A New FRB/US Price-Wage Sector

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1. Summary

This note describes a new price-wage sector that has been developed as part of the current annual re-estimation of FRB/US. Compared with the version of the sector that has been part of FRB/US for the past several years, the new price-wage equations introduce important changes in data, theory, and estimation method. The new sector's main price variable is the core PCE index and the main wage variable is ECI hourly compensation. These series replace the more volatile measures of overall PCE prices and P&C hourly compensation that were previously the focus of attention. The correspondence between the structure of the sector's equations and the New Keynesian Phillips curve (NKPC) is substantially tightened in the new version, but in a way that sacrifices little in terms of goodness of fit. The estimation approach changes from pure maximum likelihood to one that makes formal use of both maximum likelihood and Bayesian methods and also relies on guidance provided by VAR IRFs. In addition to these changes, the sector is also simplified a bit. Notably, a non-structural specification replaces the NKPC for non-consumer price inflation.

The shift from overall to core PCE prices better aligns the sector's main price measure with the sticky-price spirit of the NKPC. The flexibility of food and energy prices suggests that they should be modeled using a different paradigm. The movements of core and overall PCE inflation are compared in figure A. The case for shifting from P&C to ECI hourly compensation is based on the large amount of short-run measurement noise in the former, as can be seen in figure B.

The estimation analysis contains two main parts. (1) Maximum likelihood (ML) estimates of the revised sector over the same 1985-2007 sample that was used for the version currently in FRB/US seem quite reasonable and in some ways preferable to the current version. The IRFs of the revised sector are close to ones from a benchmark VAR. (2) Inflation in the recent recession and its aftermath did not decline nearly as much as the 1985-2007

[1] I thank John Roberts and Ed Herbst for valuable comments and suggestions.

Figure A
Measures of PCE Price Inflation

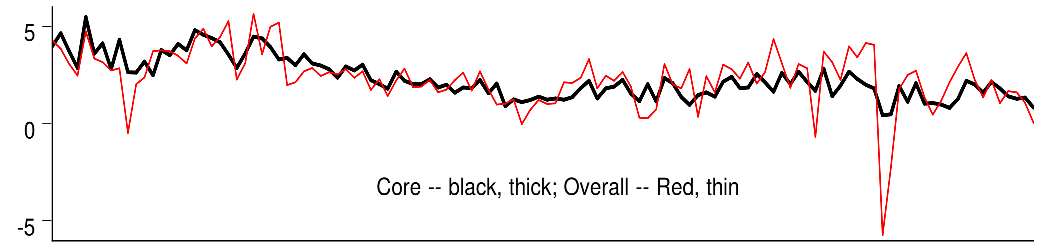
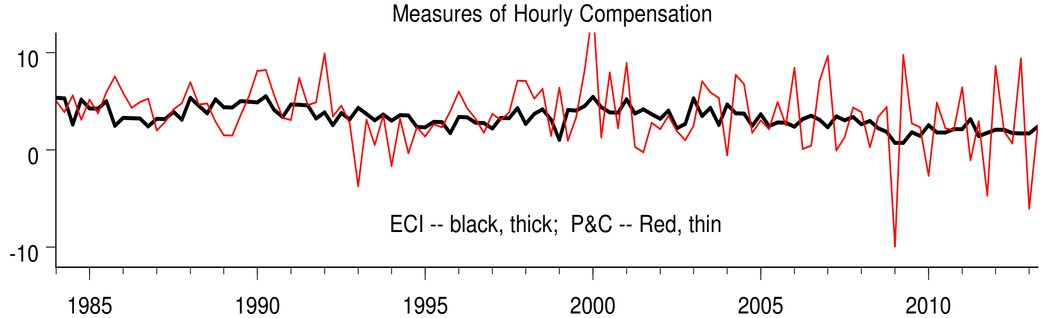


Figure B
Measures of Hourly Compensation



estimates would have predicted, a result that is common to many models of inflation. ML estimation over a longer sample period that ends in 2012 reduces the sector's unemployment slope coefficient by more than half. An alternative and more cautious re-assessment of the unemployment slope is obtained with Bayesian methods. Using the 1985-2007 ML parameter estimates and their standard errors as a prior, Bayesian estimation over the longer sample reduces the slope coefficient by one-third.

The 1985-2012 Bayesian estimates are proposed for inclusion in FRB/US. When this is done, the FRB/US responses of inflation to key current shocks tend to become somewhat smaller in the short run and less oscillatory in the medium run. The short-run responses of inflation to expected future shocks are also scaled back.

2. The FRB/US New Keynesian Phillips curve

The form of the FRB/US NKPC is based on Cogley and Sbordone (2008), specifically their equation for the case in which the subset of prices or wages that is not optimally reset each period is indexed to either past or trend inflation.

$$\Pi_t = \beta E_{t-1}\Pi_{t+1} + \kappa E_{t-1}\mu_t + \epsilon_t \tag{1}$$

$$\Pi_t \equiv \pi_t - \gamma\hat{\pi}_t - (1-\gamma)\bar{\pi}_t \tag{2}$$

Π and π refer to either price or wage inflation, β (=.98) is the discount factor, μ is the price or wage markup gap, $\hat{\pi}$ is the measure of past inflation to which the fraction γ of prices or wages that are not optimally reset in a given period is indexed, and $\bar{\pi}$ is trend inflation. Expectations are formed on the basis of "t-1" information (E_{t-1}), given an assumption that prices and wages are set at the beginning of each period. In the estimation of the price-wage sector, trend price inflation is measured using survey data on ten-year inflation expectations.

The implementation of this NKPC framework in FRB/US indexes the fraction γ of non-optimized prices and wages to the average own rate of inflation over the previous four quarters.

$$\hat{\pi}_t \equiv \sum_{i=1}^{4} \pi_{t-i}/4 \tag{3}$$

This specification is unusual but not unprecedented.[2] Compared with indexing to a single lag of inflation, the use of the four-quarter average greatly improves the fit of both of the new price and wage equations.

[2] Indexing to a four-quarter average can be found in Gali (2011), in which one of the estimated wage equations contains indexation to the lagged four-quarter average of price inflation. An alternative approach to motivating the presence of lagged inflation in a NKPC posits that some firms are backward looking and set their prices with reference to past inflation, typically the first lag. An exception is Zhang and Clovis (2009), which develops and estimates an NKPC in which the backward-looking firms base their prices on multiple lags of inflation. Mavroeidis, Plagborg-Moller, and Stock (2013) characterize the conventional approach of indexing to the previous period's inflation as "clearly arbitrary."

A key part of the price and wage markup gaps, μ^p and μ^w, is the detrended level of the log labor share in the nonfarm business (NFB) sector s,

$$s_t \equiv w_t^{nfb} - p_t^{nfb} - \bar{a}_t^{nfb} - \bar{s}_t, \tag{4}$$

where w, p, and $\bar{a}$ are respectively the log levels of hourly compensation, price, and trend labor productivity, and $\bar{s}$ is the trend in the labor share.[3] The NFB labor share would be an appropriate measure of the markup gap for an NFB price but not for a consumption price. In FRB/US, the consumption price markup gap is calculated with a set of accounting identities that, if log linearized, would express the consumption-based markup as a weighted average of the NFB labor share s and the price of imports p^m relative to the price of final sales p^{fs}.[4]

$$\mu_t^p \cong \omega_t s_t + (1 - \omega_t)(p_t^m - p_t^{fs}) \tag{5}$$

The time-varying weight, ω_t, moves with the ratio of nominal ratio of NFB output to final sales.

The NKPC wage markup gap is the difference between the marginal rate of substitution (mrs) and the real wage, which for use in FRB/US is rewritten as a function of the unemployment gap (U) and the labor share.

$$\begin{aligned} \mu_t^w &\equiv mrs_t - (w_t^{nfb} - p_t^{nfb}) \\ &\cong \theta U_t - s_t \end{aligned} \tag{6}$$

The derivation of equation 6 starts from a relationship presented in Gali (2011, section 3.4) that expresses the marginal rate of substitution as the sum of trend consumption, the scaled employment rate, and a labor supply shock, all measured in logs. Gali then proceeds to

[3]Both trends, for labor productivity and the labor share, are estimated outside of the price-wage system.

[4]For simplicity of exposition, the text omits two other terms that appear in the linearized relationship: the relative price of output in the farm, households and institutions, and government sectors, and the deviation of the price of consumption relative to the price of final sales from its trend.

show that for his model μ^w is approximately proportional to the unemployment gap, but the additional assumptions required for this outcome are not imposed in FRB/US. Rather, the derivation of the FRB/US wage markup gap continues with a limiting case of Gali's mrs formula in which the consumption trend is proportional to trend labor productivity.[5] Under the additional assumptions that the employment rate is inversely proportional to the unemployment gap and the labor supply shock to zero, μ^w becomes the linear function of the unemployment gap and the labor share that is shown in equation 6.

The final form of the price and wage equations combines equations 1-3 and 6 with the assumption that trend inflation is expected to follow a random walk: $E_{t-1}\bar{\pi}_{t+1} = E_{t-1}\bar{\pi}_t = \bar{\pi}_{t-1}$. In addition, because the computational costs of solving the full FRB/US model under model-consistent expectations roughly increases with the square of the number of expectations variables, the final NKPC equations replace the $t-1$ expectations of μ^p_t, s_t, and U_t with their observed values in period $t-1$.

$$\begin{aligned}
\pi^p_t &= \Big(.25\gamma_p\Big((1-\beta)\sum_{i=1}^{3}\pi^p_{t-i} + \pi^p_{t-4}\Big) + \beta E_{t-1}\pi^p_{t+1} && (7)\\
&+ (1-\beta)(1-\gamma_p)\bar{\pi}^p_{t-1} + \kappa_p\mu^p_{t-1}\Big)/(1+.25\beta\gamma^p) + \epsilon^p_t \\
\pi^w_t &= \Big(.25\gamma_w\Big((1-\beta)\sum_{i=1}^{3}\pi^w_{t-i} + \pi^w_{t-4}\Big) + \beta E_{t-1}\pi^w_{t+1} && (8)\\
&+ (1-\beta)(1-\gamma_w)\bar{\pi}^w_{t-1} - \kappa_w s_{t-1} + \alpha_w U_{t-1}\Big)/(1+.25\beta\gamma^w) + \epsilon^w_t
\end{aligned}$$

Each equation contains four own inflation lags, but the coefficient on the fourth lag is large relative to the coefficients on the first three.[6] By contrast, the ad hoc indexing scheme in the current FRB/US price-wage sector simply adds the four-quarter average of lagged inflation to each equation. It is easily verified that the coefficients on actual, expected, and

[5] Gali links the log levels of trend (z) and actual (c) consumption according to $z_t = \nu z_{t-1} + (1-\nu)c_t$. Setting $\nu = 1$ and shifting the frame of reference to one in which variables are not detrended, the previous expression becomes $\Delta z_t = \Delta\bar{a}_t$, or $z_t = \bar{a}_t + cnst$.

[6] However, the behavior of both price and wage inflation will generally depend on the all lags of inflation much more evenly than this would indicate, through the influence of the intermediate lags on expected inflation.

trend inflation on the right hand sides of equations 7-8 sum to one.

3. The estimation model

The estimation model combines the pair of NKPC equations, which will be part of FRB/US, with a number of reduced-form relationships, identities, and approximations. These auxiliary equations, which are not part of FRB/US, fill out the endogenous structure of the estimation model in a way that is both parsimonious and designed to be roughly consistent with FRB/US. In line with the standard approach to estimating FRB/US, the structural equations are estimated conditional on estimates of the coefficients of the auxiliary equations.

$$
\begin{aligned}
\mu_t^p &= \mu_{t-1}^p + .0025 * (\pi_t^w - \pi_t^p - g_t) + \epsilon_\mu && (9)\\
s_t &= 1.25\mu_t^p + \epsilon_s && (10)\\
g_t &= g_{t-1} + \epsilon_g && (11)\\
U_t &= \theta_1 U_{t-1} + \theta_2 \Delta U_{t-1} + \theta_3 \tilde{x}_t + \theta_4 \Delta \tilde{x}_t + \epsilon_U && (12)\\
\Delta \tilde{x}_t &= \phi_x^x \tilde{x}_{t-1} + \phi_x^p (\pi_{t-1}^p - \bar{\pi}_{t-1}^p) && (13)\\
&+ \phi_x^w (\pi_{t-1}^w - \hat{\pi}_{t-1}^w) + \phi_x^r (r_{t-1} - \bar{r}_{t-1})\\
&+ \sum_{i=1}^{3} (\psi_{x,i}^x \Delta \tilde{x}_{t-i} + \psi_{x,i}^p \Delta \pi_{t-i}^p + \psi_{x,i}^w \Delta \pi_{t-i}^w + \psi_{x,i}^r \Delta r_{t-i}) + \epsilon_x\\
\Delta r_t &= \phi_r^x \tilde{x}_t + \phi_r^p (\pi_t^p - \bar{\pi}_{t-1}^p) + \phi_r^r (r_{t-1} - \bar{r}_{t-1}) && (14)\\
&+ \sum_{i=0}^{2} (\psi_{r,i}^x \Delta \tilde{x}_{t-i} + \psi_{r,i}^p \Delta \pi_{t-i}^p) + \sum_{i=1}^{3} \psi_{r,i}^r \Delta r_{t-i} + \epsilon_r\\
\bar{\pi}_t^p &= \bar{\pi}_{t-1}^p + \epsilon_{\bar{p}} && (15)\\
\bar{r}_t &= \bar{r}_{t-1} + \epsilon_{\bar{r}} && (16)\\
\bar{\pi}_t^w &\equiv \bar{\pi}_t^p + g_t && (17)
\end{aligned}
$$

The equations for the price markup gap (μ^p) and the detrended labor share (s) are approximations in which the contributions of import prices and other differences between NFB and consumption prices are in the error terms. The time-varying estimate of the trend gap between wage and price inflation (g), which conceptually equals the difference between the trend rates of growth of labor productivity and the price of consumption relative to the price of final sales, is a random walk. The unemployment gap (U) is linked to the output gap ($\tilde{x}$) in an Okun's Law relationship. The equations for the output gap and the nominal federal funds rate (r) are part of a version of the FRB/US "core" VAR that is expanded to include wage inflation. The structure of the expanded four-lag VAR ensures that, in the absence of shocks, each of its endogenous variables converges to a time-varying "endpoint". The endpoints for the output gap (0), price inflation ($\bar{\pi^p}$), and the funds rate ($\bar{r}$) are the same as in the core VAR. The latter two are modeled as random walks. The endpoint for wage inflation ($\bar{\pi^w}$) equals the endpoint for price inflation plus g.

So that it might be plausibly be viewed as a monetary policy rule, the funds rate equation (14) has a form that differs in two ways from the form of the output gap equation (13): it permits the funds rate to respond contemporaneously to inflation and the output gap, and it omits wages from the set of explanatory variables.[7] In addition, the endpoint structure of the funds rate equation has the interpretation that the desired rate of inflation equals the inflation trend that appears in the NKPC equations.

4. Estimation results

In the estimation of the price-wage sector, π^p is core PCE inflation measured at an annual rate, π^w is the annualized rate of change of the Employment Cost Index for total compensation for private industry workers, and $\bar{\pi}$ is a survey-based measure of ten-year inflation expectations. The definitions of other variables and their correspondence to FRB/US data are given in the appendix.

Estimation is a two-step process. In the first, the coefficients of the auxiliary equations are estimated by OLS. In the second, the five parameters of the pair of NKPC equations are estimated by maximum likelihood or Bayesian methods under the assumption of model-consistent expectations.[8] The indexing parameters (γ_p, γ_w) are restricted to the [0,1]

[7] The inclusion of contemporaneous effects also improves the stability properties of the estimation model.

[8] The second estimation step is conducted in Dynare. The set of estimated parameters includes the standard errors of all — NKPC and auxiliary — equations and the error correlation of the price and wage NKPCs. Because none of the parameters of the NKPC equations appear in any of the auxiliary equations and the correlations between the errors of the NKPC and auxiliary equations are assumed to be zero, identical ML estimates are obtained when the likelihood is formed from the variance-covariance matrix of the NKPC errors only.

Table 1
Parameter Estimates

Parameter[a]	Maximum Likelihood				Bayesian
	1985-2007		1985-2012		1985-2012
	estimate	(se)	estimate	(se)	estimate
	(1)		(2)		(3)
π^p equation					
γ_p	.737	(.116)	.713	(.147)	.712
${\kappa_p}^b$	.0035	(.0018)	.0028	(.0016)	.0032
π^w equation					
γ_w	1.00	(.184)	1.00	(.173)	1.00
${\kappa_w}^{b,c}$	.0018	(restr)	.0014	(restr)	.0016
α_w	-.034	(.014)	-.015	(.008)	-.024

a. Coefficient definitions: γ, indexing; α_w, U; κ^p, μ^p; κ^w, s.
b. Divided by 400.
c. Restriction: $\kappa_w = .5\ \kappa_p$.

interval. The unemployment parameter (α_w) is restricted to be zero or less, and the labor share parameters (κ_p, κ_w) are restricted to be zero or greater.

The sample period for the first set of estimates is 1985q1-2007q4, the same period over which the current FRB/US price-wage sector was estimated. The beginning date roughly marks the start of the low inflation era that now has persisted for almost 30 years. The initial sample excludes the recent recession and its aftermath, a time that has seen many economic relationships go off track. As shown in the first set of columns of table 1, the price indexation parameter is .737 and the wage indexation parameter is 1.0, its upper bound. Based on their standard errors, the hypotheses that either parameter is zero can be strong rejected, as can the hypothesis that all prices are indexed to lagged inflation. The unemployment coefficient (α_w) is also significant, with a point estimate that is about 2-1/2 times its standard error. The price markup coefficient (κ^p) is about twice its standard error.[9]

[9]Evidence indicates, however, that these ML standard errors are too large for evaluating the significance of substantial coefficient perturbations. When the sector is reestimated with its coefficients set to zero one by one, or, when setting a coefficient to zero leads to convergence problems, close to zero, the deterioration

The unrestricted estimate of the labor share parameter in the wage equation (κ_w) is zero, its lower bound, but with a large standard error. Based partly on the theoretical underpinnings of the wage and price NKPCs and partly on evidence from IRFs, to be discussed below, all of the reported estimates set κ_w to one-half the price markup parameter (κ_p). If prices and wages were equally flexible, this is roughly the ratio of the two parameters that would obtain in the model of Smets and Wouters (2007). The restriction on κ_w, which causes only a minor deterioration in likelihood, has a p-value of 0.13.

When the estimation period is extended to 2012 (the second pair of columns), the magnitude of the unemployment slope coefficient falls by more than half to -.015.[10] The reduction of this coefficient is not surprising given the limited decline of inflation in recent years in the presence of high unemployment. Various explanations have been put forward for the absence of a larger fall in inflation — such as downward nominal wage rigidity (Daly and Hobijn (2013)), a higher-than-normal fraction of long-term unemployment, and heightened monetary policy credibility — that are not captured in the FRB/US price-wage sector. Recognizing the uncertainties that these issues present, a Bayesian approach is a natural way to allow the post-2007 years to have some influence on the sector's parameters, but not as much as in the ML estimates just discussed. To carry this out, the sector is estimated over the 1985-2012 period using the 1985-2007 ML coefficient estimates and their standard errors as a Bayesian prior. For the key coefficient of current interest, the unemployment slope, the Bayesian estimate is -.024, a value midway between the ML estimates over the shorter and longer samples.

Indexing to the lagged four-quarter average rate of inflation provides a much better characterization of the behavior of inflation since the mid-1980s than does indexing to the first lag only. For the 1985-2007 period, the likelihood of the one-lag model is more than 20 log points lower than the likelihood of the four-lag model; the equation standard errors rise from 0.52 to 0.60 for the price NKPC and from 0.84 to 0.91 for the wage NKPC. In addition, the shorter indexing lag reduces the estimates of the indexing parameters, from 0.74 to 0.57

in the likelihood is frequently larger than the standard error would predict.

[10] The estimation period is only extended for the second estimation step. The 1985-2007 estimates of the auxiliary equations for the output gap and the funds rate continue are retained on the grounds that the zero-bound constraint and the occurrence of a large financial sector shock would substantially bias their coefficients over the longer sample.

for prices and from 1.00 to 0.65 for wages.[11] A final point related to the use of four-quarter indexing is that, despite the much larger weight on the fourth lag of inflation than on any other inflation lag in the structural NKPC, the reduced-form inflation equations place relatively even weight on each inflation lag. In the reduced-form price equation associated with the 1985-2012 Bayesian estimates, for example, the coefficients on the four lags of price inflation are 0.152, 0.157, 0.165, and 0.176, respectively, The sum of these coefficients along with the reduced-form coefficients on trend inflation (0.219) and lagged wage inflation ($\sum$ =0.130) is 1.0.

Another indexing issue concerns the appropriate inflation measure for wage indexing. In the literature, some models index wages to past wage inflation; others index to past price inflation, with an adjustment for labor productivity. A specification that nests these two alternatives by permitting the indexing measure to be a weighted average of past four-quarter wage and price inflation (adjusting the latter for the trend difference between the wage and price inflation) ends up placing all of the weight on lagged wages.

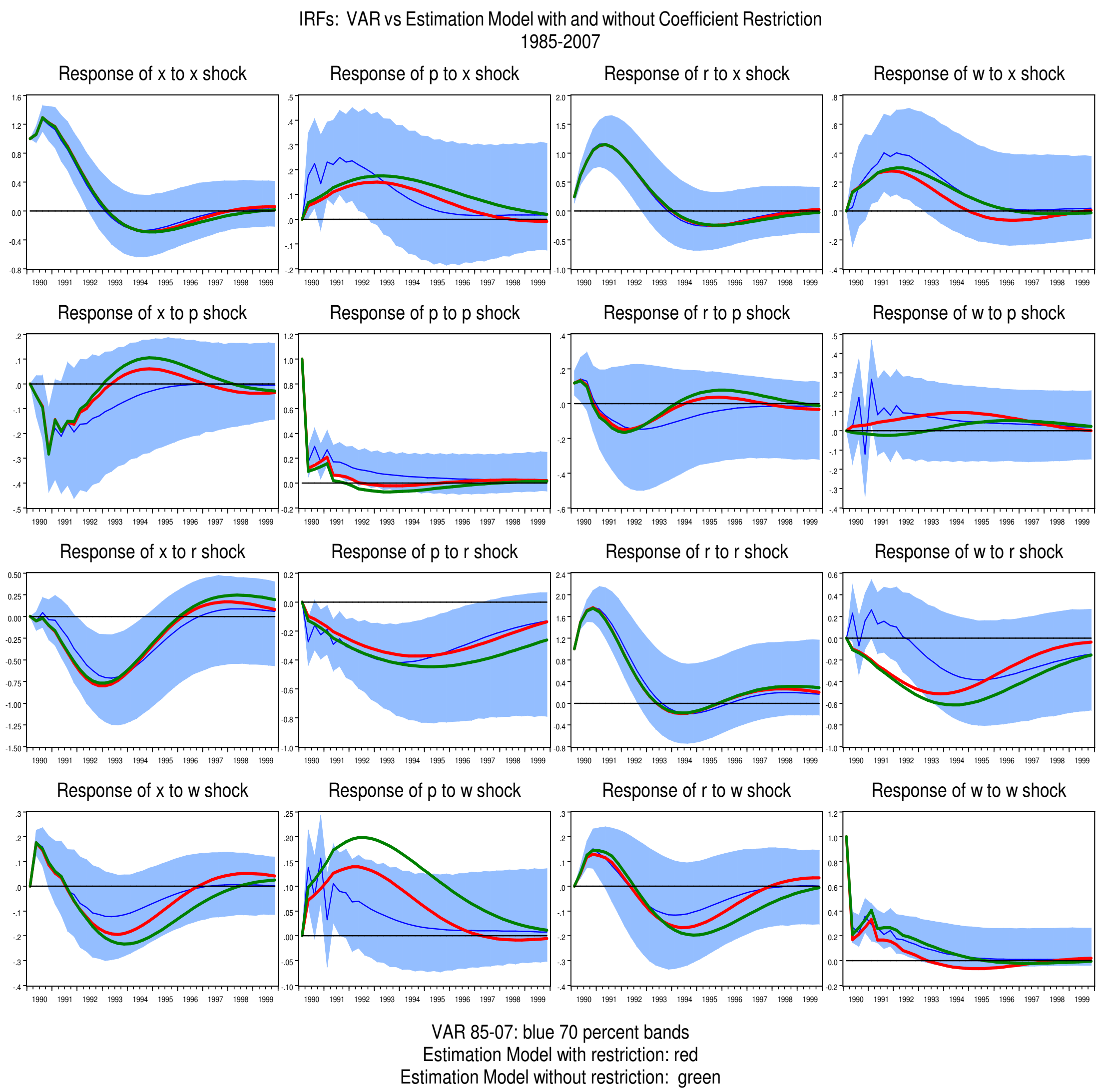
A final point regarding the estimation results concerns the magnitude of the labor share coefficient κ_p. In a survey of estimated NKPC price equations, Schorfheide (2008, table 5) reports that κ_p ranges from 0.005 to 0.135 in models for which the labor share is an observed variable, as it is here. The values of this parameter reported in table 1, which are in the vicinity of 0.003, fall below this range, but the comparison is biased by the fact that the surveyed results are all from models in which inflation is indexed to its first lag. In the one-lag version of the FRB/US sector, the estimated value of κ_p is higher and at the lower end of the surveyed range.

5. IRF comparison with VAR

One way to gauge the reasonableness of these estimates of the price-wage sector is to compare the sector's IRFs with those of a VAR. A four-variable endpoint VAR is assembled for this purpose that contains, in addition to the VAR equations for the output gap and the funds rate that appear in the price-wage estimation model, four-lag endpoint VAR equations for price and wage inflation. Although the structural estimation model is not strictly nested

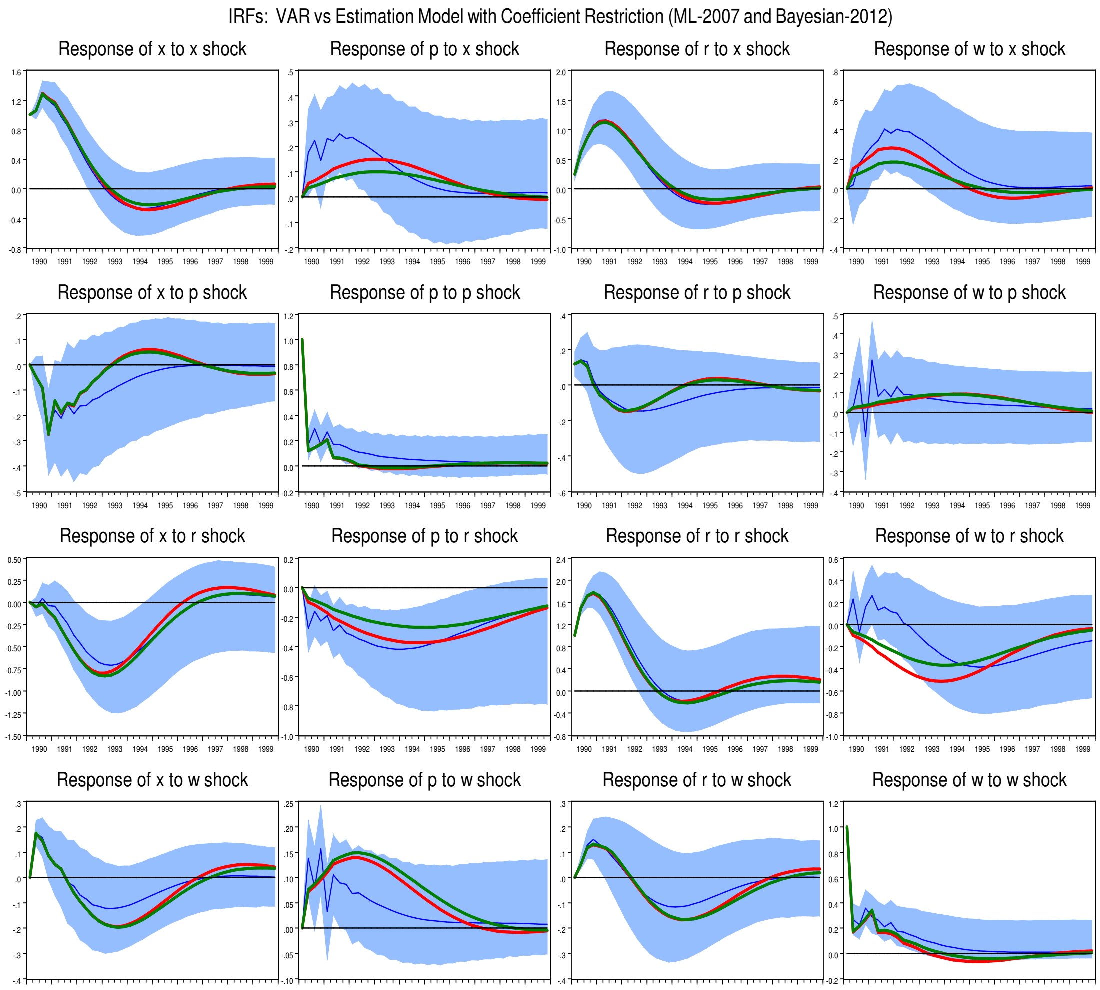
[11] In the one lag model there is no evidence of serial correlation in the error terms of either of the NKPC equations.

Figure 1



within this VAR, as the latter omits the unemployment rate and the markup gaps, this VAR is nonetheless a useful benchmark. The VAR is estimated over the 1985-2007 sample.

Figure 2



VAR 85-07: blue 70 percent bands
Estimation Model ML-2007: red-thick
Estimation Model Bayesian-2012: green-thick

Figure 1 compares the IRFs of the VAR with those of the 1985-2007 estimates of price-wage model. The impulses are unit shocks to the errors of the equations for the four main variables (ϵ^p, ϵ^w, ϵ^x, and ϵ^r). Forty quarters of responses are plotted along with the VAR's 70 percent confidence bands. Two sets of IRFs for the price-wage model are shown, one with the restriction κ_w=.5κ_p and one with κ_w at its unrestricted estimate of zero. As can be seen, the restriction moves the response of wage inflation to a price shock in the estimation model into better alignment with the VAR IRF. It also brings the model's response of price inflation to a wage shock closer to the VAR IRF. These results support the imposition of the restriction. Focusing now on the restricted model's IRFs, one immediate observation is that they are rarely outside the 70 percent VAR bands, and when outside they are near the boundary.

Figure 2 compares the IRFs of the VAR to those of the price-wage model when it is estimated alternatively over 1985-2007 by maximum likelihood and over 1985-2012 by the Bayesian method. The restriction on κ_w imposed in both cases. Not surprisingly, the Bayesian responses of price and wage inflation to the output shock (and the interest rate shock as well) are smaller in magnitude than the corresponding ML IRFs, but the differences are not dramatic and the outcomes are still almost always within the VAR bands.

6. FRB/US simulations

As mentioned above, only the pair of NKPC equations from the estimation model gets coded in FRB/US; other existing parts of FRB/US replace the auxiliary equations. The coding process involves a few other changes. First, the NKPC for non-consumption price inflation ($PIPXNC$) is dropped and replaced with a simple relationship in which the difference between non-consumption price inflation and overall PCE inflation, adjusted for the trend in relative consumption price inflation, depends on two lags of the adjusted difference and on movements in the real exchange rate. Second, the rate of P&C hourly compensation ($PIPL$ in FRB/US) is linked to the rate of ECI hourly compensation (π_w in the notation used here and $PIECI$ in FRB/US notation) with the simple identity $PIPL = PIECI$. The level of the P&C measure continues to be used in the calculation of the labor share.

The simulation analysis presented in this section uses the July version of FRB/US as a point of reference, so as not to confound the effects of revisions to the price-wage sector with the effects of changes to other parts FRB/US that are also taking place. In the five figures that follow, the "FRB/US July" lines are IRFs from the July version, the

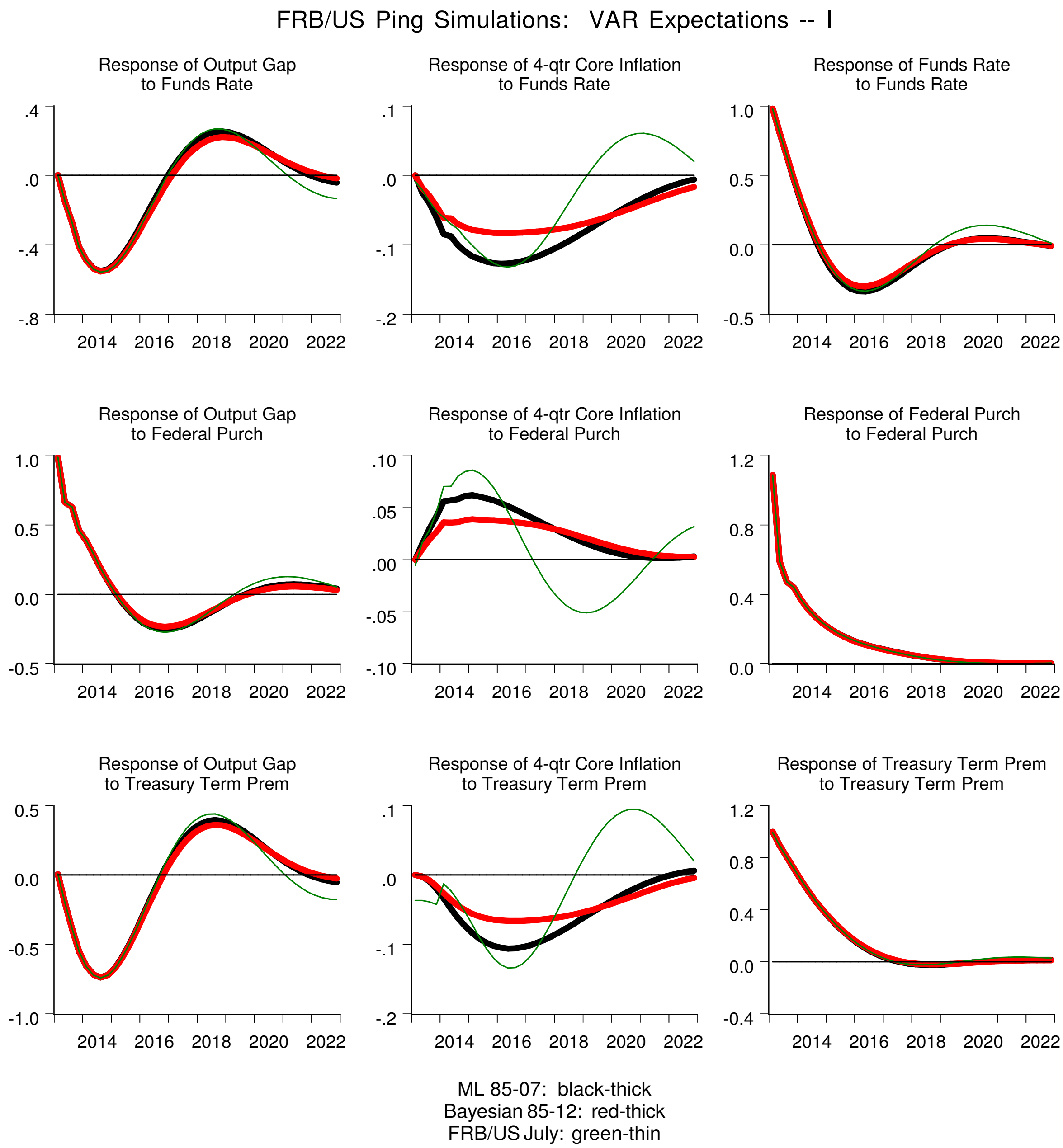
"ML 85-07" lines are IRFs from the July version when its price-wage sector is replaced with the new price-wage sector and its 1985-2007 maximum likelihood coefficients, and the "Bayesian 85-12" lines are IRFs with the new price-wage sector and its 1985-2012 Bayesian coefficients. The simulations summarized in the first two of these figures (figures 3-4) assume VAR expectations; the simulations for the other three (figures 5-7) assume model-consistent expectations in asset pricing and price-wage setting. The comments that follow focus on the middle column of each figure, which plots the response of four-quarter core PCE inflation. Some key points are:

- The responses of price inflation in both new versions under both assumptions about expectation formation are much less oscillatory than the responses in July FRB/US over the 40 IRF quarters.
- The following observations pertain to the responses over the first four years of price inflation to shocks to the federal funds rate, other financial variables, and government purchases.
  - Under VAR expectations, the responses are broadly similar in ML 85-07 and July FRB/US; the responses in Bayesian 85-12 are somewhat smaller in magnitude. (figure 3, all rows; figure 4, row 1)
  - Under MC expectations, the responses are smaller in both ML 85-07 and Bayesian 85-12 than in July FRB/US; the Bayesian 85-12 responses are modestly smaller than the ML 85-07 responses. (figure 5, all rows, figure 6, row 1)
  - The date of the peak inflation effect under MC expectations is closer to the peak date under VAR expectations in the new versions than in July FRB/US. (figures 3-4 versus figures 5-6)
  - In the new versions, the date of the peak inflation effect roughtly coincides with the date when the response of the output gap returns to zero; in July FRB/US, especially under MC expectations, the peak date significantly precedes the return of the gap to zero.
  - Except for the funds rate shock, the magnitude of the peak inflation effect under MC expectations is generally similar to the magnitude under VAR expectations,

for all model versions. The peak inflation effect of the funds rate shock is always smaller under MC expectations than under VAR expectations, perhaps because the policy rule used in the simulations results in a perturbation of the funds rate that is less persistent than would be expected by the funds rate equation in the VAR expectations system.

- The shift of the main price variable from overall to core PCE inflation removes the large and improbable negative response of core inflation to a positive oil price shock under MC expectations (figure 6, row 2). Under VAR expectations in contrast, it removes a significant positive response of core inflation (figure 4, row 2).
- The tendency for price inflation to rise in July FRB/US in response to a positive shock to MFP growth is replaced by a more reasonable tendency for inflation to fall for a period of time in both new versions (figures 4 and 6, row 3)
- A permanent increase in the level of MPF reduces price inflation for a while under both VAR (figure 4, row 4) and MC expectations (figure 6, row 4) in both new versions. This is true in July FRB/US only under MC expectations.
- The magnitudes of the short-run responses of price inflation to expected future shocks (in the tenth simulation quarter) to the funds rate and government purchases are smaller in both new versions than in July FRB/US (figure 7). In qualitative terms, these changes mirror those found for current shocks. It remains the case that the near-term effects on inflation are larger for anticipated future shocks than for current shocks (figure 5 versus figure 7).

Figure 3


FRB/US Ping Simulations: VAR Expectations -- I
Response of Output Gap
to Funds Rate
Response of 4-qtr Core Inflation
to Funds Rate
Response of Funds Rate
to Funds Rate
Response of Output Gap
to Federal Purch
Response of 4-qtr Core Inflation
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Response of 4-qtr Core Inflation
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Response of Treasury Term Prem
to Treasury Term Prem
2014
2016
2018
2020
2022
ML 85-07: black-thick
Bayesian 85-12: red-thick
FRB/US July: green-thin

Figure 4

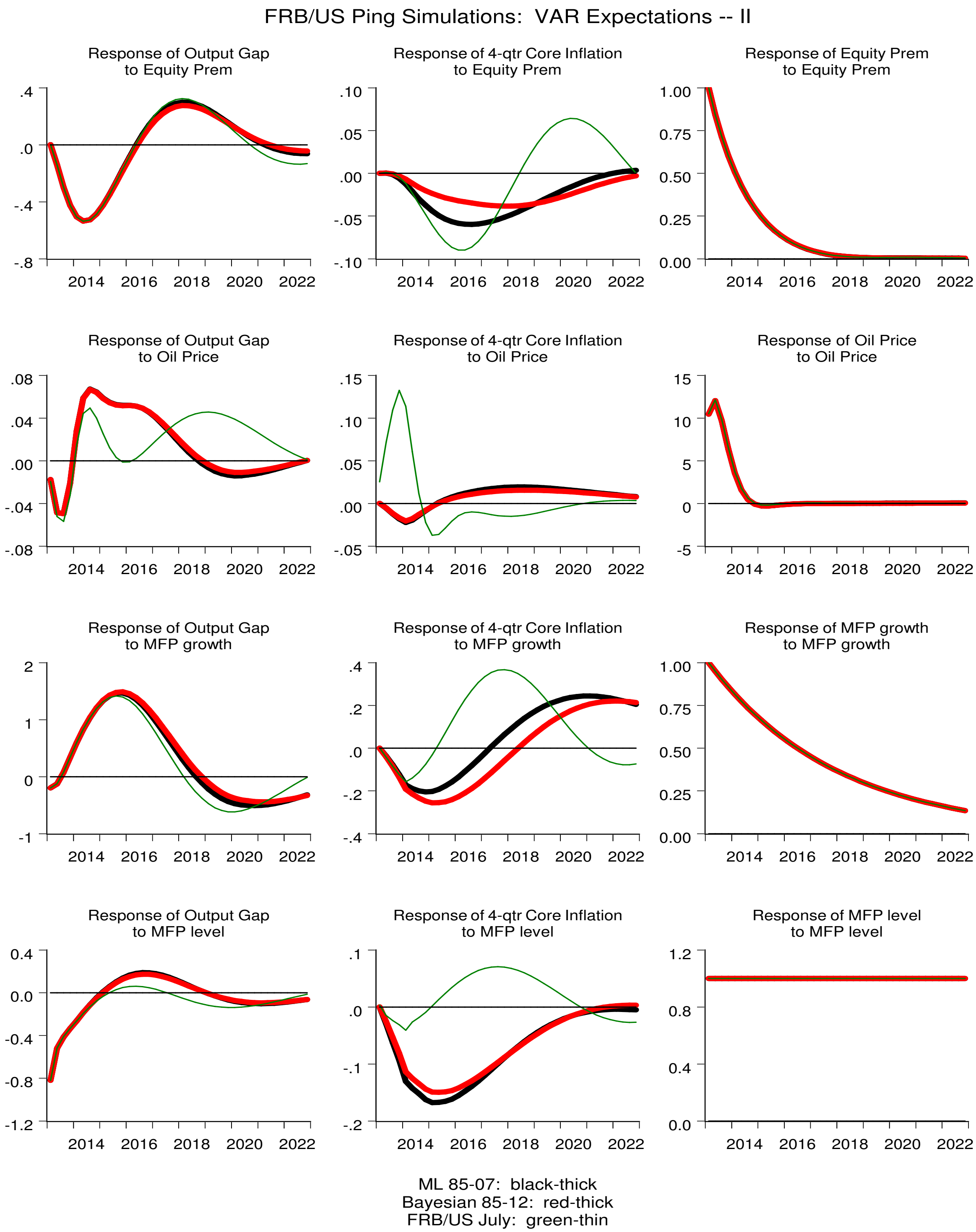

FRB/US Ping Simulations: VAR Expectations -- II
Response of Output Gap to Equity Prem
Response of 4-qtr Core Inflation to Equity Prem
Response of Equity Prem to Equity Prem
Response of Output Gap to Oil Price
Response of 4-qtr Core Inflation to Oil Price
Response of Oil Price to Oil Price
Response of Output Gap to MFP growth
Response of 4-qtr Core Inflation to MFP growth
Response of MFP growth to MFP growth
Response of Output Gap to MFP level
Response of 4-qtr Core Inflation to MFP level
Response of MFP level to MFP level
2014 2016 2018 2020 2022
ML 85-07: black-thick
Bayesian 85-12: red-thick
FRB/US July: green-thin

Figure 5

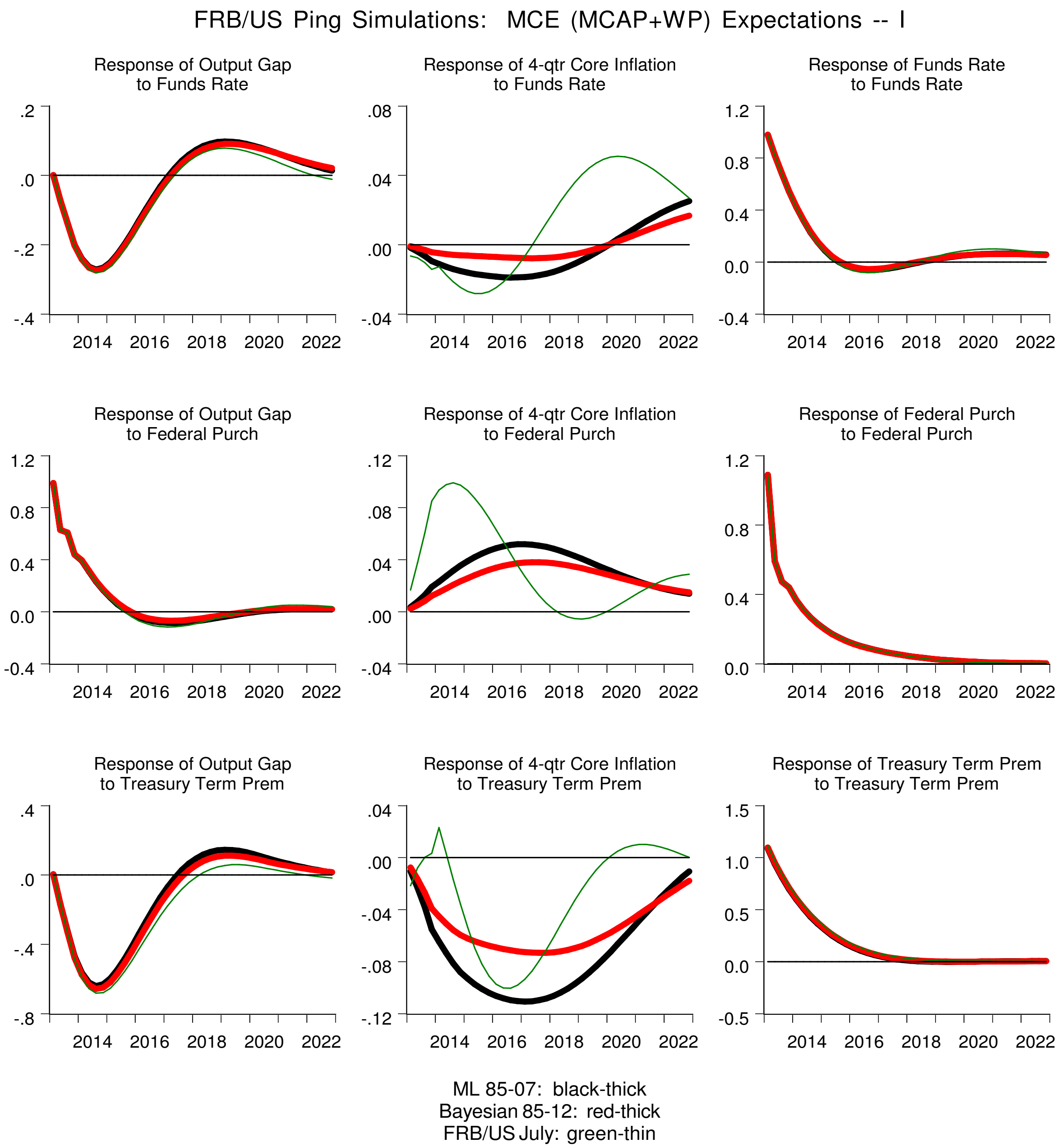
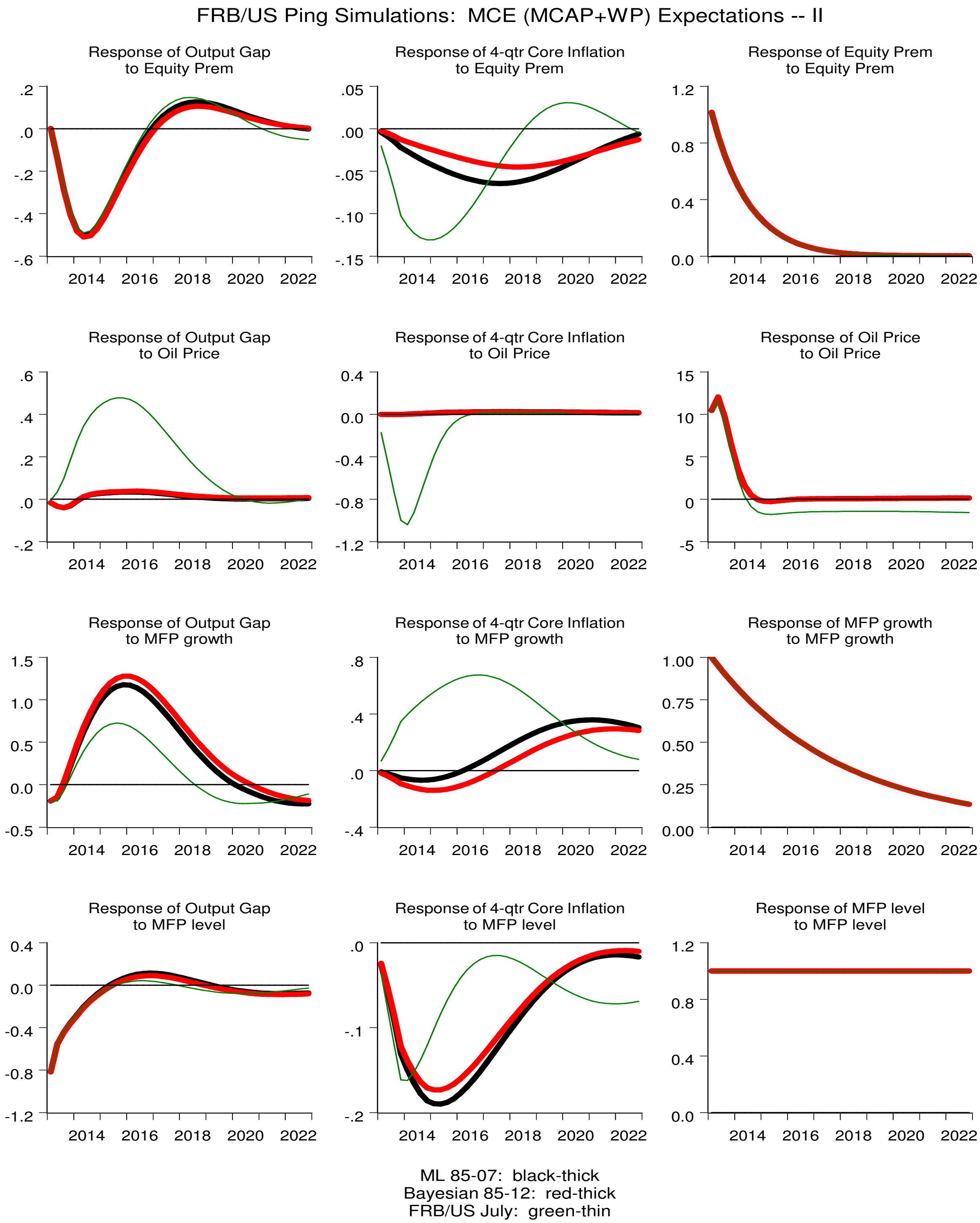
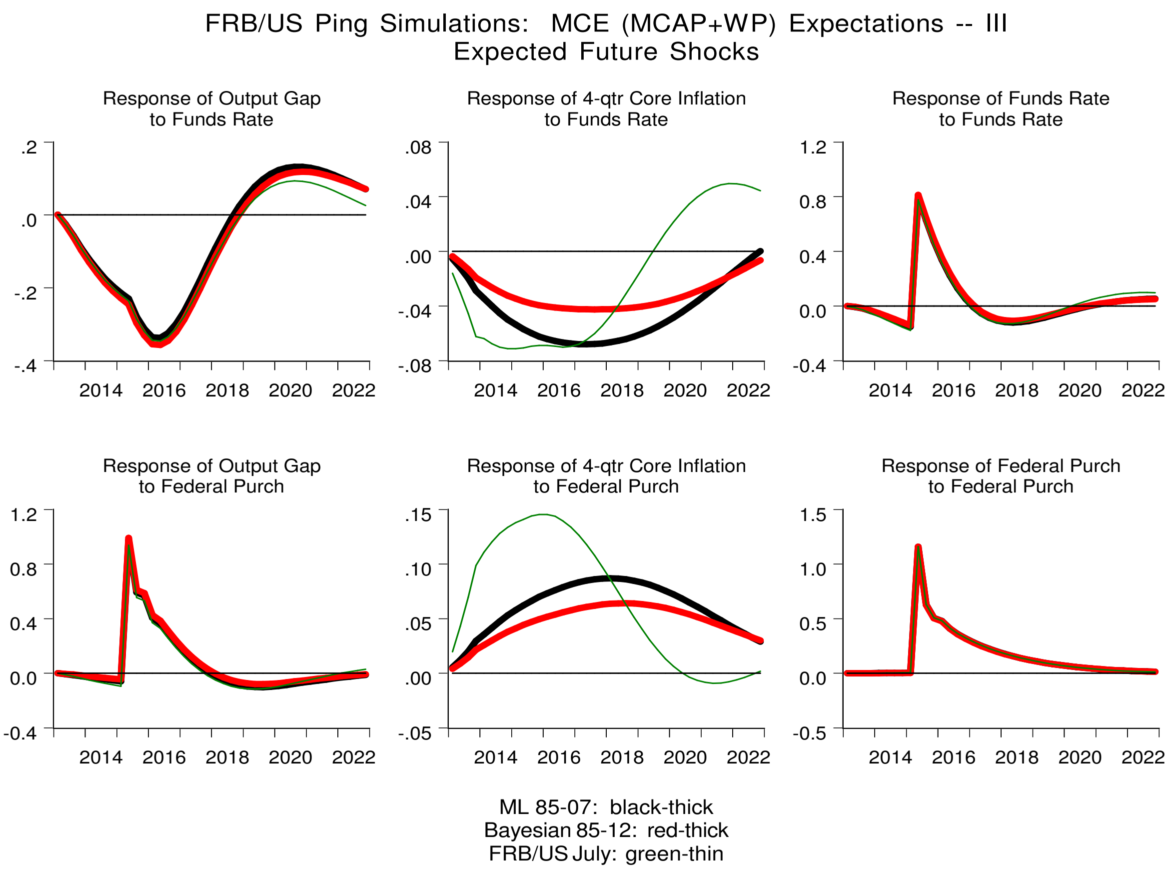

FRB/US Ping Simulations: MCE (MCAP+WP) Expectations -- I
Response of Output Gap to Funds Rate
Response of 4-qtr Core Inflation to Funds Rate
Response of Funds Rate to Funds Rate
Response of Output Gap to Federal Purch
Response of 4-qtr Core Inflation to Federal Purch
Response of Federal Purch to Federal Purch
Response of Output Gap to Treasury Term Prem
Response of 4-qtr Core Inflation to Treasury Term Prem
Response of Treasury Term Prem to Treasury Term Prem
2014 2016 2018 2020 2022
ML 85-07: black-thick
Bayesian 85-12: red-thick
FRB/US July: green-thin

Figure 6



FRB/US Ping Simulations: MCE (MCAP+WP) Expectations -- II
Response of Output Gap to Equity Prem
Response of 4-qtr Core Inflation to Equity Prem
Response of Equity Prem to Equity Prem
Response of Output Gap to Oil Price
Response of 4-qtr Core Inflation to Oil Price
Response of Oil Price to Oil Price
Response of Output Gap to MFP growth
Response of 4-qtr Core Inflation to MFP growth
Response of MFP growth to MFP growth
Response of Output Gap to MFP level
Response of 4-qtr Core Inflation to MFP level
Response of MFP level to MFP level
2014 2016 2018 2020 2022
ML 85-07: black-thick
Bayesian 85-12: red-thick
FRB/US July: green-thin

Figure 7


FRB/US Ping Simulations: MCE (MCAP+WP) Expectations -- III
Expected Future Shocks
Response of Output Gap
to Funds Rate
Response of 4-qtr Core Inflation
to Funds Rate
Response of Funds Rate
to Funds Rate
Response of Output Gap
to Federal Purch
Response of 4-qtr Core Inflation
to Federal Purch
Response of Federal Purch
to Federal Purch
2014 2016 2018 2020 2022
ML 85-07: black-thick
Bayesian 85-12: red-thick
FRB/US July: green-thin

Data appendix

Table 2
Variable Symbols, FRB/US Mnemonics, and Definitions

π^p	picxfe	core PCE inflation, annual rate
π^w	pieci	grow rate of ECI hourly compensation, annual rate
μ^p	log(qpcnia/pcnia)	consumption price gap
g	hlprdt - 400*huqpct	trend of $\pi^p - \pi^w$
s	log(qpl/pl)	detrended NFB labor share
U	lur-lurnat	unemployment gap
$\tilde{x}$	xgap2	output gap
r	rffe	federal funds rate
$\bar{\pi}^p$	ptr	long-run inflation expectation
$\bar{r}$	rtr	long-run interest rate expectation

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