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Expectations of Demand by Firms and Their Effect on Disequilibrium

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1. Introduction

Production decisions of firms are generally based on expectations of the quantities demanded from them. Since these expectations will not, in general, coincide with realized demands, firms will produce too much or too little and this will imply some production inefficiency and some disequilibria. In this paper we are essentially concerned with these misadjustments and with the measure of the effects of prediction errors.

In Section 2 we describe a microeconomic model in which each firm has a production function with complementary factors. This firms maintains a production level equal to expected demand. There is no spillover effect between firms and between periods, so that the exchanged quantity relative to each firm is the minimum of real and expected demands. This microeconomic model may be used as a basis for determining aggregate quantities, such as the aggregate demand, the aggregate exchanged quantity, the proportion of firms in a given regime and the global measure of inefficiency. This aggregation is performed along the same lines as in Malinvaud (1982), Muellbauer (1978), Lambert (1984), Gourieroux and Laroque (1985). The aggregate measures depend, in particular, on the expectation errors through the expectation bias and the variance of the expectations.

In Section 3 we first examine the special case of rational predictions of demand. The absence of expectation bias and the usual orthogonality

condition between the expectation and the expectation error allow a simple derivation of the various aggregate measures. It is then possible to analyze how these aggregates are modified when the price changes, when the heterogeneity of demand increases or when expectations are more precise.

In Section 4, the effect of expectation errors is studied more deeply by separating the effect of expectation bias from the effect of randomness of expectations. The computation of these effects is based on some interpretations of the elasticities in terms of some particular aggregates.

Finally, the introduction of a short-run dynamics on the price is discussed in Section 5.

2. The Model

We consider a continuum of firms indexed by ω. Each firm has a production function with K complementary factors, $k = 1, \dots, K$. This production function is characterized by technical coefficients $A_k(\omega)$, $k = 1, \dots, K$. A potential demand $D(\omega)$ is attached to each firm; this demand is partly unknown when production decisions are made. The firm ω expects a demand equal to $\hat{D}(\omega)$ and chooses the input levels adequately; these levels are

$$\hat{X}_k(\omega) = \hat{D}(\omega)/A_k(\omega), \qquad k = 1, \dots, K.$$

When the exchanges between suppliers and demanders take place, the resulting exchanged quantities at the microlevel will be

$$Q(\omega) = \min\left(D(\omega), \hat{D}(\omega)\right). \tag{1}$$

Among the firms some overpredict demand and are constrained by real demand while others underpredict demand and the corresponding demand cannot be entirely satisfied. Then the two regimes are defined by whichever of the two inequalities $\hat{D}(\omega) > D(\omega)$ or $\hat{D}(\omega) < D(\omega)$ is satisfied.

When the distributions of the technical coefficients $A_k(\omega)$, $k = 1, \dots, K$ and of the real and expected demands $D(\omega)$, $\hat{D}(\omega)$ are given, it is possible to compute the aggregate counterparts of all the previous quantities, simply by taking expectations. For example, the aggregate exchanged quantity is

$$\overline{Q} = E\{Q(\omega)\} = E\{\min\left(\hat{D}(\omega), D(\omega)\right)\}; \tag{2}$$

the proportions of firms in each regime are

$$\begin{aligned} \pi &= \Pr\{\hat{D}(\omega) > D(\omega)\} \\ 1 - \pi &= \Pr\{D(\omega) > \hat{D}(\omega)\}. \end{aligned} \tag{3}$$

For the purpose of tractability, we will assume a particular form for the distribution of $(A_k(\omega), D(\omega), \hat{D}(\omega))$. In order to be compatible with the positiveness of these variables, we assume that they are jointly lognormally distributed. Therefore, it will be interesting to employ the logarithm of the different variables which are normally distributed. The logarithm will be denoted by lower-case letters; thus, $d(\omega) = \log D(\omega)$, $\hat{d}(\omega) = \log \hat{D}(\omega)$, etc.

3. Rational Expectation of Demand

The introduction of rational expectations in disequilibrium models has been discussed by Maddala (1984) at the macrolevel. In our case, the problem is examined at the microlevel and the results will have different interpretations.

The first point concerns the variable of which the rational expectation (RE) is taken. Indeed, we have to choose between the RE hypothesis about demand D or log-demand d. By analogy with the "tendency" surveys of firms in which the questions pertain to the percentage modification of demand, we shall opt for the second alternative. Moreover, this is the alternative that leads to simpler derivations.

Since $d(\omega)$ and $\hat{d}(\omega)$ are normally distributed, the RE hypothesis is characterized by the conditions of unbiasedness and the orthogonality between $\hat{d}(\omega)$ and $d(\omega) - \hat{d}(\omega)$. If η^2 is the variance of demand $d(\omega)$, σ^2 the mean square error (MSE), $\sigma^2 = V[d(\omega) - \hat{d}(\omega)]$ and m the average demand (i.e., the aggregate demand), then the distribution is

$$\begin{bmatrix} d \\ \hat{d} \end{bmatrix} \sim N\left\{ \begin{bmatrix} m \\ m \end{bmatrix}, \begin{bmatrix} \eta^2 & \eta^2 - \sigma^2 \\ \eta^2 - \sigma^2 & \eta^2 - \sigma^2 \end{bmatrix} \right\}.$$

Proportion of Demand-constrained Firms

Under the RE hypothesis, the probability of overpredicting equals the probability of underpredicting. Hence, $\pi = 1 - \pi = 0.5$. This is easily verified, since

$$\pi = \Pr\{\hat{D}(\omega) > D(\omega)\} = \Pr\{\hat{d}(\omega) > d(\omega)\} = \Pr\{\epsilon(\omega) > 0\},$$

where $\epsilon(\omega)$ is the prediction error. Thus, $\pi = 0.5$, since $\epsilon(\omega)$ has a centered normal distribution.

Modification of The Price

Usually the price p of the output is introduced through aggregate demand, i.e., through the function m, but it does not appear in the second-order moments. Therefore, if u (respectively, $\hat{u}$) denotes the centered log-demand (respectively, log-expected demand), we have

$$\overline{Q} = E\{\min[e^{u(\omega)}, e^{\hat{u}(\omega)}]\} = e^{m(p)} E\{\min[e^{u(\omega)}, e^{\hat{u}(\omega)}]\}.$$

We deduce directly that the price elasticity of the exchanged quantity equals the price elasticity of demand:

$$\frac{\partial \log \overline{Q}}{\partial \log p} = \frac{\partial \log m(p)}{\partial \log p} = \frac{\partial \log \overline{D}}{\partial \log p} = \frac{\partial \log \overline{\hat{D}}}{\partial \log p}. \tag{4}$$

This equality is due to the unbiasedness assumption. On the average, a modification of the price has the same effect on D and $\hat{D}$, and also on the minimum of these quantities.

Calculation of the Exchanged Quantity

The exchanged quantity at the macro level is given by

$$\overline{Q} = e^{m(p)} E\{e^{\hat{u}(\omega)} \min[e^{u(\omega)-\hat{u}(\omega)}, 1]\} = e^{m(p)} E\{e^{\hat{u}(\omega)} \min[e^{\epsilon(\omega)}, 1]\}.$$

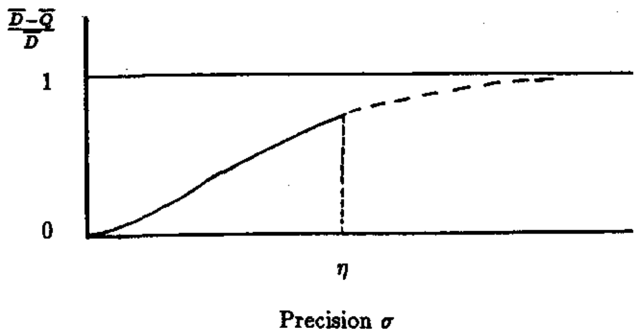
The error $\epsilon(\omega)$ and the prediction $\hat{u}(\omega)$ are uncorrelated or independent in our Gaussian case. Therefore, we obtain

$$\begin{aligned} \overline{Q} &= e^{m(p)} E\{e^{\hat{u}(\omega)}\} E\{\min[e^{\epsilon(\omega)}, 1]\} \\ &= e^{m(p)} e^{(\eta^2-\sigma^2)/2} \left[\Pr\{e^{\epsilon(\omega)} > 1\} + \int_{e^{\epsilon(\omega)}<1} \left(\frac{1}{\sigma\sqrt{2\pi}}\right) e^{\epsilon} e^{-\epsilon^2/2\sigma^2} \, d\epsilon \right] \\ &= e^{m(p)+\eta^2/2-\sigma^2/2} [0.5 + \Phi(-\sigma) e^{\sigma^2/2}] \end{aligned}$$

where Φ is the cdf of the standard normal distribution. Since $\overline{D} = e^{m(p)+\eta^2/2}$, we finally obtain the following expression:

$$\overline{Q} = \overline{D} e^{-\sigma^2/2} [0.5 + \Phi(-\sigma) e^{\sigma^2/2}]. \tag{5}$$

Figure 1: Excess Demand as a Function of σ



We note that the relative measure of excess demand is given by the ratio

$$\frac{\overline{D}-\overline{Q}}{\overline{D}} = -0.5e^{-\sigma^2/2} + \Phi(\sigma). \tag{6}$$

This excess demand depends only on the variance of the prediction error σ^2, but it is not linked to the price p or to the heterogeneity of demand η^2. In the limit case when $\sigma = 0$, no prediction error exists and this cause of disequilibrium disappears: we get $(\overline{D}-\overline{Q})/\overline{D} = 0$. When σ increases, the disequilibrium becomes increasingly important. The maximal disequilibrium is obtained when σ^2 equals the variance of the demand η^2.

4. Biased Predictions or Nonorthogonal Prediction Errors

As can be seen from the previous subsection, the rational expectations hypothesis is the conjunction of two hypotheses: those of unbiasedness and of orthogonality. We are alternately going to relax these conditions and examine how the previous results are modified.

Biased Predictions

The distribution of expected and real demands. We first consider the case of biased expectations, but with orthogonal prediction errors. The bias is denoted by B, so that the distribution of $(d, \hat{d})$ will be

$$\begin{bmatrix} d \\ \hat{d} \end{bmatrix} \sim N\left\{\begin{bmatrix} m \\ m+B \end{bmatrix}, \begin{bmatrix} \eta^2 & \eta^2-\sigma^2 \\ \eta^2-\sigma^2 & \eta^2-\sigma^2 \end{bmatrix}\right\}.$$

The proportion of demand constrained firms. This is given by

$$\Pr\{\hat{D} > D\} = \Pr\{\hat{d} > d\} = \Pr\{m + B + \hat{u} > m + u\},$$

where $\hat{u}$, u are the centered $\hat{d}$, d and, hence,

$$\pi = \Phi(B/\sigma). \tag{7}$$

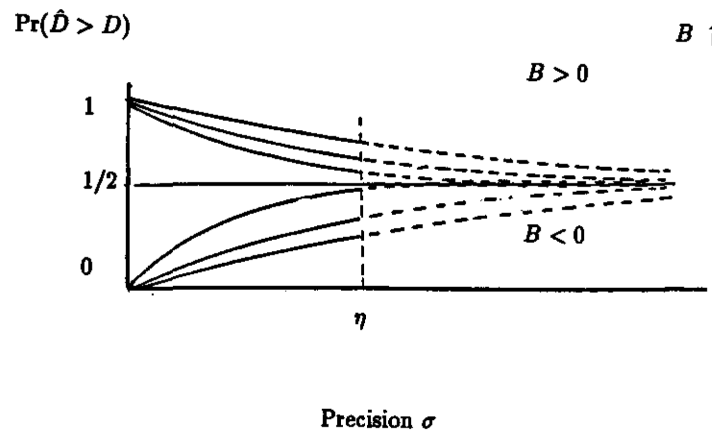
As expected, this proportion is smaller or larger than 1/2, according to the sign of the bias; it is smaller (larger) if there is overprediction (underprediction). This proportion is a nondecreasing function of the bias and is also a monotonic function of the prediction error (nonincreasing for positive bias). It tends to 1/2 when σ tends to infinity.

The exchanged quantity. This is given by

$$\begin{aligned} E\{\min(\hat{D}, D)\} &= E\{\min[e^{m+B\hat{u}}, e^{m+u}]\} \\ = E\{e^{m+\hat{u}}\min[e^B, e^\epsilon]\} &= E\{e^{m+\hat{u}}\}E\{\min[e^B, e^\epsilon]\}, \\ &= e^{m+\eta^2/2-\sigma^2/2}\left[e^B \Pr\{\epsilon > B\} + E\{e^\epsilon \Im_{e^\epsilon < e^B}\}\right] \end{aligned}$$

where $\Im_C$ is the indicator function, which has value 1 if condition C is true and value 0 if C is false. This aggregate quantity is the sum of two terms with simple interpretations. Indeed, the first term is

Figure 2: Proportion of Demand-constrained Firms as a Function of σ



$$e^{m+\eta^2/2-\sigma^2/2}e^B \Pr\{\epsilon > B\} = E\{\hat{D}\Im_{\hat{D}<D}\} = E\{Q\Im_{\hat{D}<D}\}$$
$$= \overline{Q}E\left\{\frac{Q}{E\{Q\}}\Im_{\hat{D}<D}\right\} = \overline{Q}(1-P),$$

where P is the proportion of markets constrained by demand, this proportion being computed with weight proportional to the size Q of the firm. The second term is obviously equal to $\overline{Q}P$.

The analytic forms of these terms are easily obtained. We have

$$e^B \Pr\{\epsilon > B\} = e^B\left(1-\Phi\left(\frac{B}{\sigma}\right)\right),$$

$$E\{e^\epsilon \Im_{e^\epsilon < e^B}\} = \left(\frac{1}{\sqrt{2\pi}}\right)\int_{-\infty}^{B/\sigma} e^{\sigma u}e^{-u^2/2}\,du = e^{\sigma^2/2}\Phi\left(\frac{B}{\sigma}-\sigma\right).$$

By replacing in the expression for $\overline{Q}$ we obtain

$$\overline{Q} = e^{m+\eta^2/2}\left[e^{B-\sigma^2/2}\left[1-\Phi\left(\frac{B}{\sigma}\right)\right]+\Phi\left(\frac{B}{\sigma}-\sigma\right)\right],$$
$$P = \frac{\Phi\left(\frac{B}{\sigma}-\sigma\right)}{e^{B-\sigma^2/2}\left[1-\Phi\left(\frac{B}{\sigma}\right)\right]+\Phi\left(\frac{B}{\sigma}-\sigma\right)}. \quad (8)$$

The price will generally appear through the mean m and the bias B. The elasticity of the exchanged quantity with respect to the price p has a simple form which extends (4) (see Gourieroux and Peaucelle, 1989):

$$\frac{\partial \log \overline{Q}}{\partial \log p} = \frac{\partial \log \overline{D}}{\partial \log p} + \frac{\partial B}{\partial \log p}(1-P) \quad (9).$$

It is equal to the elasticity of demand plus an additional term that takes into account the price effect on bias and the proportion $1-P$ of firms in excess demand. The introduction of the proportion of markets in a given regime, computed with appropriate weight, is linked with some results previously derived by Malinvaud (1982) for disequilibrium models with additive errors, and in Gourieroux, Laffont and Monfort (1984) for disequilibrium models with additive errors.

The value of the elasticity depends both on the derivative $\partial B/\partial \log p$ and on the bias B (through the proportion $1-P$). However, this latter effect is bounded and, in any case, we have

$$\frac{\partial \log \overline{D}}{\partial \log p} \leq \frac{\partial \log \hat{Q}}{\partial \log p} \leq \frac{\partial \log \overline{\hat{D}}}{\partial \log p}. \quad (10)$$

When the bias is large ($B = +\infty$), all the markets are demand constrained ($P = 1$) and the elasticity of the exchanged quantity coincides with the elasticity of demand. When the bias is large in absolute value and negative ($B = -\infty$), the markets are in excess demand ($P = 0$) and the elasticity of the exchanged quantity coincides with the elasticity of expected demand. In the general case it is a convex combination of these two elasticities:

$$\frac{\partial \overline{Q}}{\partial \log p} = P\frac{\partial \log \overline{D}}{\partial \log p} + (1-P)\frac{\partial \log \overline{\hat{D}}}{\partial \log p}.$$

The effect of the prediction error may be analyzed through the derivative $\partial \overline{D}/\partial \sigma$. This derivative is equal to

$$\frac{\partial \overline{Q}}{\partial \sigma} = \overline{D}\left[-\sigma e^{B-\sigma^2/2}\left[1-\Phi\left(\frac{B}{\sigma}\right)\right]-\phi\left(\frac{B}{\sigma}-\sigma\right)\right],$$

and is always negative. The exchanged quantity diminishes when the predictions are less precise.

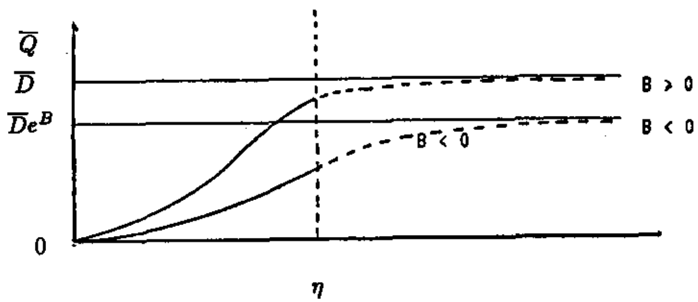
Finally, we may note that the asymptotic behavior of $\overline{Q}$ when σ is large depends heavily on the sign of the bias. Indeed, if the bias is nonnegative, we have $\lim_{\sigma\to\infty}\overline{Q}(\sigma) = \overline{D}$, but if the bias is negative, $\lim_{\sigma\to\infty}\overline{Q}(\sigma) = \overline{D}e^B$, and the disequilibrium remains asymptotically (see Figure 3).

Nonorthogonal Prediction Errors

The parametrization. Even if they are unbiased, predictions may not be optimal when the prediction error is correlated with the prediction, i.e., if $\mathrm{cov}(\hat{d}, d-\hat{d}) \neq 0$. In such a case the available information has not been fully taken into account and the prediction might be improved by considering the linear regression of demand d on the prediction $\hat{d}$. This improved prediction is given by

$$\tilde{\hat{d}} = m + \frac{\mathrm{cov}(d,\hat{d})}{V(\hat{d})}(\hat{d}-m).$$

Figure 3: The Exchanged Quantity
as a Function of σ



Precision σ

It is natural to introduce a parametrization of the variance-covariance matrix in which the correcting factor $\lambda = \text{cov}(d, \hat{d})/V(\hat{d})$ and the quality of the improved prediction, i.e., $\sigma^2 = V(d - \hat{d})$ appear simultaneously with the variance η^2 of demand. With this notation, the covariance matrix is given by

$$V\begin{bmatrix} d \\ \hat{d} \end{bmatrix} = \begin{bmatrix} \eta^2 & \dfrac{\eta^2-\sigma^2}{\lambda} \\ \dfrac{\eta^2-\sigma^2}{\lambda} & \dfrac{\eta^2-\sigma^2}{\lambda^2} \end{bmatrix},$$

assuming that the correcting coefficient λ is positive (this latter condition is generally satisfied in practice).

The no-correlation case occurs when no correction is necessary, i.e., when the correction factor equals one. A measure of the information not used optimally for predicting d is $|\lambda - 1|$.

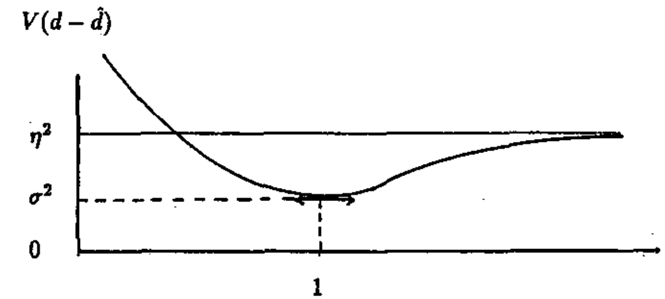
It will be useful to present this parametrization in another equivalent way. Indeed, if w denotes the centered, reduced, expected demand $w = \lambda(\hat{d} - m)/\sqrt{\eta^2 - \sigma^2}$, and v the reduced corrected prediction error, we obtain

$$\begin{aligned} \hat{d} - m &= w\frac{\sqrt{\eta^2-\sigma^2}}{\lambda}, \\ d - m &= w\sqrt{\eta^2-\sigma^2} + \sigma v, \end{aligned} \tag{11}$$

where

$$\begin{bmatrix} w \\ v \end{bmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}\right].$$

Figure 4: The Variance $V(d - \hat{d})$
as a Function of λ



Correction factor λ

The parameters have to satisfy the constraints $\eta^2 > \sigma^2$, $\lambda > 0$. Under model (11) the uncorrected prediction error is given by

$$V(d - \hat{d}) = V(d) + V(\hat{d}) - 2\text{cov}(d, \hat{d}) = \eta^2 + (\eta^2 - \sigma^2)\frac{1}{\lambda}\Big(\frac{1}{\lambda} - 2\Big).$$

The graph of this variance as a function of λ is given in Figure 4 and it attains its minimum value when orthogonality holds, i.e., when $\lambda = 1$.

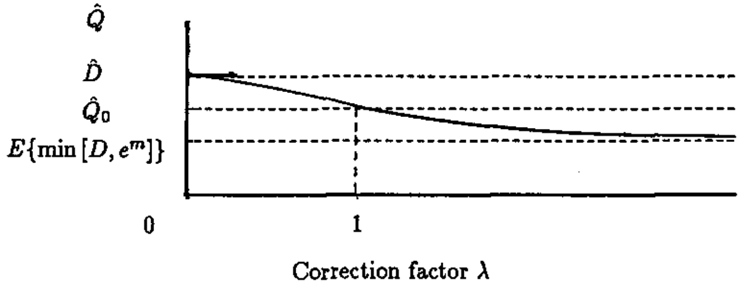
Expression for the exchanged quantity. Due to the correlation between the prediction and the prediction error, the exchanged quantity has an expression in terms of integrals. It can be proved that this expression is

$$\begin{aligned} \overline{Q} =& e^m E\left\{\exp\left[\frac{\sqrt{\eta^2-\sigma^2}}{\lambda}w\right]\left[1 - \Phi\Big(\frac{1}{\sigma}\Big(\frac{1}{\lambda} - 1\Big)(\sqrt{\eta^2-\sigma^2})w\Big)\right]\right\} \\ &+ e^m e^{\sigma^2/2} E\left\{\exp[(\sqrt{\eta^2-\sigma^2})w]\,\Phi\Big(\frac{1}{\sigma}\Big(\frac{1}{\lambda} - 1\Big)(\sqrt{\eta^2-\sigma^2})w - \sigma\Big)\right\}, \end{aligned} \tag{13}$$

where, as before, Φ is the cdf of the standard normal and w is a random variable with the standard normal distribution.

For the limit cases $\lambda = 0$ and $\lambda = +\infty$, it is easily seen that $\overline{Q} = \overline{D}$ and $\overline{Q} = E\{\min[D, e^m]\}$, respectively. In the case $\lambda = +\infty$, the variance of $\hat{d}$ is equal to zero or equivalently $\hat{d} = m$. This prediction coincides with the rational expectation in the absence of information. In particular, we know that the exchanged quantity associated with $\hat{d} = m$ is smaller than the ex-

Figure 5: The Exchanged Quantity as a Function of λ



changed quantity corresponding to $\lambda = 1$, since for $\lambda = 1$ the prediction is rational but does not coincide with $m = E\{d\}$. The evolution of the exchanged quantity as a function of λ is described in Figure 5 above.

Some additional results might be obtained concerning the elasticity of the exchanged quantity with respect to the correction factor λ (Gourieroux and Peaucelle, 1989). Some bounds for the elasticity are given by the following

Property 1. *$\partial \log \overline{Q} / \partial \log \lambda$ is less than or greater than $-(\eta^2 - \sigma^2)(1 - P)$, according to whether $\lambda > 1$ or $\lambda < 1$.*

5. Discussion of a Price-adjustment Equation

In the previous sections we have considered the case when the price is fixed in the short run and we have studied the disequilibria created by the expectations of demand by firms. However, in the medium term, the aggregate disequilibria are likely to have some effects on the evolution of the price. To analyze this effect, we introduce a price-adjustment equation, taking into account the multiplicative form of the model and the possibility of different speeds of adjustment, depending on the regime, i.e., whether excess demand or excess supply is the case. The price-adjustment equation is

$$\begin{aligned}\log p_t - \log p_{t-1} = {} & \lambda_1 E\{(d_{t-1} - \hat{d}_{t-1})\Im_{d_{t-1} - \hat{d}_{t-1} > 0}\} \\ & + \lambda_2 E\{(d_{t-1} - \hat{d}_{t-1})\Im_{d_{t-1} - \hat{d}_{t-1} < 0}\},\end{aligned} \tag{14}$$

where $\lambda_1, \lambda_2 > 0$.

Since the two regimes exist simultaneously, the two effects, namely an increase in price when $d_{t-1} > \hat{d}_{t-1}$ and a decrease in price in the reverse case, are both introduced in the equation and may balance each other. If we denote $E\{d_{t-1} - \hat{d}_{t-1}\}$ by $-B(p_{t-1})$, the opposite of the prediction bias, and $V(d_{t-1} - \hat{d}_{t-1})$ by $\mu^2(p_{t-1})$, the mean prediction error, we obtain

$$\begin{aligned}\log p_t - \log p_{t-1} = {} & \lambda_1 \Big[-B + B\Phi\Big(\frac{B}{\mu}\Big) + \mu\phi\Big(\frac{B}{\mu}\Big)\Big] \\ & + \lambda_2 \Big[-B\Phi\Big(\frac{B}{\mu}\Big) - \mu\phi\Big(\frac{B}{\mu}\Big)\Big], \\ \log p_t - \log p_{t-1} = {} & \mu[\lambda_1(-\gamma + \Psi(\gamma)) - \lambda_2\Psi(\gamma)],\end{aligned}$$

where $\gamma = B/\mu$ and $\Psi(\gamma) = \gamma\Phi(\gamma) + \phi(\gamma)$.

It is now interesting to study the asymptotic behavior of this difference equation, especially to see if it has a fixed point $\overline{p}$ and how this fixed point will depend on aggregate demand and aggregate expected demand.

It is easily seen that the function $\gamma \to \Psi(\gamma)/(-\gamma + \Psi(\gamma))$ is an increasing function which takes the values $0, 1, +\infty$ if γ equals $-\infty, 0, +\infty$ respectively. We deduce that there exists one and only one solution $\overline{\gamma}(\lambda_1/\lambda_2)$ to the equation

$$\frac{\Psi(\overline{\gamma})}{-\overline{\gamma} + \Psi(\overline{\gamma})} = \frac{\lambda_1}{\lambda_2}.$$

We deduce the following:

Property 2. *The price adjustment equation has a fixed point $\overline{p}$, if and only if the equation $B(\overline{p})/\mu(\overline{P}) = \overline{\gamma}(\lambda_1/\lambda_2)$ has a solution.*

This condition shows that an expectation scheme, i.e., knowledge of the two functions $B(p)$ and $\mu(p)$, is compatible with a stable price, if and only if the above equation has a solution. For example, unbiased expectations (in particular, rational expectations) satisfy this condition if and only if

$$\frac{B(p)}{\mu(p)} = 0 = \overline{\gamma}\Big(\frac{\lambda_1}{\lambda_2}\Big) \iff \lambda_1 = \lambda_2.$$

In the opposite case, unbiased expectations would lead to a continuous increase (decrease) of the price if $\lambda_1 > (<) \lambda_2$. Moreover, it is seen that when the fixed point exists, it is determined only through λ_1, λ_2 and the quality of the expectations. It depends on the real part of the model, i.e., of the parameters m, η only through the bias and the precision of the predictions.

6. Econometric Perspectives

The previous analysis was undertaken with the idea of specific econometric applications. Indeed, firms are surveyed in France for obtaining short-run information. In these tendency surveys the questions are qualitative and concern the evolution of demand, expected demand and also the constraints experienced by firms. Of course, it is natural to study these variables jointly and the model outlined above may be used as a basis for such a study.

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