Macroeconomic Dynamics, **17**, 2013, 1355–1365. Printed in the United States of America.
doi:10.1017/S1365100512000284

INFLATION AND QUALITY DISPERSION

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One questionable aspect of price posting with directed search is the strong commitment by sellers to commit to the advertised terms of trade. In this paper I explore the welfare implications of assuming that sellers cannot commit and vary the quality of their output ex post according to realized demand. I show that such lack of commitment translates into lower participation by buyers, lower average quality, and a consumption-equivalent loss of 0.3% of annual GDP.

Keywords: Directed Search, Commitment, Quality, Welfare

1. INTRODUCTION

Price posting with directed search—also known as competitive search—is a pricing mechanism in which sellers advertise terms of trade; buyers observe those terms of trade and decide which seller to visit. Price posting with directed search has several attractive properties. First, it combines competition (sellers compete for buyers) with trading frictions (neither buyers nor sellers are sure to trade). Second, sellers internalize trading frictions, which increases efficiency relative to random matching [Moen (1997)]. Finally, it provides a realistic description of the way many markets work. As a result, it is widely used in the macro-labor literature [see Section 5 in Rogerson et al. (2005)] and in the macro-money literature [e.g., Rocheteau and Wright (2005)].

One questionable aspect of this pricing mechanism, however, is the strong commitment by sellers to stick to the advertised terms of trade. In particular, if two or more buyers show up, the good is randomly allocated to one of the buyers, who pays the advertised price. One may wonder why sellers do not try to take advantage of competition among buyers by either raising their prices (offering the good to the buyer who is ready to pay the most) or lowering the quality of the good for sale. Similarly, why do buyers not try to take advantage of their ex post bargaining power in case they are alone at one seller's?

I wish to thank an anonymous referee, Pedro Gomis-Porqueras, Benoît Julien, Ian King, Guillaume Rocheteau and John Tressler for very helpful discussions. I also thank the seminar participants at the Bank of Canada, the Cleveland Fed, the Canadian Economics Association Meeting, the Workshop on Macroeconomic Dynamics in Melbourne and the universities of Melbourne and Paris West. All errors are mine. Address correspondence to: Richard Dutu, Deakin Graduate School of Business, 221 Burwood Highway, 3125 Burwood, Victoria, Australia; e-mail: rdutu@deakin.edu.au.

 1365-1005/12

In this paper, I study the qualitative and welfare implications of relaxing the commitment assumption by allowing the real side of the transaction, i.e., the quality of the good or service delivered, to adjust to realized demand. For instance, if sellers face high demand because of a large number of buyers present, they are able to decrease the quality of their output, lowering their production costs. Although giving the impression that the terms of the contract are fulfilled, shifts in quality allow ex post market conditions to reflect into buyers' utility and sellers' production costs. Also, ex post variation in quality accords with the popular belief that one does not get a good deal in crowded places. I do not provide a rationale for why sellers are not able to commit, however. The approach is simply to acknowledge that quality does seem to vary with realized demand and to measure the associated welfare effect.[1]

To do that, I first build a price posting economy in which sellers allow the quality of the output to vary ex post with realized demand. The equilibrium and welfare properties of this economy are characterized. I then compare this economy with an economy in which sellers can commit to a certain quality level for their output. I show first that sellers are better off committing than not, and given free entry on the buyers' side, welfare is also higher with commitment. This positive effect plays via average quality and entry by buyers, both of which are greater when sellers can commit to quality. The model is one of directed search with monetary exchange, where the implied money demand is used, along with other statistics, to estimate the parameters of the model.

Second, I measure the welfare cost triggered by sellers' inability to commit. To do that, I ask agents how much consumption in the economy with commitment they would have to sacrifice to bring welfare on par with that of the economy without commitment. This compensated measure, in the spirit of Lucas (1987), is evaluated for the U.S. economy at the average interest rate, 4.76%, over the study period, which is 1900–2000. I find that sellers' ability to commit to quality is on average equal to 0.3% of consumption each year. That the welfare effect of quality commitment is positive may provide a normative justification for such commitment.

The rest of the paper is organized as follows. In Section 2 I present the environment and characterize the unique equilibrium. In Section 3 I contrast the equilibrium and welfare properties of the economy with commitment to that of the economy without commitment, and calculate the compensated measure. Section 4 concludes.

2. THE ENVIRONMENT

Time is discrete and goes on forever. Each period is divided into two trading subperiods. In the first subperiod, agents participate in a centralized Walrasian market where they can produce and consume any quantity of a single, homogenous consumption good, called the general good. Then they enter a second, frictional market where a second good, called the search good, is allocated via price posting

https://doi.org/10.1017/S1365100512000284 Published online by Cambridge University Press

with directed search. Each seller can produce only one unit of that good at a quality level q. I use β to denote the discount factor between the Walrasian market and the directed search market, also called the frictional market.

There is a continuum of anonymous, infinitely lived agents who, following Rocheteau and Wright (2005), differ in terms of when they produce and consume the two goods. In the first subperiod, i.e., in the centralized market, all agents can produce and consume the general good. In the second subperiod, i.e., during the frictional market, agents are divided into buyers who want to consume the search good but cannot produce it, and sellers who want to produce the search good but cannot consume it. This assumption generates a temporal double-coincidence problem. Combined with the assumption that the goods are perishable (no commodity money) and that agents are anonymous (no credit), this ensures that money is essential for trade.

The mass of sellers in this economy is fixed and denoted by s. The mass of buyers is $\bar{b}$ but only $b \leq \bar{b}$ buyers participate in the frictional market. This mass b is determined endogenously by a free entry condition with entry cost $k > 0$. I consider an economy in which the numbers of buyers and sellers are arbitrarily large, but the buyer–seller ratio $\theta = b/s$ (market tightness) is finite.

Money comes in the form of a perfectly divisible and storable object whose value relies on its use as a medium of exchange. It is available in quantity M_t at time t, and can be stored in any non-negative quantity m_t by any agent. New money is injected or withdrawn via lump-sum transfers by the central bank at a rate τ such that $M_{t+1} = (1 + \tau)M_t$. Only buyers receive the transfer. Inflation is forecast perfectly and both the quantity theory and the Fisher effect apply: if the money supply increases at rate τ, so do prices and the nominal interest rate. Denoting the real interest rate as r, because $\beta = 1/(1 + r)$, the nominal interest rate is simply $i = (1 - \beta + \tau)/\beta$.[2] The price of the good in the centralized market is normalized to 1 and the clearing price of money in terms of the good in this market is denoted ϕ_t. That is, 1 unit of the good costs $1/\phi_t$ units of money.

The instantaneous utility of a buyer at time t is given by $U_t^b = x_t + \beta u(q_t)$, where x_t is the net consumption of the general good in the Walrasian market, and q_t is the quality of the search good produced and consumed in the directed search market. When a buyer wins the good, he consumes it immediately and enjoys utility $u(q_t)$, with $u' > 0$ and $u'' < 0$. I let q^* be such that $u'(q^*) = c'(q^*)$ and assume that $u'(0) > c'(0) > 0$. Similarly, the instantaneous utility of a seller at time t is given by $U_t^s = x_t - \beta c(q_t)$, where $c(q_t)$ is the cost of producing one unit of the search good of quality q in the frictional market, with $c(q) = q$ for simplicity. Note that buyers are homogenous (they have the same utility function), as are sellers (they have the same production costs), and that u and c are common knowledge.

Terms of trade are determined as follows. Sellers post a price d for their unit of search good but do not commit on quality. Whenever two or more buyers approach a seller (multilateral meetings), because buyers have homogeneous preferences, the quality of the good produced falls until it leaves the winning buyer, chosen at random, indifferent between trading or not. I denote this quality as q_m. Alternatively, whenever a seller is visited by only one buyer (pairwise meetings), ex post quality will be such that the seller is indifferent between trading or not and I denote this quality level as $q_p > q_m$.[3]

2.1. The Value Functions

Let $W^b(m)$ and $V^b(m)$ be the value functions for a buyer holding m units of money in the centralized market and the frictional market, respectively. Denoting as T the lump-sum transfer by the central bank, if a buyer decides to take part in the frictional market, we have

$$W^b(m) = \max_{x,\hat{m}} x + \beta V^b(\hat{m}), \tag{1}$$

$$\text{s.t.} \quad \phi\hat{m} + x = \phi\,(m + T)\,. \tag{2}$$

When choosing the net consumption of the general good, x, and a quantity of money to bring to the frictional market, $\hat{m}$, buyers take into account that the combined real value of these two quantities must be equal to the money they brought to this market, ϕm, and received from the central bank, ϕT. Substituting out x yields

$$W^b(m) = \phi\,(m + T) + \max_{\hat{m}} \left[-\phi\hat{m} + \beta V^b(\hat{m})\right]. \tag{3}$$

If a buyer does not participate in the frictional market, this is simply

$$W^b(m) = \phi\,(m + T) + \max_{\hat{m}} \left\{-\phi\hat{m} + \beta W^b(\hat{m})\right\}, \tag{4}$$

in which case $\hat{m} = 0$.

The Bellman equation for a buyer in the decentralized market is

$$V^b(m) = \psi_p \left\{u\left(q_p\right) + W^b_{+1}\,(m - d)\right\} + \psi_m \left\{u\,(q_m) + W^b_{+1}\,(m - d)\right\} + \left(1 - \psi_p - \psi_m\right) W^b_{+1}(m) - k. \tag{5}$$

With probability ψ_p, a buyer is alone and trades with a seller, in which case he purchases and consumes one unit of the search good of quality q_p. He then enters tomorrow's centralized market with $m - d$ units of money. With probability ψ_m, the buyer meets several other buyers but wins the good, whose quality is lower and equal to q_m. He then carries on to the centralized market with $m - d$ units of money as well. In all other cases he proceeds to the centralized market with an unchanged amount of money. In all cases, buyers pay k to participate.

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Turning now to sellers, they solve the following program on the centralized market:

$$W^s(m) = \max_{x,d,\theta} x + \beta V^s(d, \theta), \tag{6}$$

$$\text{s.t.} \quad x = \phi m. \tag{7}$$

A seller chooses net consumption on the centralized market, which cannot exceed its monetary resources from the previous period, and a price and queue length for the coming directed search market.[4] In the directed search market, the probability of a pairwise match for a seller is denoted ξ_p, whereas ξ_m is the probability of a multilateral match and $1 - \xi_p - \xi_m$ that of no buyer showing up. In the frictional market we then have

$$V^s(d, \theta) = \xi_p \left\{-c\left(q_p\right) + W^s_{+1}(d)\right\} + \xi_m \left\{-c(q_m) + W^s_{+1}(d)\right\} \\ + \left(1 - \xi_p - \xi_m\right) W^s_{+1}(0), \tag{8}$$

with an interpretation similar to that for (5). If a symmetric equilibrium exists we will have $\psi_p = e^{-\theta}$ and $\psi_m = \frac{1-e^{-\theta}-\theta e^{-\theta}}{\theta}$.[5] Similarly, $\xi_p = \theta e^{-\theta}$ and $\xi_m = 1 - e^{-\theta} - \theta e^{-\theta}$.

2.2. The Equilibrium

Let $z = \phi_{+1} d$ denote the real value of the posted price. If a buyer faces no competitor, he is able to impose terms of trade that leave the seller indifferent between trading or not, i.e., a quality level q_p such that

$$z = c(q_p). \tag{9}$$

Similarly, competition between two or more buyers leads to

$$z = u(q_m). \tag{10}$$

See Figure 1.

From insertion of (8) into (6), linearity of W^s, and removal of constant terms, the seller's objective becomes

$$\max_{z,\theta} \xi_p \left[-c(q_p) + z\right] + \xi_m \left[-c(q_m) + z\right]. \tag{11}$$

As for buyers, they take part into the directed search market if

$$-\phi m + \beta V^b(m) \geq \beta W^b_{+1}(0). \tag{12}$$

It is easy to check that the buyer will bring in just enough money to meet the posted d. Using this and applying the same simplification technique as before transforms (12) into

$$-iz + \psi_p \left[u(q_p) - z\right] + \psi_m \left[u(q_m) - z\right] \geq k. \tag{13}$$

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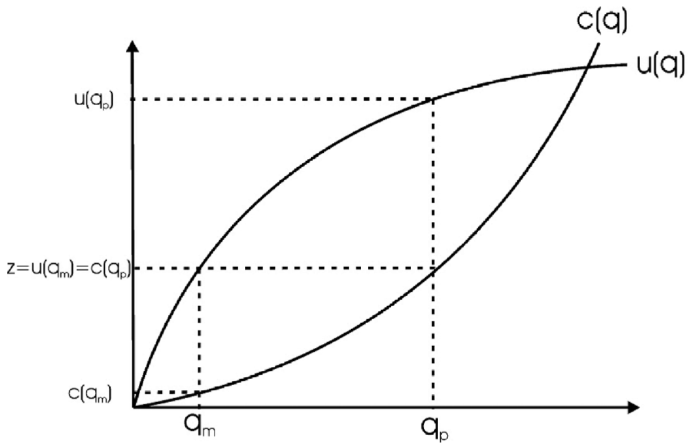

FIGURE 1. z, q_p, and q_m.

Inserting (9), (10), $q_p = c^{-1}(z)$, and $q_m = u^{-1}(z)$ into (11) and (13) yields

$$\max_{z,\theta} \xi_m(\theta)\left\{-c\left[u^{-1}(z)\right]+z\right\} \tag{14}$$

$$\text{s.t.} \quad -iz+\psi_p(\theta)\left\{u\left[c^{-1}(z)\right]-z\right\} \geq k. \tag{15}$$

Effectively, sellers maximize the surplus they get out of multilateral meetings. This maximization is subject to the constraint that buyers' net gains from participation are no smaller than their outside option. Note that buyers gain only in the case of a pairwise meeting with a seller, which happens with probability ψ_p. Similarly, sellers gain only in the case of multilateral meetings, which happen with probability ξ_m. Note that the distribution of money holdings is degenerate and equal to z in real terms.

The monetary strategy is obvious (participating buyers bring the equivalent to the posted price, $m = d$), so it is not included in the following definition of an equilibrium:

DEFINITION 1. *A symmetric equilibrium is a list* $\{W^b, V^b, W^s, V^s, d, \theta, \phi\}$ *such that*

(i) *buyers are indifferent between all sellers;*
(ii) *buyers' and sellers' beliefs about the relationship between* d, θ, *and* ϕ *are correct, and the probability of a seller being visited by n buyers is* $\frac{\theta^n}{n!}e^{-\theta}$;
(iii) *sellers maximize (14) subject to (15);*
(iv) *(15) is binding because of free entry on the buyer's side;*
(v) ϕ *solves* $M^D = M^S$, *where* M^S *is the money supply.*

3. THE PRICE OF COMMITMENT

Using the functional forms for ξ_m and ψ_p, the seller's program can be written

$$\max_{z,\theta} \left(1-e^{-\theta}-\theta e^{-\theta}\right)\left\{-c\left[u^{-1}(z)\right]+z\right\} \tag{16}$$

$$\text{s.t.} \quad -iz+e^{-\theta}\left\{u\left[c^{-1}(z)\right]-z\right\} \geq k. \tag{17}$$

If (17) is used to plug θ into (16), the resulting function in z has a global maximum.[6] It is then straightforward to see that an equilibrium exists and is unique, in which the two quality levels q_m and q_p are recovered using $q_m = u^{-1}(z)$ and $q_p = c^{-1}(z)$.

Welfare in this economy with no commitment, denoted W_{nc}, is measured by

$$W_{\text{nc}} = sV^s(d,\theta) + bV^b(m). \tag{18}$$

Substituting $V^b(m)$ by (5) and V^s by (8) and dividing by s, we obtain welfare per seller:

$$w_{\text{nc}} = \theta e^{-\theta}\left[u(q_p)-c(q_p)\right] + \left(1-e^{-\theta}-\theta e^{-\theta}\right)\left[u(q_m)-c(q_m)\right] - \theta k. \tag{19}$$

The social planner maximizes the number of pairwise trades times the corresponding surplus, plus the number of multilateral trades times the corresponding surplus, minus the cost from buyer's entry. The first-order conditions on the central planner's problem are

$$u'(q_p) = c'(q_p), \tag{20}$$

$$u'(q_m) = c'(q_m), \tag{21}$$

$$\theta e^{-\theta}\left[u(q_m)-c(q_m)\right] + e^{-\theta}(1-\theta)\left[u(q_p)-c(q_p)\right] = k. \tag{22}$$

On the intensive margin, the first best requires marginal utility to equal marginal cost in pairwise and multilateral meetings; i.e., $q_p = q_m = q^*$. On the extensive margin, the first best requires the buyer's expected marginal contribution to a match to be equal to his participation cost k. On insertion of $q_p = q_m = q^*$ into (22), it becomes

$$\theta e^{-\theta}\left[u(q^*)-c(q^*)\right] + e^{-\theta}(1-\theta)\left[u(q^*)-c(q^*)\right] = k, \tag{23}$$

so that

$$\theta^* = -\ln\left[\frac{k}{u(q^*)-c(q^*)}\right]. \tag{24}$$

Because sellers always produce $q_m < q_p$, terms of trade are always inefficient, because efficiency requires a unique quality level $q_p = q_m = q^*$ that is not achievable under dispersion—see also Figure 2.

We then compare the allocation and welfare of this economy without commitment to that of the same economy in which sellers post a unique price–quality pair

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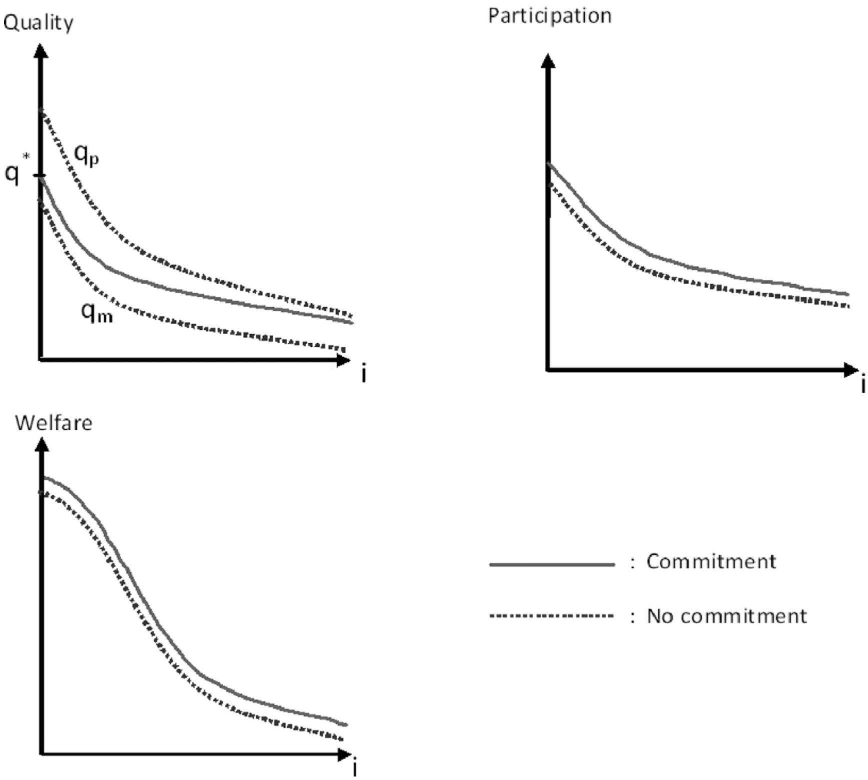

FIGURE 2. Comparing an economy with quality commitment to an economy without such commitment.

ex ante, to which they commit. In this economy, terms of trade are given by

$$\max_{z,\theta,q} \left(1 - e^{-\theta}\right) [-c(q) + z] \tag{25}$$

$$\text{s.t.} \quad -iz + \frac{\left(1 - e^{-\theta}\right)}{\theta} [u(q) - z] \geq k, \tag{26}$$

where $z = \phi_{+1} d$ is the real price posted by sellers in the unique symmetric equilibrium. Equations (25) and (26) are to be compared with equations (16) and (17). We use w_c to denote welfare per seller when sellers are able to commit to a certain quality level. This is given by

$$w_c = (1 - e^{-\tilde{\theta}}) [u(\tilde{q}) - c(\tilde{q})] - \tilde{\theta} k, \tag{27}$$

where $\tilde{q}$ and $\tilde{\theta}$ are determined by (25) and (26). Taking the first-order conditions with respect to q and θ, the central planner recommends the same level of quality and the same entry as in the no-commitment economy, q^* and θ^*.

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In Figure 2, we compare the allocation and welfare across the two economies at the same inflation rate. The value of this approach is that it makes it possible to isolate the welfare effect of quality commitment by controlling for the effect of inflation on the allocations. Note that, as the nominal interest rate departs from zero, quality, entry, and welfare fall in both economies. However, they are all greater in the economy in which sellers are able to commit. Note also that the variance of goods' quality decreases as q_p and q_m get closer to each other.

To measure the consumption-equivalent cost of quality dispersion, I follow Lucas (1987) and calculate the amount of consumption that agents would need to give up to be indifferent between an economy in which sellers can commit and an economy in which they cannot. In order to do that, we proceed as follows. First, we use data on money demand and the average markup across markets of 10% used by Lagos and Wright (2005) to calibrate the three parameters of the model: the curvature of the utility function η in $u(q) = \frac{q^{1-\eta}}{1-\eta}$, the entry cost k, and real output per seller in the centralized market, denoted C, which is left undetermined by the model.[7] Using those estimated parameters, we compare welfare in the economy with quality commitment to welfare in the economy without quality commitment.

To calibrate (η, C, k) we proceed as follows. For a given entry cost k, we estimate η and C by fitting the money demand derived from the model using least squares to observed U.S. annual combinations of real balances and nominal interest rates from 1900 to 2000. Because closed-form expressions for money demand cannot be obtained, because of the use of inverse functions, we adopt the following strategy. For each pair (η, C) in a grid, we compute the implied equilibrium $(z_i, q_{m,i}, q_{p,i}, \theta_i)$ for all observed nominal interest rates i and then the corresponding (simulated) real balances $L(i)$. We then estimate the sum of the squares of the errors between the actual data and the simulated data. We then pick the pair (η, C) in the grid that minimizes this sum for the chosen k. We repeat this procedure for all $k \in [0, u(q^*) - c(q^*)]$ until the procedure yields an average percentage markup μ of 10% across both markets, as in Lagos and Wright (2005), at the average interest rate over the study period, 4.76%. We denote the resulting triple as (η^*, C^*, k^*). The markup $1 + \mu$ is equal to the ratio of price to marginal cost. Given that two qualities are produced and $c'(q) = 1$, note that the average markup in the decentralized market is given by

$$\left(1 - e^{-\theta} - \theta e^{-\theta}\right) \frac{z}{q_m} + \theta e^{-\theta} \frac{z}{q_p} = \left(1 - e^{-\theta} - \theta e^{-\theta}\right) \frac{z}{u^{-1}(z)} + \theta e^{-\theta}, \quad \textbf{(28)}$$

because $z = c(q_p) = q_p$.

We use $L(i)$ to denote money demand as a function of the nominal interest rate. It is given by M/PY, where M/P is real balances and Y is total real output. Using M^b to denote average real balances carried by each buyer, we have $M/P = bM^b = bz$. Total real output Y is the sum of output in the centralized and decentralized markets, given by $B = sC$ and $\frac{(1-e^{-\theta})}{\theta} z$, respectively, where

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$C = B/s$ is real output in the centralized market normalized by the number of sellers. Therefore

$$L(i) = \frac{bz}{sC + \frac{(1-e^{-\theta})}{\theta} bz}. \quad \textbf{(29)}$$

Dividing the numerator and denominator by s, we have

$$L(i) = \frac{\theta z}{C + \left(1 - e^{-\theta}\right) z}. \quad \textbf{(30)}$$

When this is fitted to the data using the procedure outlined previously, we find $(\eta^*, C^*, k^*) = (0.51, 14.12, 0.012)$.

Using these estimated parameters, we calculate the fraction Δ by which consumption in an economy with commitment must be reduced at $i = 4.76\%$ to leave agents indifferent between that economy and an economy in which sellers do not commit. That is, Δ solves

$$(1 - e^{-\tilde{\theta}_i}) [u([\tilde{q}_i (1 - \Delta)] - c(\tilde{q}_i)] - \tilde{\theta}_i k - \Delta C \quad \textbf{(31)}$$

$$= \theta_i e^{-\theta_i} [u(q_{p,i}) - c(q_{p,i})] + (1 - e^{-\theta_i} - \theta_i e^{-\theta_i})[u(q_{p,i}) - c(q_{p,i})] - \theta_i k, \quad \textbf{(32)}$$

where ΔC is the reduction in total consumption in the centralized market normalized by the number of sellers. We find that $\Delta = 0.003$; that is, the gain for U.S. households due to sellers' ability to commit to quality is equivalent to an additional 0.3% of consumption.

4. CONCLUSION

A central feature of directed search is the ability of sellers to commit to the posted terms of trade. In this paper I have allowed quality to vary ex post according to buyers' and sellers' ex post market power. Although this gives the impression that the terms of the contract are fulfilled, shifts in quality allow ex post market conditions to reflect into buyers' utility and sellers' production costs. The goal of this exercise was twofold: first, I showed that the ability of sellers to commit to a certain quality raises welfare overall; second, I aimed at measuring this gain, and found it to be about 0.3%. Given the extreme bargaining power given to buyers or sellers when market conditions are in their favor, this measure should be considered as an upper bound.

Several authors [e.g., Bils and Klenow (2001), Bils (2009)] have noted that a large portion of observed inflation can actually be attributed to higher-quality goods instead of pure nominal inflation. Because our model predicts that quality falls as inflation rises, this suggests that the higher inflation, the lower the portion of CPI inflation that can be attributed to quality improvements. It would then be interesting to conduct a study similar to that conducted by Bils and Klenow (2001) and Bils (2009), but for high-inflation countries, and calculate the quality component of the CPI inflation to see whether it is indeed lower, as predicted by the model. I leave this for future research.

NOTES

1. There are other ways for sellers to let terms of trade reflect ex post market conditions. Auctions are one of them, as are demand-contingent prices, as in Coles and Eeckhout (2003).

2. Using $(1+i) = (1+r)(1+\tau)$ yields i in the text.

3. Note that the model generalizes the ex post pricing model of Julien et al. (2008) to an economy with divisible money.

4. Sellers compete in expected terms of trade; hence the maximization over θ. See Burdett et al. (2001) and Shi (2008) for details.

5. In the symmetric equilibrium (to be defined shortly), as buyers are indifferent between all sellers, the probability that a seller is visited by n buyers is given by $\frac{\theta^n}{n!}e^{-\theta}$. Therefore the probability for a buyer of getting served in a multilateral match is $\sum_{n\in\mathbb{N}^*}\frac{\theta^n}{n!}e^{-\theta}\frac{1}{n+1} = \frac{1}{\theta}\sum_{n\in\mathbb{N}^*}\frac{\theta^{n+1}}{(n+1)!}e^{-\theta} = \frac{1}{\theta}\sum_{n\geq 2}\frac{\theta^n}{n!}e^{-\theta} = \frac{1-e^{-\theta}-\theta e^{-\theta}}{\theta}$.

6. Although it is not obvious at first glance, it has been checked via computer simulation under various functional forms for u and c.

7. The data we use are from Craig and Rocheteau (2008); that is, yearly data are from 1900 to 2000, the interest rate is the short-term commercial paper rate, and money demand is M1 not seasonally adjusted.

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