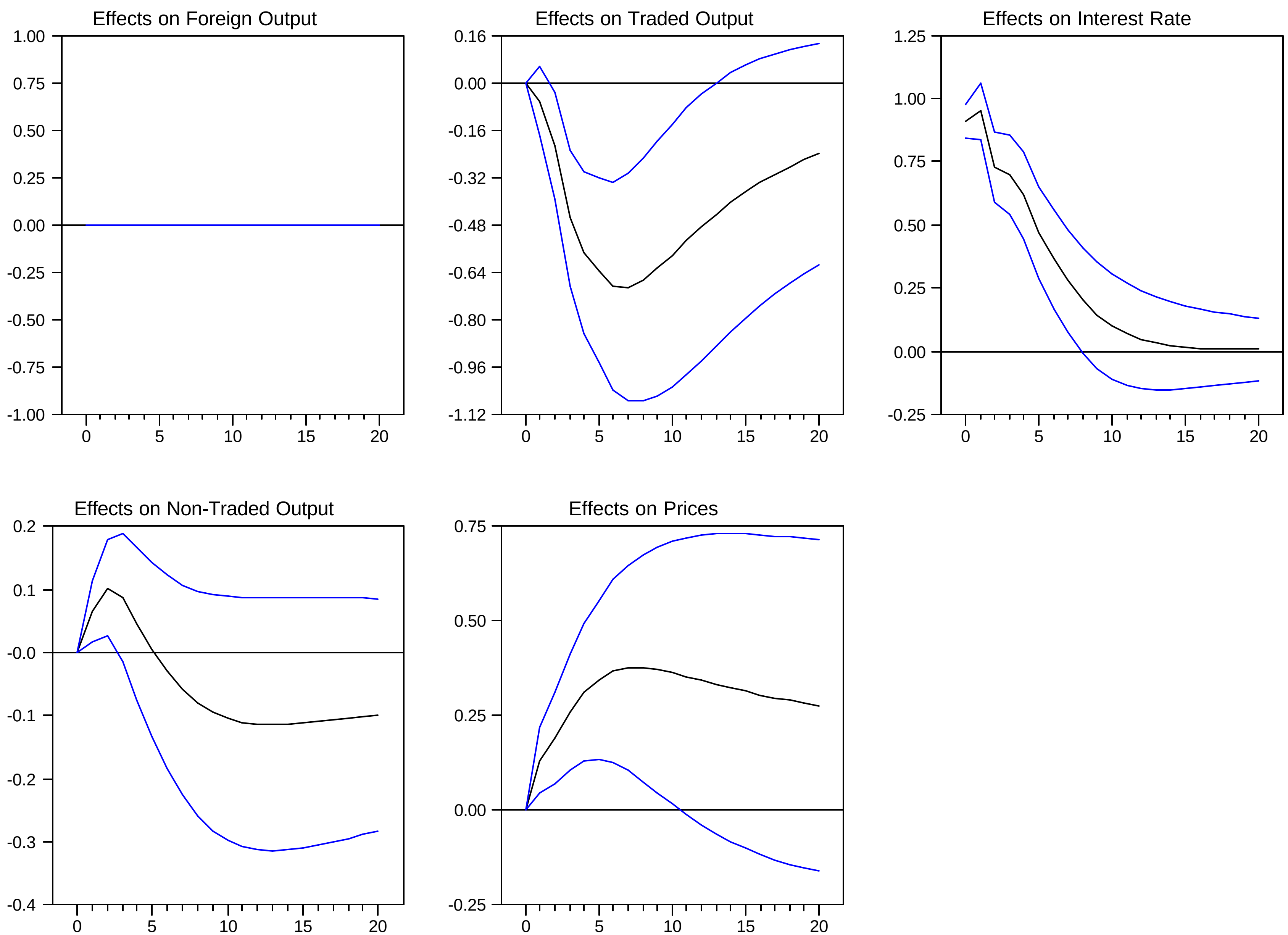

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Figure 3a: Persistent Rise in Risk Premium

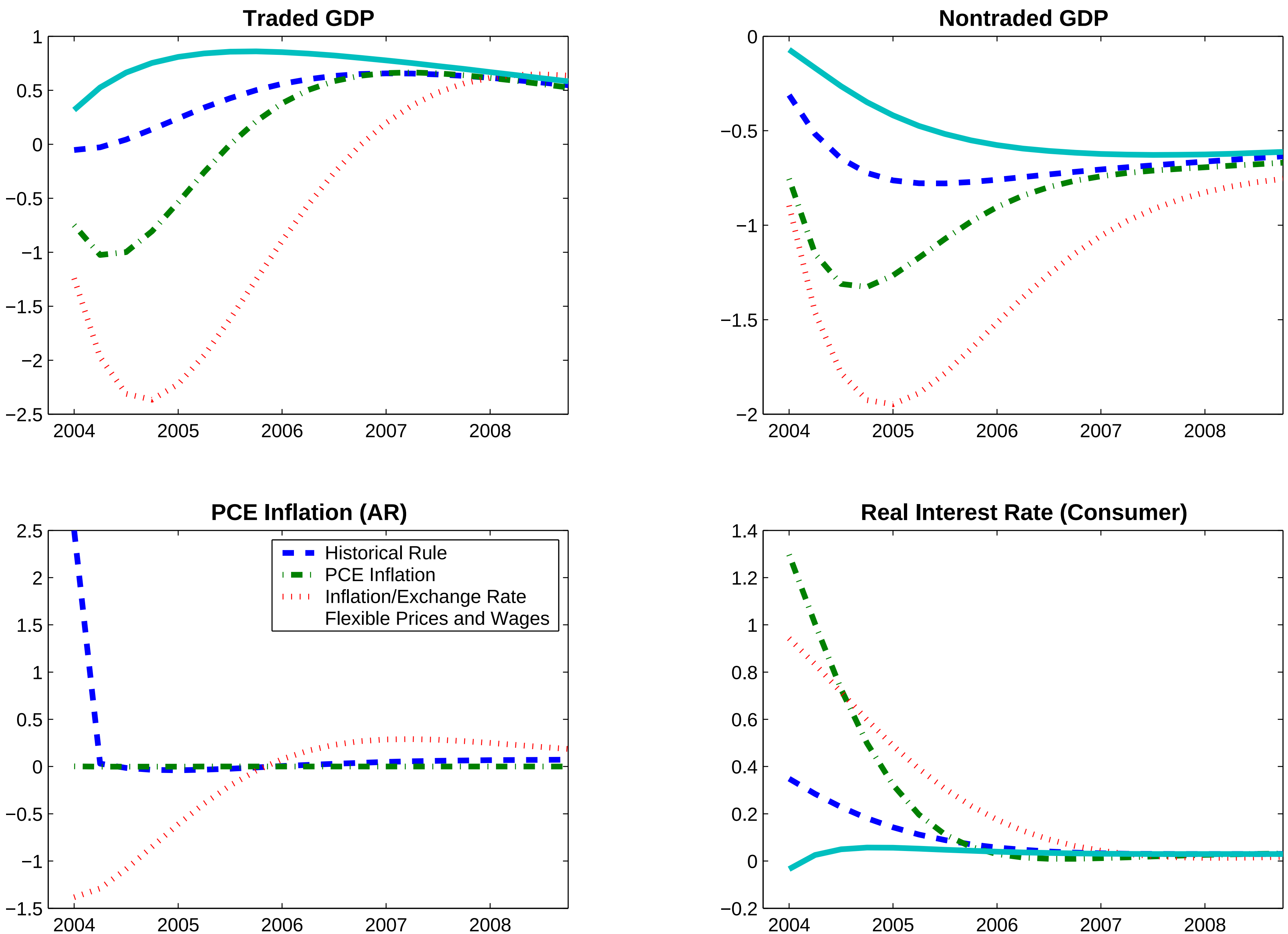

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Figure 3b: Persistent Rise in Risk Premium

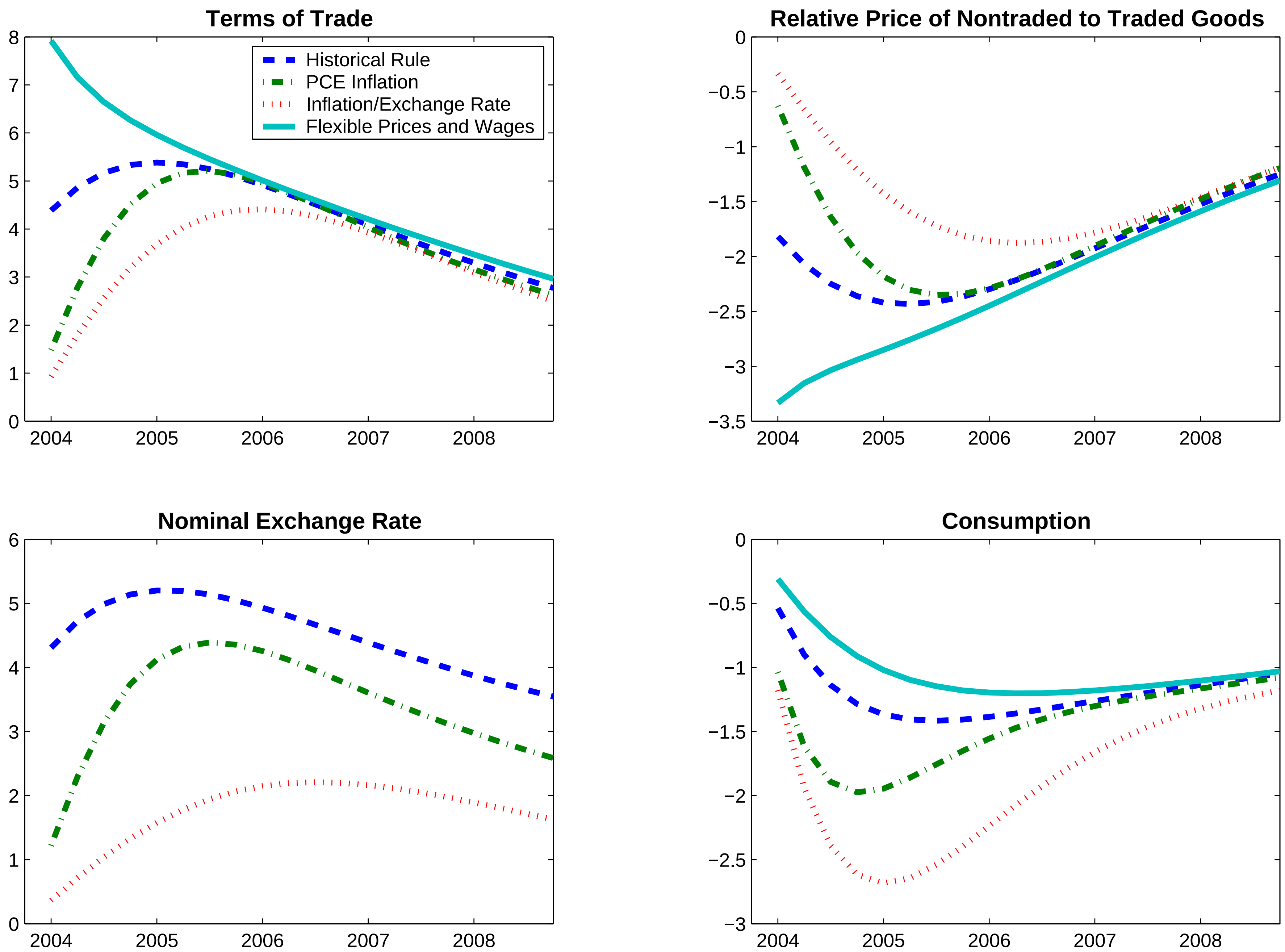

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Figure 4a: Persistent Rise in Risk Premium

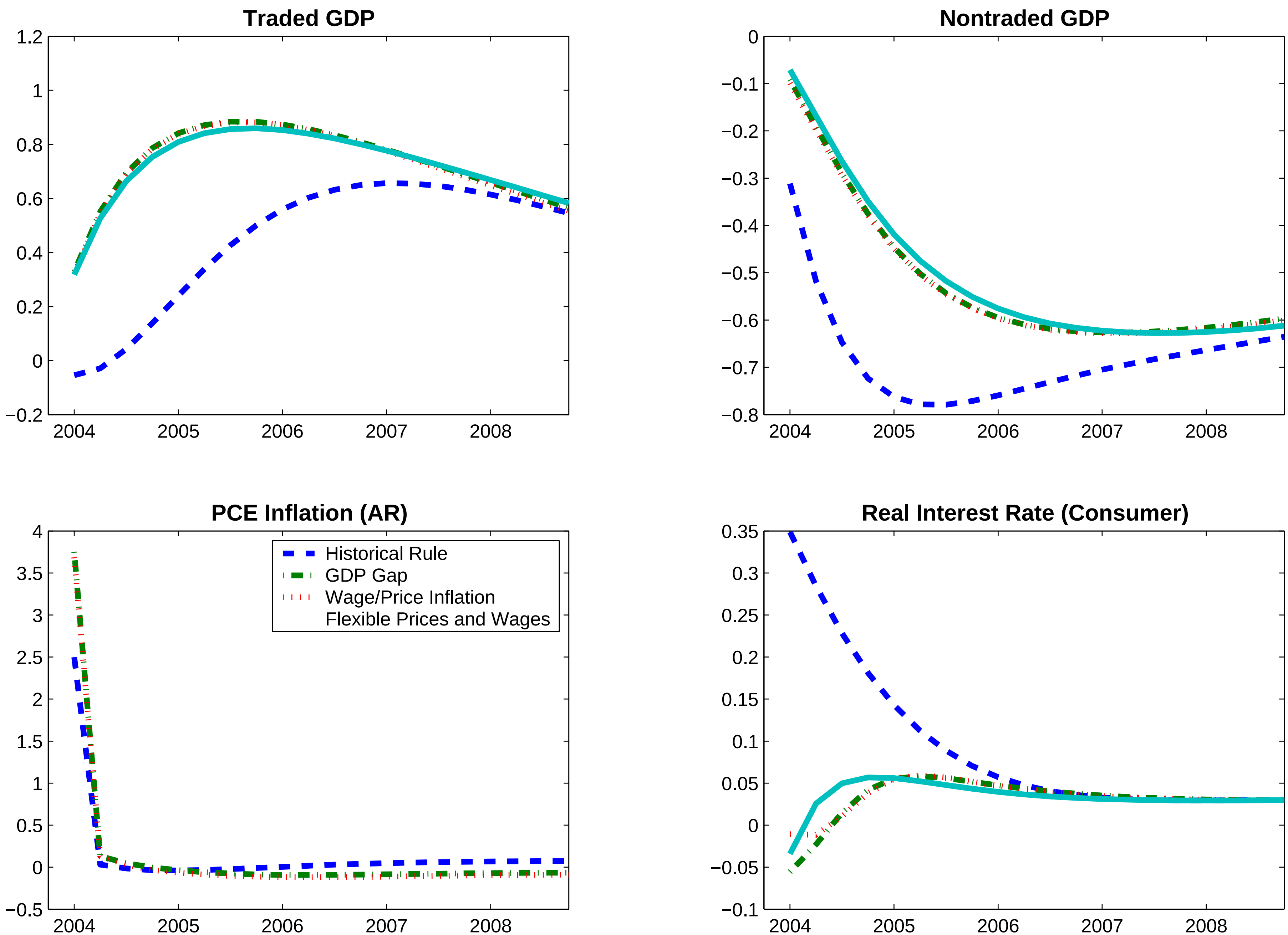

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Figure 4b: Persistent Rise in Risk Premium

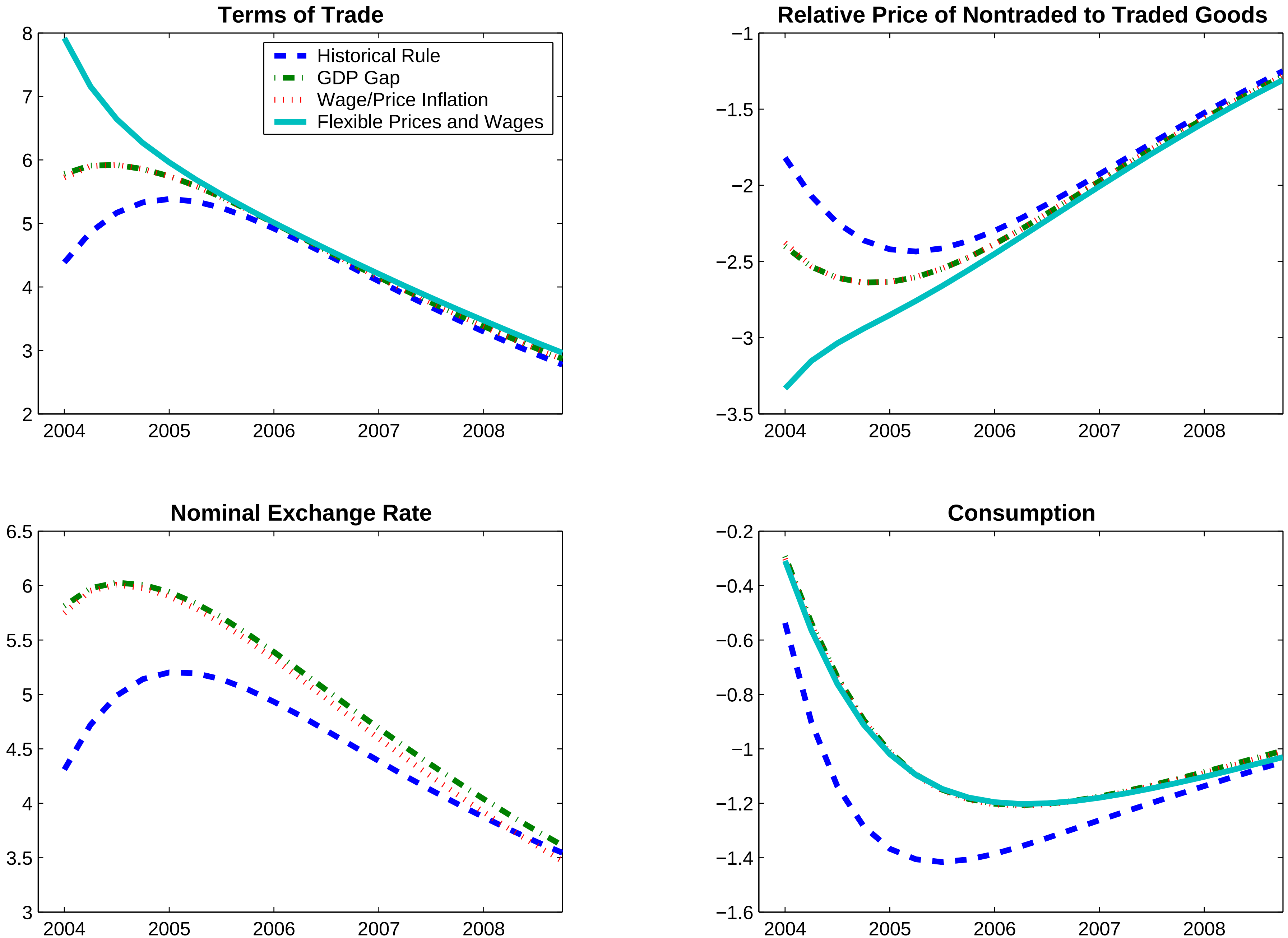

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Figure 5a: Rise in Govt Spending on Traded Goods

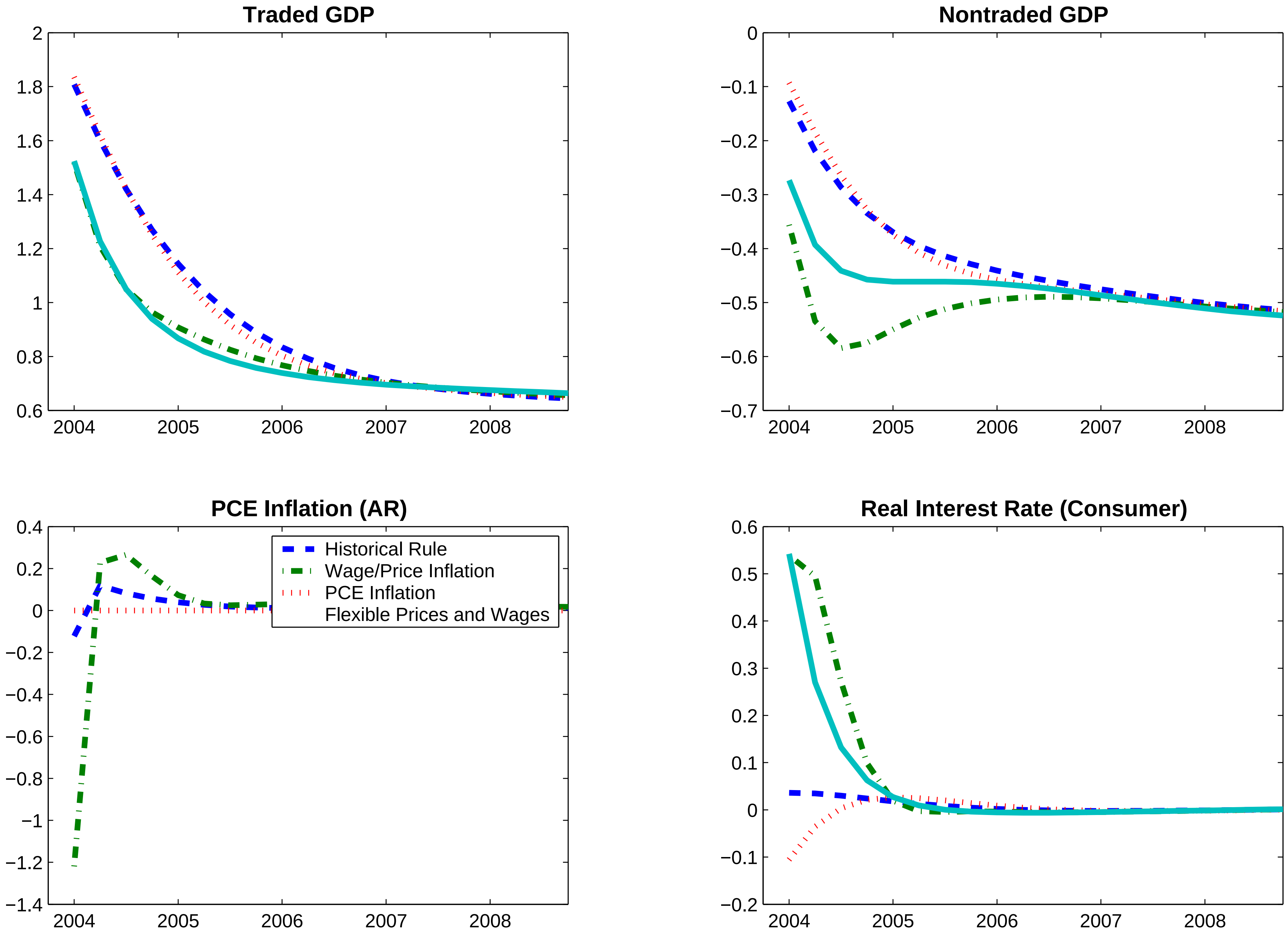

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Figure 5b: Rise in Govt Spending on Traded Goods

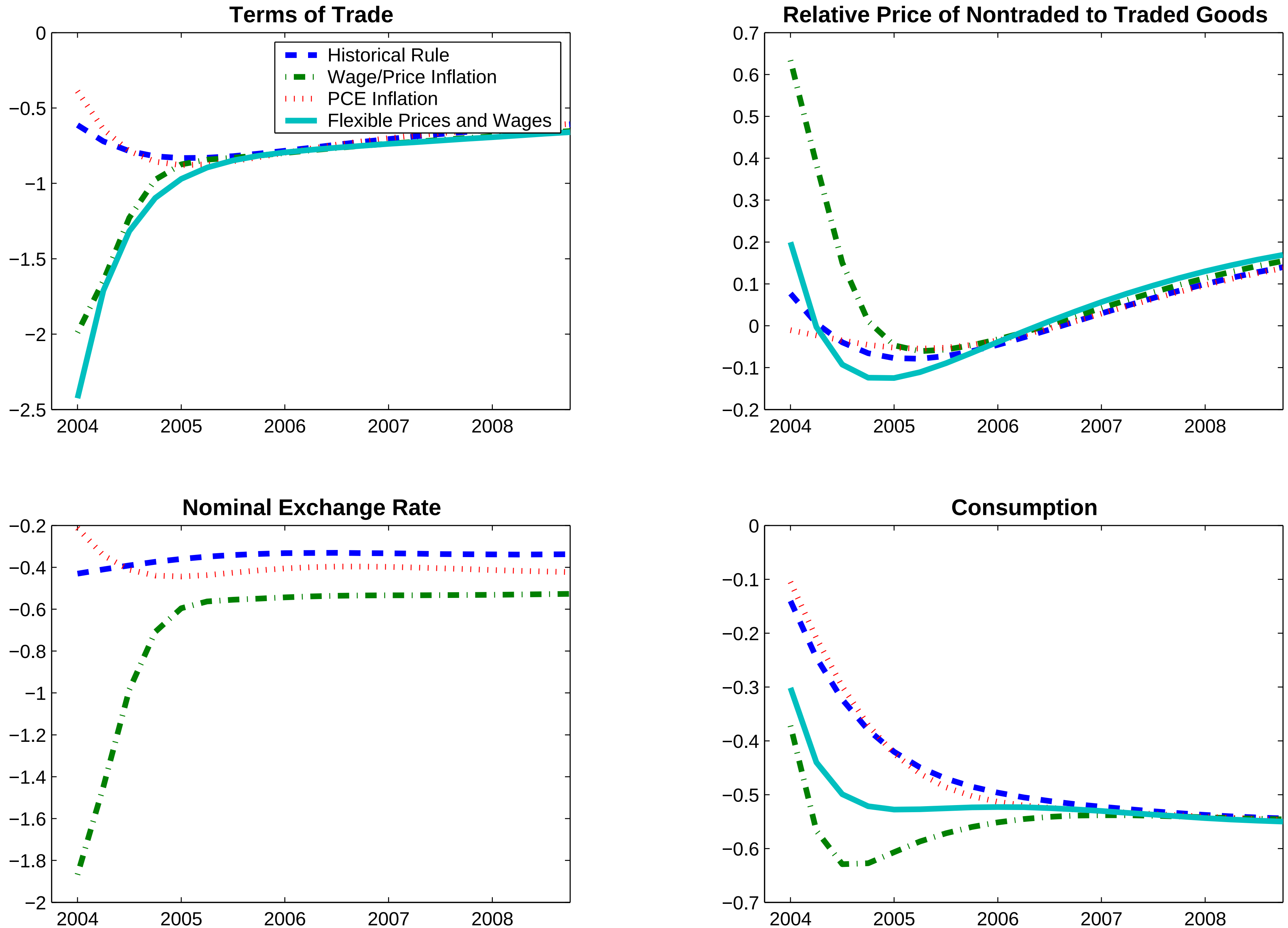

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Figure 6a: Productivity Rise in Traded Sector

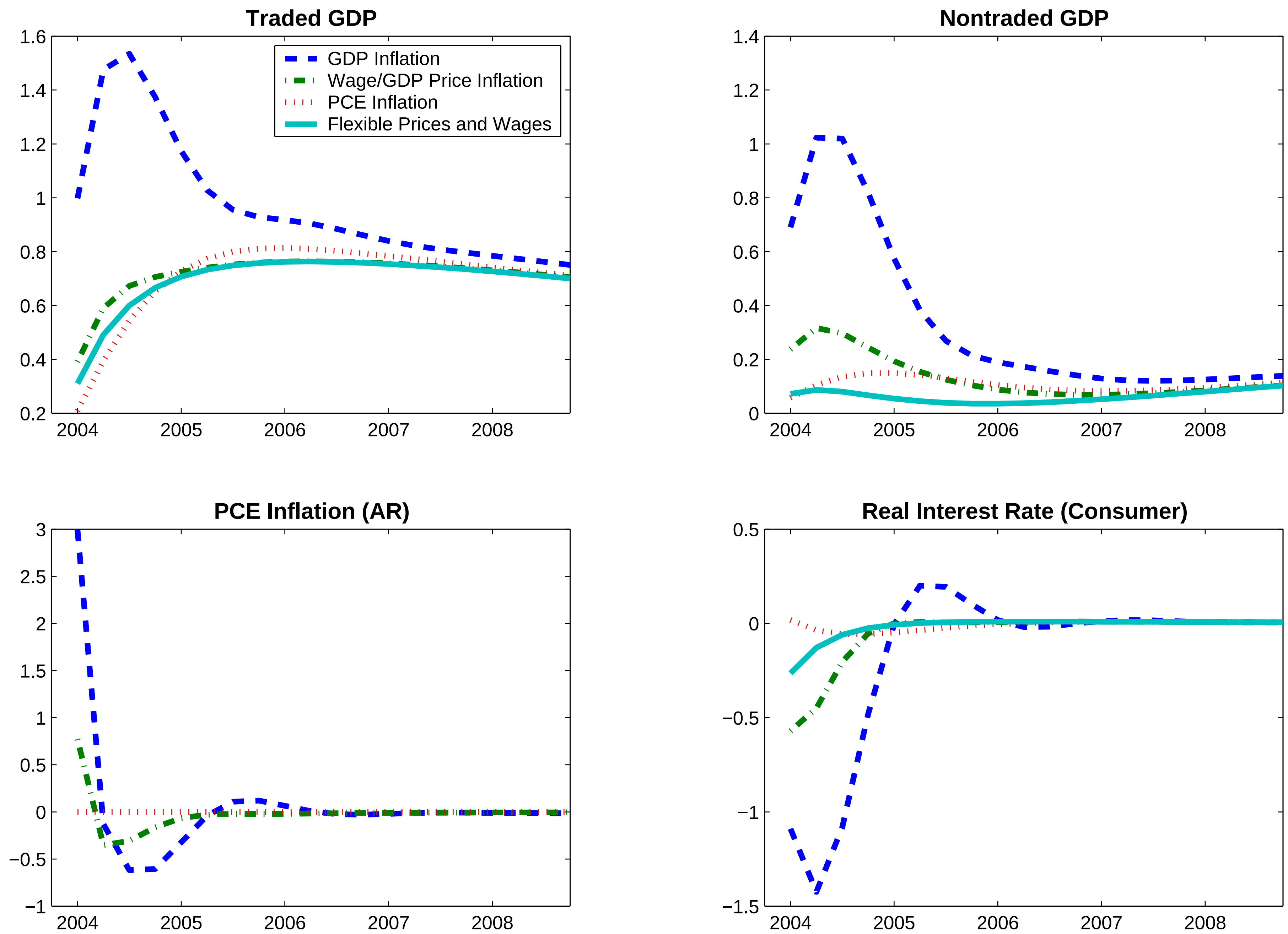

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Figure 6b: Productivity Rise in Traded Sector