Monetary/Fiscal Policy Mix and Asset Prices

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Abstract

This paper estimates monetary and fiscal policy rules using a New Keynesian model that allows for changes in the monetary/fiscal policy mix, generates a sizeable bond risk premia, and takes into account the effects of the zero lower bound.

Keywords: Fiscal theory of the price level, Government debt, Inflation, Bond risk premia, Markov-switching DSGE, Nonlinear solution methods, Estimation.

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1 Introduction

Understanding the effects of the fiscal and monetary authorities' actions on the real economy is of primordial importance. Previous studies have shown that the intensity with which they intervene in the economy changes over time. For example, Clarida, Gali, and Gertler (2000) show that the reactions of the monetary authority to expected inflation are quite different between the pre-Volcker period and the Volcker-Greenspan period. Recent studies allow for more complex models; for example, Sims and Zha (2006) estimate a model where the monetary policy can stochastically change between different regimes, they find that a three-regime model fits the data best. Bikbov and Chernov (2013) extend the previous model to take into account the information contained in the term structure of interest rate. The recent literature has shown that it is important to consider the interaction between the monetary authority and the fiscal authority (e.g. Davig and Leeper (2007) and Bianchi and Ilut (2013)). We contribute to this literature by estimating a Markov-switching New Keynesian model with several key features. First, the fiscal and monetary authorities interact, the interaction conditions vary over time (i.e. different regimes). Second, the model takes into account the effects of the zero lower bound. Third, the model can quantitatively match the term structure of interest rates. Fourth, the model is solved using a global projection method, that helps to better identify the different regimes. Following Leeper (1991), the model has two different regimes: the monetary-led regime and the fiscally-led regime. In the monetary-led regime, the Taylor principle is satisfied and the monetary authority controls inflation while the fiscal authority is committed to stabilizing the value of debt by adjusting primary surpluses. In the fiscally-led regime, the fiscal authority determines the price level through the government budget constraint while the monetary authority passively stabilizes debt and anchors expected inflation.

2 Model

This section presents the model.

2.1 Households

The representative household is assumed to have Epstein-Zin preferences over streams of consumption C_t and labor L_t:

$$\begin{aligned} U_t &= \left\{ (1-\beta_t)\left(C_t^\star\right)^{1-1/\psi} + \beta_t \left(E_t\left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{\theta}} \right\}^{\frac{\theta}{1-\gamma}} \\ C_t^\star &= C_t \left(\frac{\bar{L}}{L_t} \right)^{\tau} \end{aligned}$$

where γ is the coefficient of risk aversion, ψ is the elasticity of intertemporal substitution, $\theta \equiv \frac{1-\gamma}{1-1/\psi}$ is a parameter defined for convenience, $\bar{L}$ is the agent's time endowment, and β_t is the time-varying subjective discount factor. The discount factor of the agent is assumed to follow:

$$\ln(\beta_t) = (1-\rho_\beta)\ln(\beta^\star) + \rho_\beta \ln(\beta_{t-1}) + \sigma_\beta \epsilon_{\beta t},$$

where $\beta^\star$ is the unconditional mean of β_t, and $\epsilon_{\beta t}$ is a standard normal shock. The time t budget constraint of the household is

$$\mathcal{P}_t C_t + \mathcal{B}_{t+1} = \mathcal{P}_t D_t + \mathcal{W}_t L_t + \mathcal{R}_t \mathcal{B}_t - \mathcal{T}_t,$$

where $\mathcal{P}_t$ is the aggregate price level, $\mathcal{B}_t$ is the nominal market value of a portfolio of government bonds, D_t represents real dividends received from the intermediate firms, $\mathcal{R}_t$ is the gross nominal interest rate on the bond portfolio, $\mathcal{W}_t$ is the nominal competitive wage, and $\mathcal{T}_t$ are lump sum taxes from the government. The household chooses sequences of C_t, L_t, and B_t to maximize lifetime utility subject to the budget constraints.

The household's intertemporal condition is

$$E_t \left[\frac{M_{t+1}}{\Pi_{t+1}} \mathcal{R}_{t+1} \right] = 1$$

where Π_{t+1} is the inflation rate between t and $t+1$, and

$$M_{t+1} = \beta \left(\frac{C^\star_{t+1}}{C^\star_t} \right)^{1-\frac{1}{\psi}} \left(\frac{C_{t+1}}{C_t} \right)^{-1} \left(\frac{U_{t+1}^{1-\gamma}}{E_t \left[U_{t+1}^{1-\gamma} \right]} \right)^{1-\frac{1}{\theta}}$$

is the real stochastic discount factor. The intratemporal labor condition is,

$$\frac{\mathcal{W}_t}{\mathcal{P}_t} = \frac{\tau C_t}{L_t}.$$

2.2 Firms

Production in our economy is comprised of two sectors: the final goods sector and the intermediate goods sector.

Final Goods A representative firm produces the final consumption goods Y_t in a perfectly competitive market. The firm uses a continuum of differentiated intermediate goods X_{it} as input in a constant elasticity of substitution (CES) production technology:

$$Y_t = \left(\int_0^1 (X_{i,t})^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}}$$

where ν is the elasticity of substitution between intermediate goods. The profit maximization problem of the final goods firm yields the following isoelastic demand schedule[1] with price elasticity ν:

$$X_{i,t} = Y_t \left(\frac{\mathcal{P}_{i,t}}{\mathcal{P}_t} \right)^{-\nu}$$

where $\mathcal{P}_t$ is the nominal price of the final goods and $\mathcal{P}_{i,t}$ is the nominal price of the intermediate goods i. The inverse demand schedule is

[1] See the appendix for derivations.

$$\mathcal{P}_{i,t} = \mathcal{P}_t Y_t^{\frac{1}{\nu}} X_{i,t}^{\frac{-1}{\nu}}$$

Intermediate Goods The intermediate goods sector is characterized by a continuum of monopolistic firms. Each intermediate goods firm produces $X_{i,t}$ using labor $L_{i,t}$:

$$X_{i,t} = Z_t L_{i,t} - \Phi Z_t,$$

where Z_t represents an aggregate productivity shock common across firms, and is composed of both transitory and permanent components (e.g., Croce (2014) and Kung and Schmid (2014)):

$$\begin{aligned}
\ln(Z_t) &= z^\star + a_t + n_t \\
a_t &= \rho_a a_{t-1} + \sigma_a \epsilon_{at} \\
\Delta n_t &= \rho_n \Delta n_t + \sigma_n \epsilon_{nt}
\end{aligned}$$

where $z^\star$ is the unconditional mean of $\log(Z_t)$, $\Delta n_t = n_t - n_{t-1}$, ϵ_{at} and ϵ_{nt} are standard normal shocks with a contemporaneous correlation equal to ρ_{an}. The low-frequency component in productivity, Δn_t, is used to generate long-run risks and sizeable risk premia (i.e., Bansal and Yaron (2004)). The fixed cost of production Φ is multiplied by Z_t to ensure that it does not become trivially small along the balanced growth path.

Using the inverse demand function from the final goods sector, nominal revenues for intermediate firm i can be expressed as

$$\mathcal{P}_{i,t} X_{i,t} = \mathcal{P}_t Y_t^{\frac{1}{\nu}} \left[Z_t L_{i,t} - \Phi Z_t \right]^{1-\frac{1}{\nu}}$$

The intermediate firms face a cost of adjusting the nominal price à la Rotemberg (1982), measured in terms of the final good as

$$G(\mathcal{P}_{i,t}, \mathcal{P}_{i,t-1}; \mathcal{P}_t, Y_t) = \frac{\phi_R}{2} \left(\frac{\mathcal{P}_{i,t}}{\Pi_{ss} \mathcal{P}_{i,t-1}} - 1 \right)^2 Y_t$$

where $\Pi_{ss} \geqslant 1$ is the steady-state inflation rate and ϕ_R is the magnitude of the costs.

The source of funds constraint is

$$\mathcal{P}_t D_{i,t} = \mathcal{P}_{i,t} X_{i,t} - \mathcal{W}_t L_{i,t} - \mathcal{P}_t G(\mathcal{P}_{i,t}, \mathcal{P}_{i,t-1}; \mathcal{P}_t, Y_t)$$

where $D_{i,t}$ is the real dividend paid by the firm. The objective of the firm is to maximize shareholder's value $V_t^{(i)} = V^{(i)}(\cdot)$ taking the pricing kernel M_t, the competitive nominal wage $\mathcal{W}_t$, and the vector of aggregate state variables $\Upsilon_t = (\mathcal{P}_t, Z_t, Y_t)$ as given:

$$V_t^{(i)}(\mathcal{P}_{i,t-1}; \Upsilon_t) = \max_{P_{i,t}, L_{i,t}} \left\{ D_{i,t} + E_t \left[M_{t+1} \, V^{(i)}(\mathcal{P}_{i,t}; \Upsilon_{t+1}) \right] \right\}$$

subject to:

$$\begin{aligned} D_{i,t} &= \frac{\mathcal{P}_{i,t}}{\mathcal{P}_t} X_{i,t} - \mathcal{W}_t L_t - G(\mathcal{P}_{i,t}, \mathcal{P}_{i,t-1}; \mathcal{P}_t, Y_t) \\ \frac{\mathcal{P}_{i,t}}{\mathcal{P}_t} &= \left(\frac{X_{i,t}}{Y_t} \right)^{-\frac{1}{\nu}} \end{aligned}$$

The corresponding first order conditions are derived in the appendix.

Government The flow budget constraint of the government is given by:

$$\mathcal{B}_{t+1} = \mathcal{R}_t^g \mathcal{B}_t - \mathcal{S}_t$$

where $\mathcal{B}_{t+1}$ is the total nominal public debt issued at the end of period t, $\mathcal{R}_t^g$ is the nominal interest paid on debt, $\mathcal{S}_t$ denotes the nominal value of primary surpluses. Following Bianchi and Melosi (2013), we assume that the government only levies lump-sum taxes and government expenditures are excluded. Thus, the primary surplus equals lump-sum taxes. Scaling the budget constraint by nominal output $\mathcal{P}_t Y_t$,

$$b_{t+1} = \frac{\mathcal{R}_t^g}{\Pi_t \Delta Y_t} b_t - s_t \tag{1}$$

where $b_{t+1} \equiv \mathcal{B}_{t+1}/(\mathcal{P}_t Y_t)$, $s_t \equiv \mathcal{S}_t/(\mathcal{P}_t Y_t)$. The government issues nominal debt of maturity 1.

Monetary and Fiscal Rules The central bank follows an interest rate feedback rule that takes into account the zero lower bound (ZLB):

$$\ln\left(\frac{\mathcal{R}_t^{(1)}}{\mathcal{R}^{(1)}}\right) = \max\left\{0, \rho_r \ln\left(\frac{\mathcal{R}_{t-1}^{(1)}}{\mathcal{R}^{(1)}}\right) + (1-\rho_r)\left(\rho_{\pi,\varrho_t}\ln\left(\frac{\Pi_t}{\Pi}\right) + \rho_y \ln\left(\frac{\widehat{Y}_t}{\widehat{Y}}\right)\right) + \sigma_r \epsilon_{rt}\right\}. \qquad (2)$$

where $\mathcal{R}_{t+1}^{(1)}$ is the gross one-period nominal interest rate, Π_t is inflation, $\widehat{Y}_t$ is detrended output, and ϵ_{rt} is a normal i.i.d. shock. Note that the coefficient ρ_{π,ϱ_t} is indexed by ϱ_t, which determines the policy mix at time t.

The fiscal authority adjusts primary surpluses according to the following rule:

$$s_t - s = \rho_s(s_{t-1} - s) + (1-\rho_s)\,\delta_{b,\varrho_t}(b_t - b) + \sigma_s \epsilon_{s_t}.$$

The coefficient δ_{b,ϱ_t} is also indexed ϱ_t and is therefore depends on the policy mix at time t.

Monetary/Fiscal Policy Mix Leeper (1991) distinguishes four policy regions in a model with fixed policy parameters. Two of the parameter regions admit a unique bounded solution for inflation. One of the determinacy regions is the Active Monetary/Passive Fiscal (AM/PF) regime, which is the familiar textbook case (e.g., Woodford (2003) and Galí (2008)). The Taylor principle is satisfied ($\rho_\pi > 1$) and the fiscal authority adjusts taxes to stabilize debt ($\delta_b > \left(\beta \Delta Y^{1-\frac{1}{\psi}}\right)^{-1} - 1$). In this policy mix, monetary policy determines inflation while fiscal policy passively provides the fiscal-backing to accommodate the inflation targeting objectives of the monetary authority.

The other determinacy region is the Passive Monetary/Active Fiscal (PM/AF) regime. The fiscal authority is not committed to stabilizing debt ($\delta_b < \left(\beta \Delta Y^{1-\frac{1}{\psi}}\right)^{-1} - 1$), but instead the monetary authority passively accommodates fiscal policy ($\rho_\pi < 1$) by allowing the price level to adjust (to satisfy the government budget constraint). In this setting, fiscal policy determines inflation while monetary policy stabilizes debt and anchors expected inflation. Importantly, in this regime, fiscal disturbances, including non-distortionary taxation, have a direct impact on the price level via the government budget constraint because households know that changes in taxes will not be offset by future tax changes.[2]

When both the fiscal and monetary authorities are active (AM/AF), no stationary equilibrium exists. When both authorities are passive, there exist multiple equilibria. Thus, in our regime-switching specification, we follow Bianchi and Melosi (2013) and assume that the policy mix alternates between AM/PF and PM/AF regimes according to a two-state Markov chain with the following transition matrix:

$$\mathcal{M} = \begin{pmatrix} p_{MM} & 1 - p_{FF} \\ 1 - p_{MM} & p_{FF} \end{pmatrix}$$

where $p_{ij} \equiv Pr(\varrho_{t+1} = i | \varrho_t = j)$ and M denotes the monetary-led (AM/PF) regime and F denotes the fiscally-led (PM/AF) regime.

[2]In this regime, the government budget constraint is an equilibrium condition (rather than a constraint that has to hold for any price path), which Cochrane (2005) refers to as the government debt valuation equation.

Appendix A. Numerical Procedure

The model is solved using a global approximation method. The global method follows Judd, Maliar, and Maliar (2012) and Judd, Maliar, Maliar, and Valero (2013). A subset of policy functions are approximated by piece-wise polynomials of the state variables, as in Aruoba and Schorfheide (2013). Let $\mathcal{L}$ be a policy function, the policy function is approximated as:

$$\widehat{\mathcal{L}} = \mathbb{1}_F p_F + \mathbb{1}_M p_M, \tag{A.1}$$

where $\mathbb{1}_j$ is an indicator function that takes value one in regime j and zero otherwise, and p_j is a polynomial. Equation A.1 shows that for each regime a different polynomial is used, p_F for the fiscally-led regime and p_M for the monetary-led regime. The use of piece-wise polynomials allows for a more flexible structure to fit the model. The state variables are:

$$\mathbb{S}_t = \left(r_{t-1}, a_{t-1}, s_{t-1}, b_{t-1}, Y_{t-1}, \Delta n_{t-1}, \beta_t, \epsilon_{at}, \epsilon_{nt}, \epsilon_{st}, \mathbb{1}_F\right),$$

where r_{t-1} is the nominal one-period risk-free rate, a_{t-1} is the transitory productivity shock, s_{t-1} is the governments' surplus, b_{t-1} is the total debt of the government, Y_{t-1} is the final consumption goods, Δn_{t-1} is the permanent productivity shock, β_t is the subjective discount rate, ϵ_{at} is the innovation to the transitory productivity shock, ϵ_{nt} is the innovation to the permanent productivity shock, and ϵ_{st} is the innovation to the government's surplus. The approximated policy functions are:

$$\mathbb{G} = \left(F_t, C_t, \mathrm{U}_t\right),$$

where

$$F_t = \left(\frac{\Pi_t}{\Pi_{ss}} - 1\right)\frac{\Pi_t}{\Pi_{ss}},$$

C_t is the household's consumption, and U_t is the household's utility.

The model is solved by finding the set of polynomial coefficients Θ that minimizes the mean squared residuals for the approximated decision rules over a fixed grid. For each point j on the grid the residuals are calculated as:

$$\begin{aligned}
\mathfrak{R}_1^j &= \phi_R F_t^j Y_t^j - E_t^j \left[M_{t+1} \; \phi_R F_{t+1} Y_{t+1} \right] - \Lambda_t, \\
\mathfrak{R}_2^j &= E_t^j \left[M_{t+1} R_{t+1}^W \right] - 1, \\
\mathfrak{R}_3^j &= U_t^j - \left\{ (1-\beta) \left(C_t^{j\star} \right)^{1-1/\psi} + \beta \left(E_t^j \left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{\theta}} \right\}^{\frac{1}{1-1/\psi}}.
\end{aligned}$$

$\mathfrak{R}_1^j$ is calculated using the first order condition (in equilibrium) of the firms in the intermediate goods sector, $\mathfrak{R}_2^j$ is calculated using the Euler equation for the return on the wealth portfolio. Finally, $\mathfrak{R}_3^j$ is computed using the value function equation.

The grid on the state variables space is calculated in 4 steps. First, the initial guess for the set of coefficients Θ is calculated solving a single-regime model for each of the regimes. Second, the model is simulated and the principal components of the state variables are calculated. Third, an auxiliary grid on the principal components space is calculated using the Smolyak algorithm. Finally, the grid on the state variables space is calculated by performing a linear transformation of the auxiliary grid calculated in the previous step.

The Smolyak algorithm is used for the auxiliary grid because it is a highly efficient method to calculate a sparse grid in a hypercube. The drawback of the Smolyak algorithm is that the points are not chosen to maximize the number of points on the region of the state space where the model's ergodic distribution is located. The Smolyak algorithm is improved by adapting it to the characteristics of the model using the principal components transformation.

Appendix B. Household Problem

The time-t Lagrangian writes

$$U_t = \left\{ (1-\beta) \left(C_t^\star \right)^{1-1/\psi} + \beta \left(E_t \left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{\theta}} \right\}^{\frac{1}{1-1/\psi}} + \lambda_t \left[D_t + \frac{\mathcal{W}_t}{\mathcal{P}_t} L_t + \mathcal{R}_t \frac{\mathcal{B}_t}{\mathcal{P}_t} + \mathcal{T}_t - C_t - \frac{\mathcal{B}_{t+1}}{\mathcal{P}_t} \right]$$

The first order conditions are

$$[C_t] : (1-\beta)\, U_t^{1/\psi} (C_t^\star)^{-1/\psi} \left(\frac{\bar{L}}{L_t}\right)^{\tau} = \lambda_t \tag{B.2}$$

$$[\mathcal{B}_{t+1}] : U_t^{1/\psi} \beta E_t \left[U_{t+1}^{1-\gamma}\right]^{\frac{1}{\theta}-1} E_t \left[U_{t+1}^{-\gamma} \lambda_{t+1} \frac{\mathcal{P}_t}{\mathcal{P}_{t+1}} \mathcal{R}_{t+1}\right] = \lambda_t \tag{B.3}$$

$$[L_t] : (1-\beta)\, \tau U_t^{1/\psi} (C_t^\star)^{-1/\psi} C_t \left(\frac{\bar{L}}{L_t}\right)^{\tau-1} \bar{L} = \lambda_t \frac{\mathcal{W}_t}{\mathcal{P}_t} \tag{B.4}$$

Dividing both sides of (B.3) by $\left(\lambda_t / U_t^{1/\psi}\right)$ and using (B.2) to replace λ_{t+1}, we get

$$\beta E_t \left[U_{t+1}^{1-\gamma}\right]^{\frac{1}{\theta}-1} E_t \left[\left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\psi}} U_{t+1}^{1/\psi-\gamma} \frac{\mathcal{R}_{t+1}}{\Pi_{t+1}}\right] = 1$$

or

$$E_t \left[\frac{M_{t+1}}{\Pi_{t+1}} \mathcal{R}_{t+1}\right] = 1$$

where

$$M_{t+1} = \beta \left(\frac{C_{t+1}^\star}{C_t^\star}\right)^{1-\frac{1}{\psi}} \left(\frac{C_{t+1}}{C_t}\right)^{-1} \left(\frac{U_{t+1}^{1-\gamma}}{E_t\left[U_{t+1}^{1-\gamma}\right]}\right)^{1-\frac{1}{\theta}}$$

The intratemporal decision is obtained by plugging (B.2) into (B.4).

Appendix C. Monopolistic firm problem

The maximization problem of the individual firm is

$$V_t^{(i)}\left(\mathcal{P}_{i,t-1}; \Upsilon_t\right) = \max_{P_{i,t}, L_{i,t}} \left\{D_{i,t} + E_t\left[M_{t+1}\, V^{(i)}\left(\mathcal{P}_{i,t}; \Upsilon_{t+1}\right)\right]\right\}$$

subject to:

$$D_{i,t} = \frac{\mathcal{P}_{i,t}}{\mathcal{P}_t} X_{i,t} - \frac{\mathcal{W}_t}{\mathcal{P}_t} L_{i,t} - G(\mathcal{P}_{i,t}, \mathcal{P}_{i,t-1}; \mathcal{P}_t, Y_t)$$

$$\frac{\mathcal{P}_{i,t}}{\mathcal{P}_t} = \left(\frac{X_{i,t}}{Y_t}\right)^{-\frac{1}{\nu}}$$

After plugging the definition of $D_{i,t}$, the Lagrangian of the problem is

$$\begin{aligned}\mathcal{L}_t &= Y_t^{\frac{1}{\nu}}\left[Z_t L_{i,t} - \Phi Z_t\right]^{1-\frac{1}{\nu}} - \frac{\mathcal{W}_t}{\mathcal{P}_t} L_{i,t} - \frac{\phi_R}{2}\left(\frac{\mathcal{P}_{i,t}}{\Pi_{ss}\mathcal{P}_{i,t-1}} - 1\right)^2 Y_t \\ &+ \Lambda_{i,t}\left(\frac{\mathcal{P}_{i,t}}{\mathcal{P}_t} - Y_t^{\frac{1}{\nu}}\left[Z_t L_{i,t} - \Phi Z_t\right]^{-\frac{1}{\nu}}\right) \\ &+ E_t\left[M_{t+1}\ V_{t+1}^{(i)}\left(\mathcal{P}_{i,t};\Upsilon_{t+1}\right)\right]\end{aligned}$$

The first order conditions are

$$\begin{aligned}\frac{\Lambda_{i,t}}{\mathcal{P}_t} &= \phi_R\left(\frac{\mathcal{P}_{i,t}}{\Pi_{ss}\mathcal{P}_{i,t-1}} - 1\right)\frac{Y_t}{\Pi_{ss}\mathcal{P}_{i,t-1}} - E_t\left[M_{t+1}\phi_R\left(\frac{\mathcal{P}_{i,t+1}}{\Pi_{ss}\mathcal{P}_{i,t}} - 1\right)\frac{Y_{t+1}\mathcal{P}_{i,t+1}}{\Pi_{ss}\mathcal{P}_{i,t}^2}\right] \\ \frac{\mathcal{W}_t}{\mathcal{P}_t} &= \left(1 - \frac{1}{\nu}\right) Y_t^{\frac{1}{\nu}} X_{i,t}^{-\frac{1}{\nu}} Z_t + \Lambda_{i,t}\left(\frac{1}{\nu}\right) Y_t^{\frac{1}{\nu}} X_{i,t}^{-\frac{1}{\nu}-1} Z_t\end{aligned}$$

This specification yields a symmetric equilibrium in which $\mathcal{P}_{i,t} = \mathcal{P}_t$, $X_{i,t} = X_t$, $L_{i,t} = L_t$, $D_{i,t} = D_t$, and $V_t^{(i)} = V_t$. The equilibrium condition for the economy are:

$$\begin{aligned}\frac{\mathcal{W}_t}{\mathcal{P}_t} &= \left(1 - \frac{1}{\nu}\right) Z_t + \Lambda_{i,t}\left(\frac{1}{\nu}\right)\frac{Z_t}{Y_t} \\ \Lambda_t &= \phi_R\left(\frac{\Pi_t}{\Pi_{ss}} - 1\right)\frac{\Pi_t Y_t}{\Pi_{ss}} - E_t\left[M_{t+1}\ \phi_R\left(\frac{\Pi_{t+1}}{\Pi_{ss}} - 1\right)\frac{Y_{t+1}\Pi_{t+1}}{\Pi_{ss}}\right]\end{aligned}$$

where Λ_t is the Lagrange multipliers on the inverse demand constraint.

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