



A Bargaining Model of Monetary Nonneutrality

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Édition électronique

URL : <http://journals.openedition.org/economiepublique/2529>

DOI : [10.4000/economiepublique.2529](https://doi.org/10.4000/economiepublique.2529)

ISSN : 1778-7440

Éditeur

IDEP - Institut d'économie publique

Édition imprimée

Date de publication : 21 avril 2007

ISBN : 39-84-87-J

ISSN : 1373-8496

Référence électronique

Robert Wilson, « A Bargaining Model of Monetary Nonneutrality », *Économie publique/Public economics* [En ligne], 17 | 2005/2, mis en ligne le 11 mai 2007, consulté le 12 septembre 2020. URL : <http://journals.openedition.org/economiepublique/2529> ; DOI : <https://doi.org/10.4000/economiepublique.2529>

public economics
économie publique

Revue de l'**Institut d'Économie Publique**

Deux numéros par an

n° 17 – 2005/2



~~économie~~publique sur internet : www.economie-publique.fr

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Imprimé en France.

La revue ~~économie~~publique bénéficie du soutien du Conseil régional Provence-Alpes-Côte d'Azur

ISSN 1373-8496

Dépôt légal avril 2006 – n° imprimeur 398487J

**“Strategic Interactions in Collective Organizations”
a Symposium in Memory of Louis-André Gérard-Varet**

« *Interactions stratégiques dans les organisations collectives* »
un symposium en mémoire de Louis-André Gérard-Varet

A Bargaining Model of Monetary Nonneutrality

Robert Wilson *

Summary

Models of bargaining in which prices are negotiated in nominal terms, and one party has superior information about real terms, have equilibrium outcomes insensitive to this information. These models illustrate that if negotiations are conducted in nominal terms then information transmission can be sticky in the sense used in macroeconomic theories of sticky prices.

Résumé

Des modèles de négociation dans lesquels les prix sont négociés en termes nominaux, mais où l'une des parties possède une information supérieure en termes réels, exhibent à l'équilibre des résultats qui restent insensibles à cette information. Ces modèles illustrent le fait que, si des négociations sont conduites en termes nominaux, alors la transmission de l'information peut être « rigide » dans le sens du mot utilisé dans la théorie macroéconomique des prix rigides.

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This work was supported in part by the National Science Foundation of the United States.

Keywords: Bargaining models, sticky prices, monetary nonneutrality.

Mots clés : Modèles de négociation, prix rigides, nonneutralité monétaire.

J.E.L. : C7, E3, E5

1. Introduction

Economic theorists have long found it difficult to address systematically the empirical fact that monetary policy has real effects. Because the unit of account or the medium of exchange has no real effect in Walrasian models of general equilibrium, macroeconomists rely on *ad hoc* explanations. Some explanations envision money illusions or non-rational expectations, others suppose that one or another friction or transaction cost is the source (menu costs, cash in advance constraints). Most successful are those explanations that assume agents cannot distinguish statistically between the effects of monetary and real shocks. An implication of the latter view is that information about monetary conditions diffuses slowly through the economy (Mankiw and Reis, 2001). To explain “sticky prices” imperfectly responsive to monetary shocks, Mankiw and Reis (2002) propose that the cause is “sticky information” about monetary policy. This hypothesis is vulnerable to the criticism that periodically each central bank publishes ample data about various categories of the money supply, such as M1 and M2. Nevertheless, in this paper we examine seriously the hypothesis that sticky information is a possible explanation.

Our aim is to establish the more fundamental premise that, if bilateral negotiations about transaction prices are conducted in nominal rather than real terms (as in Yıldız, 2001), and one party (say, the buyer) has some information about the nominal-to-real conversion ratio, then there is no presumption that the buyer’s information is conveyed to the seller during the bargaining – that is, information diffusion can stop at the buyer. We analyze various simple models of bargaining in nominal terms and show that their sequential equilibria entail “pooling”; that is, the resulting price is unaffected by the information known to the buyer. These models illustrate that negotiations in nominal terms are severely affected by asymmetric information about the purchasing power of money. The peculiar role of the nominal-to-real conversion ratio is an instance of the more general role of asymmetric information about the quality of a good traded in a “lemons” market afflicted with adverse selection (Akerlof, 1970; Vincent, 1989), but our

results differ in that asymmetric information affects the real terms of trade without diminishing the likelihood of trade. Thus the consequences are distributional.

We focus on monetary inflation to simplify. We adopt the view that the effect of monetary expansion, undertaken secretly by the central bank, is to make money available to a sequence of borrowers, who then use the money to make purchases. Each borrower who obtains a loan therefore obtains also a small sample of information about the subsequent general price level. In open market operations, for instance, the central bank buys government bonds from sellers who then deposit money in commercial banks. These banks loan money to developers of real projects, who use the money to buy labor or other resources from sellers, who in turn also deposit money in banks, and so on, until eventually the money returns to the central bank when it is deposited in a commercial bank's reserve account. In this process of circulation, each seller, bank, or borrower might interpret its receipt of money as a signal that perhaps the central bank is expanding the money supply. The concerns of lenders and borrowers, and of buyers and sellers, about this possibility are opposite: a borrower can later repay a load with inflated money, a seller is apprehensive that the purchasing power of the money received might decline.

Even when each borrower's iota of information is minuscule, if his information were invariably conveyed to sellers during price negotiations, then it could soon become widely known among all market participants that the central bank is expanding the money supply. That is, in every transaction the nominal price would reflect the totality of all information in the economy about the money supply, and thus about prospects for inflation. In this scenario, nominal prices would be flexible – not sticky – responding quickly to the aggregate of all information in the economy about the real purchasing power of money. This scenario has substantial support in the large literature on rational expectations models in which some or all of the private information initially dispersed among traders is revealed in the clearing prices of markets with multilateral trading.

But here we explore the alternative scenario in which transactions are concluded by many distinct pairs of buyers and sellers who negotiate bilaterally. We examine whether there is a similarly strong presumption in this context that a buyer's bit of information about the purchasing power of money is revealed, even partially, in the price resulting from negotiations with a seller. We find that the answer is no. The failure of information transmission in individual negotiations raises doubt that quick and reliable information aggregation could be a robust feature on the larger scale of a national economy. Indeed, the bargaining models studied here at the microeconomic level provide elementary building blocks for theories of sticky information and thus sticky prices at the macroeconomic level. These models do not clarify why prices are negotiated in nominal terms, but they do suggest that negotiations in nominal terms are peculiarly susceptible to stickiness. This supports

the general observation that an advantage of stability of the money supply, as in natural rate theories, is that it facilitates negotiations in nominal terms.

Section 2 establishes the ingredients of the formulation. Section 3 uses the methodology of efficient mechanism design to establish a general result. Sections 4, 5, and 6 obtain more detailed results by studying the equilibria of bargaining games having formal procedural rules. Section 7 concludes.

2. Formulation

To focus on the main issue, we study a single negotiation between a seller and a buyer. Neither party is risk averse and neither has any private information affecting his or the other's valuation of trade in real terms. Therefore, in real terms the gain from trade is normalized to be 1: the seller's cost is 0 and the buyer's valuation is 1. We make no particular assumption about how this gain from trade is obtained; e.g., it might result from sale of a single item, or of multiple items or multiple units of a commodity. As in many standard bargaining models, each party's impatience for a deal is represented by discounting the delayed gain from trade by a discount factor δ per period between offers, where $0 < \delta < 1$.

The parties negotiate in nominal terms, so if they agree on a nominal price p at time $t \in \{0, 1, \dots, T\}$ then the net payoffs to the seller and the buyer are $pr\delta^t$ and $[1 - pr]\delta^t$, respectively, or their payoffs are both zero if they never agree. A key feature of this specification is the parameter r that is the conversion factor from nominal amounts to real amounts; that is, r is the reciprocal of the general price level, or more generally, $r = E[1/P | \mathcal{H}]$ is the conditional expectation of the reciprocal of an index P of purchasing power based on their combined information symbolized by \mathcal{H} . The second key feature is our assumption that the buyer knows the realization of the conversion factor r but the seller knows only that the cumulative probability distribution function of r is F . We refer to r as the buyer's type. Assume that F has a positive density function f on an interval (a, b) , where $0 \leq a < b$.

To obtain clear-cut results we impose regularity assumptions on F . For y in the interval (x, b) define

$$H(x, y) = \int_x^y r dF(r) \quad \text{and} \quad G(x, y) = [1/y] \int_x^y r dF(r).$$

In Section 3 we assume that H is a strictly convex function of y . In Sections 4 and 5 we impose the alternative assumption that $G(x, y)$ is a strictly increasing function of y . Both these assumptions are satisfied if F is strictly convex, but convexity is much stronger than necessary; e.g., if $F(r) = r^\alpha$ then $\alpha > 0$ suffices. For purposes of studying inflation, convexity is relevant because typically one supposes that the

density f is increasing on the unit interval to convey that small inflation ($r \approx b = 1$) is more likely than large inflation ($r \approx a = 0$). For purposes of interpreting the seller's risk that payment is received in inflated money, it is often convenient to suppose that $b = 1$ is the upper bound of the nominal-to-real conversion rate r .

3. A General Result

Our first indication that little or no information transmission occurs is obtained as a corollary of the following general result derived via the method of mechanism design.

Proposition 3.1 – *If $H(x, y)$ is strictly convex in y then every trading mechanism that is efficient subject to incentive compatibility and individual rationality constraints requires either immediate trade ($t = 0$) or no trade ($t = \infty$).*

Proof. Assume that a trading mechanism produces trade at the price $p(r)$ at time $t(r)$ if the buyer's type is r . In the direct revelation game induced by this mechanism, if the buyer reports his type as s when his true type is r then his payoff is

$$\hat{U}(r, s) = \delta^{t(s)} - p(s)r\delta^{t(s)}.$$

Incentive compatibility requires that this payoff is maximized by reporting $s = r$. Define $U(r) = \hat{U}(r, r)$. Then the envelope theorem implies that $U'(r) = -p(r)\delta^{t(r)}$, and therefore

$$U(r) = U(b) + \int_r^b p(s)\delta^{t(s)} ds.$$

Assign welfare weights that are 1 for the seller and $w(r) \geq 0$ for the buyer of type r , and define

$$W(r) = \int_a^r w(s) dF(s) \quad \text{and} \quad h(r) = rf(r) + W(r).$$

Then the welfare function maximized by an efficient mechanism can be written as

$$\begin{aligned}
 \mathcal{W} &= \int_a^b p(r)r\delta^{t(r)} dF(r) + \int_a^b w(r)U(r) dF(r) \\
 &= \int_a^b p(r)r\delta^{t(r)} dF(r) + \int_a^b w(r)[U(b) + \int_r^b p(s)\delta^{t(s)} ds] dF(r) \\
 &= \int_a^b [rf(r) + W(r)]p(r)\delta^{t(r)} dr + W(b)U(b) \\
 &= - \int_a^b h(r)U'(r) dr + W(b)U(b) \\
 &= -bf(b)U(b) + h(a)U(a) + \int_a^b U(r) dh(r),
 \end{aligned}$$

where the last line uses integration by parts. An efficient mechanism maximizes \mathcal{W} subject to the constraint that each $U(r) \geq 0$ and $U'(r) \leq 0$. Because H is strictly convex, $rf(r)$ is strictly increasing, so h is also increasing. Therefore, the transversality condition yields $U(b) = 0$, and because $U' \leq 0$, trade occurs on an interval (a, r^*) where r^* is the least r for which the constraint $U(r) \geq 0$ is binding. If $t(r^*) > 0$ then both constraints at r^* are relaxed by reducing $t(r^*)$, so $t(r^*) = 0$. This being true, if any $p(r) < p(r^*)$ then type r^* prefers to report $s = r$, which violates incentive compatibility, so $p(r) = p(r^*)$ for all $r \leq r^*$. Then incentive compatibility for each type $r < r^*$ requires $t(r) \leq t(r^*)$. Therefore, \mathcal{W} is maximized by choosing $t(r) = 0$ and $p(r) = p^*$ for every type r in the interval (a, r^*) , where the price p^* exactly satisfies type r^* 's individual rationality constraint, $p^*r^* = 1$. Thus $U(r) = \max\{0, 1 - r/r^*\}$ for all $r \in (a, b)$, and then substituting this formula into the last line of the formula for \mathcal{W} enables optimization of r^* . ■

A corollary of Proposition 1 is that from the transaction price p^* the seller can infer only that the buyer's type r lies in the interval (a, r^*) of those types who trade immediately, or in the complementary interval (r^*, b) comprising those types who never trade. In subsequent sections we develop further implications in models of bargaining with explicit procedural rules.

4. A Specific Model of Bargaining

In this section we study the bargaining procedure in which the seller makes offers repeatedly until the buyer accepts or bargaining expires at a time T , in which case both parties obtain zero payoffs.

Proposition 4.1 – *If $G(x,y)$ is a strictly increasing function of y then the unique sequential equilibrium outcome is that the parties trade immediately at the*

nominal price $p = 1/b$ offered initially by the seller.

Proof. The proof is by induction on the number of offers allowed. The induction hypothesis is that, if the support of r is (x, y) where $a \leq x < y \leq b$, then the expected payoff to the seller is

$$[1/y] \int_x^y r d[F(r) - F(x)]/[F(y) - F(x)].$$

First we prove this hypothesis for the case $T = 0$ in which the seller makes a single offer. In this case, the buyer of type r accepts the offer p if and only if $1 - pr \geq 0$ or $r \leq 1/p$. Alternatively, interpreting the seller's decision variable as the highest value \hat{r} of r for which the buyer accepts (i.e., $p = 1/\hat{r}$), the seller's expected profit can be written as:

$$[1/\hat{r}] \int_x^{\hat{r}} r d[F(r) - F(x)]/[F(y) - F(x)] = G(x, \hat{r})/[F(y) - F(x)].$$

By assumption, this expected profit increases as \hat{r} increases up to the maximum y of the support of r . Thus when $T = 0$ the optimal offer is $p = 1/y$, which is surely accepted by the buyer, and the seller's expected payoff is as hypothesized. Next we prove the general case using the assumption that the induction hypothesis is true when one or more offers remain after the current offer. Again interpreting the seller's decision variable as \hat{r} , namely the highest value of r for which the buyer accepts the initial offer p , we can write the seller's expected profit using the induction hypothesis as

$$p \int_x^{\hat{r}} r dF(r) + \delta [1/y] \int_{\hat{r}}^y r dF(r),$$

all divided by $[F(y) - F(x)]$. In this case the critical value \hat{r} is determined by the indifference relation

$$1 - p\hat{r} = \delta [1 - [1/y]\hat{r}],$$

since the buyer of type \hat{r} expects the price $1/y$ to be offered next period if he refuses the offer p this period. Using this relation to substitute for p in the profit expression, we obtain the expected profit entirely in terms of the decision variable \hat{r} in the form

$$[1 - \delta][1/\hat{r}] \int_x^{\hat{r}} r dF(r) + \delta [1/y] \int_x^y r dF(r) = [1 - \delta]G(x, \hat{r}) + \delta G(x, y),$$

again divided entirely by $[F(y) - F(x)]$. Because G is increasing in its second argument, this shows that the optimal choice for the seller is again $\hat{r} = y$ and thus $p = 1/y$, which confirms the induction hypothesis that the seller's expected profit is $G(x, y)/[F(y) - F(x)]$ regardless of how many offers remain. Since the bargaining starts with $(x, y) = (a, b)$ this shows that the outcome is that the initial offer $p = 1/b$ is surely accepted by the buyer. ■

An analog of Proposition 2 is obtained from the alternative assumption that $G(x, y)$ is a strictly convex function of y . In this version, \hat{r} is one of the two extreme points of the interval (x, y) , so starting from (a, b) either there is no trade or the seller offers $p = 1/b$ as in Proposition 2. If $G(x, y)$ is both increasing and convex in y then $H(x, y)$ is convex, as assumed in Proposition 1.

Proposition 2 indicates that information transmission is sticky in two senses. First, the transaction time and price are independent of the discount factor δ and the distribution function F , provided only that it satisfies the stated assumption; thus, it is immaterial how impatient the parties are, and immaterial whether the buyer's information is very slight or very precise – all that matters is the upper bound b of the support of r . Second, from the negotiations the seller infers nothing about the buyer's type. Although the seller could screen the buyer's types with a series of successively lower prices, and thereby infer r with considerable precision, the seller ignores this opportunity and accepts the entire risk of receiving inflated money when $r < b$.

Is there any incentive for the buyer to reveal information voluntarily? Proposition 2 shows that the buyer's profit if he reveals no information is $1 - r/b$, whereas if he were to reveal the realization of r to the seller then the equilibrium would entail an initial offer $p = 1/r$ from the seller that he would accept, yielding a profit of zero. More generally, any revelation that would enable the seller to truncate the distribution of r from above (i.e., reduce b to $y < b$) is disadvantageous to the buyer. One can plausibly surmise that informative communication might occur in more elaborate formulations of the bargaining procedure, or in case the seller or the buyer has additional private information about the gains from trade in real terms. In the latter case, screening by the seller and/or signaling by the buyer might play important roles to determine the existence and magnitude of the real gains from trade, and in the process some of the confounding information of the buyer about the price level might be revealed. In the example above, however, the existence and magnitude of the gains from trade in real terms are common knowledge, so none of these features arise.

In this simple example there are no direct real effects from the possibility of inflation: trade occurs surely and immediately, as it would if there were no uncertainty about the price level. In the economy as a whole, however, the real effects can be substantial. The absence of information transmission from buyer to seller enables expansion of the money supply to stimulate more transactions overall by increasing the supply of loanable funds at commercial banks without inflating transaction prices.

5. Extension to Alternating Offers

Proposition 2 shows that if only the seller makes offers then her optimal strategy is always to offer the price $1/b$, which all buyer types accept immediately. If the parties alternate offers then there is a similar equilibrium in which, in the infinite-horizon case, the seller always offers the nominal price $p = 1/b[1 + \delta]$, the buyer always offers $q = \delta p$ regardless of his type, and each offer is accepted immediately by the other party. To see this, observe that given the seller's strategy, the buyer has no incentive to offer any price above δp , which the seller is willing to accept, and any lower price is obviously rejected by the seller. Given the buyer's strategy, a modification of the previous argument shows that the seller's strategy is optimal. She anticipates that an offer p is accepted if $r \leq \hat{r}$, where $1 - p\hat{r} = \delta[1 - q\hat{r}]$, and therefore her expected profit can be expressed as

$$p \int_a^{\hat{r}} r dF(r) + \delta q \int_{\hat{r}}^b r dF(r) = [1 - \delta]G(a, \hat{r}) + \delta q G(a, b).$$

Because G is increasing in its second argument, her optimal choice is $\hat{r} = b$. The two equations that determine p and q are therefore that (a) $1 - pb = \delta[1 - qb]$ so that the buyer of type b is indifferent about accepting p , and (b) $q = \delta p$ so that the seller is indifferent about accepting q ; together these imply that $p = 1/b[1 + \delta]$ as claimed above. Thus in the case of alternating offers there is an equilibrium in which none of the buyer's information is revealed by the outcome of bargaining.

If the number of offers is finite then a pooling equilibrium, analogous to the one described above for the infinite-horizon case, is the only sequential equilibrium that satisfies some selection criterion, such as in Grossman and Perry (1986). These criteria typically exclude sequential equilibria in which the seller rejects a pooling offer from the buyer that provides at least her profit in the continuation game. Suppose the seller makes the final offer in period T if negotiations last that long. As we have seen, in period T she offers $p = 1/y$ if the current support of r is (x, y) , and this price is surely accepted by the buyer. In period $T - 1$, therefore, the buyer's optimal offer is the pooling offer $q = \delta/y$, independently of his type, since any lesser price is rejected by the seller, and according to the selection criterion, this price is accepted by the seller. Anticipating this in period $T - 2$, the seller's optimal offer is $p = [1 - \delta + \delta^2]/y$, corresponding to $\hat{r} = y$; so again in period $T - 3$, the buyer's optimal offer $q = \delta p$ is pooling. Continuing in this fashion, we see that in every period a pooling offer is made and surely accepted. As the number of periods remaining increases, the two parties' offers converge to the ones shown above to be equilibrium offers in the infinite-horizon case. Thus, the only sequential equilibrium outcome is that they trade immediately, although the price depends on the number of offers remaining.

6. Generalization

In this section we sketch the analysis of a more general case in which we assume only that, for each x , $G(x, y)$ is a unimodal function of y . In this case, let $\eta(x)$ denote the unique value of y that maximizes $G(x, y)$. As in Section 4, assume that only the seller makes offers, and bargaining ends after time T .

A repetition of the argument in Section 4 shows that in period T , when the support of the buyer's type is (x, y) the seller's expected profit is $G(x, \hat{r})/[F(y) - F(x)]$ if she offers $p = 1/\hat{r}$. Hence the optimal offer is $1/\eta(x)$. At time $T - 1$, therefore, her expected profit when the support is (x, y) and she offers nominal price p is

$$p \int_x^{\hat{r}} r dF(r) + \delta[1/\eta(\hat{r})] \int_{\hat{r}}^{\eta(\hat{r})} r dF(r)$$

divided by $[F(y) - F(x)]$, where the critical rate \hat{r} satisfies

$$1 - p\hat{r} = \delta[1 - [1/\eta(\hat{r})]\hat{r}]$$

because type \hat{r} is the one indifferent between the offer p now and the offer $1/\eta(\hat{r})$ next period. Using this relation to eliminate p , the expected profit is

$$[1 - \delta]G(x, \hat{r}) + \delta G(x, \eta(\hat{r}))$$

divided by $[F(y) - F(x)]$. Recall now that $G(\hat{r}, \cdot)$ is maximized at $\eta(\hat{r})$.

7. Discussion

The gist of the example in Sections 4 and 5, given the key assumptions, is the demonstration that the seller has no incentive to use the negotiation process to extract information about the purchasing power of the money she receives in payment – she simply bears the risk that $r < b$. The net result is that information transmission from the buyer to the seller about the price level is excluded or muted. Our assumption in Section 4 that G is increasing in its second argument can be interpreted essentially as assuming that the seller has no incentive when making a final offer to run the risk that the offer is rejected. The proof of Proposition 2 then says that if she has no incentive to risk a final rejection then also she has no incentive to risk rejection earlier. The assumption that she is unwilling to risk rejection in the final period seems appropriate when considering situations in which the buyer's information about the price level does not allow much chance (for the seller) that expected inflation is severe. On the other hand, our results depend on the implicit assumption that the real gains from trade are sufficiently large to outweigh the risk of inflation. If the buyer's decision were about how

much (rather than whether) to purchase, then we might expect some information to be revealed via the buyer's decision about the quantity to purchase. Similarly, more information revelation might be possible if the seller deals with many buyers, and information obtained from one buyer is useful in dealing with others.

The intuitive motivations for these results are fairly evident. The seller is negotiating for payment in a currency about which she has inferior information. She therefore faces a severe problem of adverse selection: any price offer is more likely to be accepted by those buyer types who know that the currency has a low real value. On the other hand, she knows that there is gain from trade in real terms. Under the circumstances, her best strategy is to make an offer that surely realizes the real gains from trade and then to bear the risk that the currency is inflated. The substance of our key assumptions is to assure that this risk is less important than assuring early realization of the gain from trade.

Regarding theories of sticky prices, we take the example as indicative that there is no presumption that information about the money supply gets revealed in any single bilateral negotiation. This indicates that one cannot expect information dispersed among many bargaining relationships to be reflected in prices. Therefore, sticky information transmission could indeed be a source of the effectiveness of monetary expansion in stimulating real activity.

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