E C O N O M I C S   B U L L E T I N

A model of a spatial economy with trading posts

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Abstract

This paper develops a framework in which exchange takes place at pairwise markets in a monetary economy with locations. In the economy there are several towns, each of which has pairwise markets characterized by trading posts. At each trading post, taking prices as given, agents submit commodities simultaneously with no resale, as opposed to an instantaneous trading in the Walrasian economy. Commodities can be transported across towns with costs. In this setting, we demonstrate that a trading center emerges in equilibrium if, and only if, heterogeneity in transportation costs among towns is large enough.

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1. Introduction

In the real world, we can observe that a large variety of commodities are traded in a small number of locations. We call such a location a *trading center*. The purpose of this paper is to explain where and why a trading center emerges. To this end, we develop a simple model of a spatial economy where exchange takes place at pairwise markets called *trading posts*. In the model, there are several locations, or towns, each of which has trading posts where a single commodity and fiat money are exchanged. We formulate a trading center as a town at which active trading posts concentrate.

This paper builds on two strands of literature: monetary economics and urban economics. In the traditional Walrasian economy, there is an economy-wide market, and agents are allowed to instantly resell their purchases. In such an economy, money plays no essential role, so that in order to provide a theoretical foundation for monetary economics, one has to depart from the Walrasian economy. The trading post approach, introduced by Shapley and Shubik (1977) and applied to a situation with fiat money by Hayashi and Matsui (1996), postulates that there are trading posts where prespecified pairs of objects are traded and that trade takes place simultaneously so that agents cannot use revenues from trade in one trading post for purchase in other posts.[1] Monetary exchange patterns can be explicitly described by such a model. The present paper is an attempt to introduce the concept of location into a model of monetary exchange with trading posts.

Spatial agglomeration in economic activities has been one of the central issues in the field of urban economics. It is often argued that the difference in transportation costs among locations plays an important role in generating the asymmetry of economic activities. Recently, Konishi (2000) studies the formation of transportation hub in a general equilibrium model with three locations. He shows that when transportation costs between locations are heterogeneous enough, a hub city emerges and population agglomeration occurs in that city.[2] The present paper addresses agglomeration in transaction activities in a model of decentralized trade with trading posts.

We pursue these two lines described above by analyzing a simple spatial model with trading posts. There are three towns and three types of perishable commodities in the economy. In each town, there are agents endowed with a location-specific production technology. We assume the complete lack of double coincidence of wants: residents in town i desire the commodity produce in town $i+1$ (mod 3). Commodities can be transported across towns with the so-called "iceberg" transportation costs. There are three

[1] In Shapley and Shubik (1977), the price at a trading post is determined by the ratio of aggregate offers of each of the two objects, while in Hayashi and Matsui (1996), there is an auctioneer in each trading post, and each agent behaves as a price taker. The present paper follows the latter.

[2] Berliant and Konishi (2000) study a model of market places with setup costs.

trading posts in each town where exchange between each commodity and fiat money takes place, so that any commodity is possibly traded in each town. All trades occur simultaneously with no resale, so that any trade involves the exchange of fiat money for commodities. Each agent can behave as simultaneously a buyer and a seller in one period: as a buyer, he uses his current money holdings to purchase the desired commodity; as a seller, he produces his home commodity and then sells it to accumulate money that is used in later periods. A trading center is defined to be a town where all trading posts are active. Our goal is to identify the condition under which concentration in transaction activities occurs. We show that in the presence of positive transportation costs, a trading center can emerge in equilibrium if, and only if, heterogeneity in transportation costs among towns is large enough.

Economides and Siow (1988) also relate agglomeration in economic activities to the distribution of markets, incorporating trading frictions into a spatial economy. In their model, agents faced with endowment shocks are located along a linear city. Each agent must select a market to participate in before his endowment is realized, unlike in the standard Walrasian economy where agents can participate in a complete market structure without first going to any particular market location. Due to liquidity considerations, agents prefer to trade in a single location, while transportation costs have potential to spread trading activities over locations. Economides and Siow (1988) illustrate this tradeoff between liquidity and transportation costs and show that in a Nash equilibrium, several markets operate. The present paper differs from their paper in that in our model, agglomeration is generated by heterogeneity in transportation costs, while in theirs, it is caused by participation externality.

It is important to relate our framework to the spatial impossibility theorem due to Starrett (1978), which is one of the central results in urban economics. The theorem says that if (i) markets are complete, (ii) markets are perfectly competitive, (iii) there are no relocation costs, (iv) there are no externalities, and (v) space is homogeneous, then there is no equilibrium with a positive aggregate transportation cost in a closed spatial economy. Thus, in order to demonstrate transaction agglomeration, we must violate at least one of these conditions. The present paper drops (i) in that no resale is assumed, as well as (iii) and (v). Examples which violate at least (i) and (v) include Wang (1990), Berliant and Wang (1993), and Konishi (2000).

This paper is organized as follows. Section 2 presents our model. Section 3 establishes our results. Section 4 concludes.

2. Model

We consider an infinite horizon economy with locations inhabited by infinitely lived agents. Time is discrete, and periods are indexed by t ($t = 0, 1, \ldots$). There are three towns $\{1, 2, 3\}$ and three types of commodities $\{1, 2, 3\}$ in the economy. In addition, there is fiat money, which is distributed to the agents at time 0 in a lump-sum fashion. All commodities completely perish within a period, while fiat money is completely durable. In each town, there is a unit mass of identical agents. A typical agent who lives in town i is denoted by i. Agent i can produce commodity i, i.e., each agent has access to a location-specific production technology. Agent i derives utility only from commodity $i+1$ (mod 3), so that there is a complete lack of double coincidence of wants.[3]

In each town, there are three trading posts. At each trading post $\{0, j\}$, $j = 1, 2, 3$, fiat money and commodity j are exchanged. We assume that in each period, trading takes place simultaneously with no resale of commodities acquired in other trading posts. Thus, since commodities are completely perishable and there is a lack of double coincidence of wants, agents other than agents $j-1$ and j do not participate in the transaction at trading post $\{0, j\}$.[4]

Commodities can be transported across towns with costs, while fiat money can be transported with no cost. We assume that transportation costs are paid by the transported commodity; in other words, the commodity melts away during the transportation. Transportation of one unit of commodity from town j to town k ($j \neq k$) requires $(t_{jk} - 1)/t_{jk}$ units of the commodity, where $t_{jk} > 1$. Here we assume that $t_{jk} = t_{kj}$ for all distinct j and k. Therefore, when one unit of commodity is transported between j and k, only $1/t_{jk}$ units arrive at the destination. We set $t_{jj} = 1$.

Indirect transportation is allowed. If, for example, $t_{12} \times t_{13} < t_{23}$ holds, commodities can be transported from town 2 to town 3 through town 1 with less cost. We define $[t_{jk}] = \min\{t_{jk}, t_{j\ell} \times t_{\ell k}\}$, where $\ell \neq j, k$.

We assume that each agent must consume commodities in his own town. If agent i obtains x^i_{i+1}, y^i_{i+1}, and z^i_{i+1} units of commodity $i+1$ from trading posts in towns 1, 2, and 3, respectively, then the amount of his consumption of commodity $i+1$ is

$$c^i = \frac{x^i_{i+1}}{[t_{i1}]} + \frac{y^i_{i+1}}{[t_{i2}]} + \frac{z^i_{i+1}}{[t_{i3}]}.$$

[3] This assumption, which is standard in the literature of search-theoretic monetary economics (e.g., Kiyotaki and Wright (1989) and Green and Zhou (1998)), gives fiat money an essential role as a medium of exchange.

[4] For the same reason, no barter trading posts could be used.

Agent i's utility is given by

$$\sum_{t=0}^{\infty} \beta^t \left(\log c^i(t) - k^i(t)\right),$$

where $c^i(t)$ is the amount of i's consumption of commodity $i+1$ at time t, $k^i(t)$ is the amount of i's production of commodity i at time t, and $\beta \in (0,1)$ is the common discount factor.

The price of commodity j at trading post $\{0,j\}$ in town 1 (town 2, town 3, respectively) at time t is denoted by $p_j(t)$ ($q_j(t)$, $r_j(t)$, respectively).[5] Given a sequence of price profiles, agent i is faced with the following decision problem:

$$\begin{aligned}
&\max \sum_{t=0}^{\infty} \beta^t \left(\log\left(\frac{x^i_{i+1}(t)}{[t_{i1}]} + \frac{y^i_{i+1}(t)}{[t_{i2}]} + \frac{z^i_{i+1}(t)}{[t_{i3}]}\right) - k^i(t)\right), \\
&\text{s.t. } [t_{i1}]\frac{x^i_{\mathrm{m}}(t)}{p_i(t)} + [t_{i2}]\frac{y^i_{\mathrm{m}}(t)}{q_i(t)} + [t_{i3}]\frac{z^i_{\mathrm{m}}(t)}{r_i(t)} = k^i(t), \\
&\quad p_{i+1}(t)x^i_{i+1}(t) + q_{i+1}(t)y^i_{i+1}(t) + r_{i+1}(t)z^i_{i+1}(t) \\
&\qquad\qquad + m^i(t) = M^i(t), \\
&\quad M^i(t+1) = x^i_{\mathrm{m}}(t) + y^i_{\mathrm{m}}(t) + z^i_{\mathrm{m}}(t) + m^i(t), \\
&\quad M^i(0)\text{: given,}
\end{aligned} \tag{1}$$

where $x^i_{\mathrm{m}}(t)$ ($y^i_{\mathrm{m}}(t)$, $z^i_{\mathrm{m}}(t)$, respectively) is the money demand submitted to post $\{0,i\}$ in town 1 (town 2, town 3, respectively), $m^i(t)$ is the nominal money balances not used for monetary exchange, and $M^i(t)$ is the nominal money balances at the beginning of time t. The Kuhn-Tucker conditions for this problem are: for all $i = 1,2,3$, and all $t = 0,1,2,\ldots,$

$$\frac{\beta^t}{[t_{i1}]c^i(t)} - \mu^i(t)p_{i+1}(t) \le 0, \qquad \text{“=” if } x^i_{i+1}(t) > 0, \tag{KT 1}$$

$$\frac{\beta^t}{[t_{i2}]c^i(t)} - \mu^i(t)q_{i+1}(t) \le 0, \qquad \text{“=” if } y^i_{i+1}(t) > 0, \tag{KT 2}$$

$$\frac{\beta^t}{[t_{i3}]c^i(t)} - \mu^i(t)r_{i+1}(t) \le 0, \qquad \text{“=” if } z^i_{i+1}(t) > 0, \tag{KT 3}$$

$$-\frac{\lambda^i(t)}{p_i(t)/[t_{i1}]} + \mu^i(t+1) \le 0, \qquad \text{“=” if } x^i_{\mathrm{m}}(t) > 0, \tag{KT 4}$$

$$-\frac{\lambda^i(t)}{q_i(t)/[t_{i2}]} + \mu^i(t+1) \le 0, \qquad \text{“=” if } y^i_{\mathrm{m}}(t) > 0, \tag{KT 5}$$

[5] We assume that the price of a trading post is always called, say, by an auctioneer, even though no amount of commodity is submitted to the trading post. Otherwise, there could be an equilibrium where all amount of commodity j is traded in a unique $\{0,j\}$ trading post only because no other $\{0,j\}$ trading post has the price called.

$$-\frac{\lambda^i(t)}{r_i(t)/[t_{i3}]} + \mu^i(t+1) \le 0, \qquad \text{“=” if } z^i_{\mathrm{m}}(t) > 0, \qquad \text{(KT 6)}$$

$$\mu^i(t+1) - \mu^i(t) \le 0, \qquad \text{“=” if } m^i(t) > 0, \qquad \text{(KT 7)}$$

$$-\beta^t + \lambda^i(t) \le 0, \qquad \text{“=” if } k^i(t) > 0. \qquad \text{(KT 8)}$$

At trading post $\{0, i\}$ in town 1, for example, if x^i_{i+1} units of commodity $i+1$ are to be obtained by agent i, then the amount of money that i needs to pay is $p_{i+1}x^i_{i+1}$, which in turn is equal to agent $i+1$'s money demand x^{i+1}_{m} when the market clears. Equilibrium is thus defined as follows.

Definition 1. For given $M(0)$, a *monetary equilibrium* is defined to be a sequence $\{x^i_{i+1}(t), x^i_{\mathrm{m}}(t), y^i_{i+1}(t), y^i_{\mathrm{m}}(t), z^i_{i+1}(t), z^i_{\mathrm{m}}(t), m^i(t), M^i(t), k^i(t); p_i(t), q_i(t), r_i(t),\ i = 1, 2, 3\}^{\infty}_{t=0}$ such that:

1. for each agent $i = 1, 2, 3$, $\{x^i_{i+1}(t), x^i_{\mathrm{m}}(t), y^i_{i+1}(t), y^i_{\mathrm{m}}(t), z^i_{i+1}(t), z^i_{\mathrm{m}}(t), m^i(t), M^i(t), k^i(t)\}$ satisfies the Kuhn-Tucker conditions (KT 1)–(KT 8) with the constraints in the problem (1).

2. markets clear: for all $i = 1, 2, 3$,

$$p_{i+1}(t)x^i_{i+1}(t) = x^{i+1}_{\mathrm{m}}(t),$$
$$q_{i+1}(t)y^i_{i+1}(t) = y^{i+1}_{\mathrm{m}}(t),$$
$$r_{i+1}(t)z^i_{i+1}(t) = z^{i+1}_{\mathrm{m}}(t).$$

Trading post $\{0, j\}$ is said to be *active* if a positive amount of fiat money and commodity j are submitted to the post. We define a trading center in terms of active trading posts.

Definition 2. A town is said to be a *trading center* if all trading posts in this town are active.

Throughout the rest of the paper, we focus only on stationary equilibria, in which every variable is constant over time, while our model can generate rich patterns of trading.

3. Results

In this section, we identify the condition under which concentration in transaction activities occurs. We show that in our environment with positive transportation costs (i.e., $t_{jk} > 1$ for all distinct j and k), a trading center can emerge in equilibrium if, and only if, heterogeneity in transportation costs among towns is large enough.

The first proposition establishes the “only if” part: transaction concentration does not occur unless transportation costs are sufficiently heterogeneous.

Proposition 1. *If town i is a trading center in a monetary equilibrium, then*

$$t_{ii+1} \times t_{ii+2} \leq t_{i+1i+2}. \tag{2}$$

Proof. See Appendix. ∎

For town i to be a trading center, the residents of town $i+1$ and of town $i+2$ need to exchange in town i. Inequality (2) implies that the indirect transportation through town i yields less cost for them than the direct transportation between towns $i+1$ and $i+2$. If $t_{ii+1} \times t_{ii+2} > t_{i+1i+2}$ holds for all i, there exists no trading center: for each town i, trading post $\{0, i+2\}$ does not activate.

Since (2) can not hold simultaneously for distinct towns, we obtain the following.

Corollary 1. *There is at most one trading center.*

Next, the following claim clarifies where and why the trading center emerges under large enough heterogeneity. An argument analogous to the proof of Proposition 1 can be applied, so that the claim is stated without a proof.

Claim 1. If $t_{ii+1} \times t_{ii+2} \leq t_{i+1i+2}$, then in a monetary equilibrium,

(a) trading post $\{0, i\}$ is active in either town i or town $i+2$, or in both towns;

(b) trading post $\{0, i+1\}$ is active in either town i or town $i+1$, or in both towns; and

(c) trading post $\{0, i+2\}$ is active in town i, $i+1$, or $i+2$ or some (or all) of them.

The following proposition demonstrates that if inequality (2) holds, then town i can become the trading center in equilibrium.

Proposition 2. *If $t_{ii+1} \times t_{ii+2} \leq t_{i+1i+2}$, then there exists a monetary equilibrium in which town i is a trading center.*

Proof. See Appendix. ∎

We construct in Appendix a stationary equilibrium where town 1 is the trading center, which is depicted in Figure 1. In this equilibrium, all trading posts in town 1 are active, while each of towns 2 and 3 has only one active trading post: trading post $\{0, 2\}$ in town 2, and $\{0, 1\}$ in town 3. Fraction $\eta\,(\in (0, 1))$ of agents 1 sell at $\{0, 1\}$ in town 1 their production of commodity 1, which fraction η of agents 3 buy. The rest of agents 1 transport their production to $\{0, 1\}$ in town 3 to trade with fraction $1 - \eta$ of agents 3. By utilizing fiat money they obtained in the previous period, fraction ξ ($\in (0,1)$) of agents 1 buy commodity 2 transported from town 2 at $\{0,2\}$ in town 1, and the rest of agents 1 buy commodity 2 at $\{0,2\}$ in town 2. Since the indirect transportation through town 1 provides less cost to agents 2 and 3, commodity 3 may be traded at $\{0,3\}$ in town 1. In this equilibrium, the whole amount of commodity 3, which is produced in town 3 and then consumed in town 2, is traded in town 1.[6]

4. Conclusion

We have presented a simple spatial model with trading posts to demonstrate concentration in transaction activities. The model allows us to depict the trading center as a location where all trading posts activate and the suburbs as locations where some of trading posts are inactive. We have shown that in the presence of positive transportation costs, a town can become the trading center in equilibrium if and only if the indirect transportation though this town requires less cost than the direct transportation between the suburbs.

The present framework which includes fiat money would also allow us to discuss various topics on monetary economics. We could examine the effect of monetary policy on the distribution of transactions by introducing the government, as in Alonso (2001) and Matsui (1998). We leave these issues for future research.

[6] We also have equilibria where $\xi = 0$ or 1, and $\eta = 0$ or 1. In equilibria with $\xi = 0$ and/or $\eta = 0$, even though large enough heterogeneity exists, there is no trading center.

Appendix

Proof of Proposition 1. For the expositional convenience, we set $i = 1$. Suppose that town 1 is a trading center.

Since town 1 is a trading center, trading post $\{0, 3\}$ at town 1 is active. For the buyers of commodity 3 (the residents of town 2) to join trading post $\{0, 3\}$ at town 1, the following conditions must hold:

$$\frac{1}{p_3[t_{12}]} \geq \frac{1}{q_3}, \tag{3}$$

$$\frac{1}{p_3[t_{12}]} \geq \frac{1}{r_3[t_{23}]}. \tag{4}$$

Similarly, for the sellers of commodity 3 (the residents of town 3),

$$\frac{p_3}{[t_{13}]} \geq \frac{q_3}{[t_{23}]}, \tag{5}$$

$$\frac{p_3}{[t_{13}]} \geq r_3 \tag{6}$$

must hold.

For p_3, q_3, and r_3 satisfying (3)–(6) to exist, we must have $[t_{23}] \geq [t_{12}] \times [t_{13}]$, and hence,

$$t_{23} \geq [t_{12}] \times [t_{13}] \tag{7}$$

(recall that $[t_{23}] = \min\{t_{23}, t_{12} \times t_{13}\}$).

Since $t_{12}, t_{13} > 1$, we obtain $[t_{12}] = \min\{t_{12}, t_{13} \times t_{23}\} = t_{12}$ and $[t_{13}] = \min\{t_{13}, t_{12} \times t_{23}\} = t_{13}$ from (7), so that (7) implies $t_{23} \geq t_{12} \times t_{13}$. ▮

Proof of Proposition 2. Setting $M^i(0) = M$ for all i, we construct a stationary monetary equilibrium in which town 1 is the trading center (i.e., all trading posts in town 1 are active), and trading post $\{0, 2\}$ in town 2 and trading post $\{0, 1\}$ in town 3 are active.

Since $x_2^1, y_2^1 > 0$, (KT 1) and (KT 2) hold with equality for $i = 1$. Hence we have

$$q_2(t) = \frac{p_2(t)}{t_{12}}.$$

Similarly, we have

$$r_1(t) = t_{13} p_1(t).$$

That $k^i > 0$ and $x_{\mathrm{m}}^i > 0$ implies that

$$\lambda^i(t) = \beta^t$$

and

$$\mu^i(t) = \frac{\beta^{t-1}}{p_i(t-1)/t_{i1}}.$$

Then, from (KT 1)–(KT 3), we have

$$\begin{aligned}
c^1(t) &= \beta\,\frac{p_1(t-1)}{p_2(t)}, \\
c^2(t) &= \beta\,\frac{q_2(t-1)}{t_{12}p_3(t)}, \\
c^3(t) &= \beta\,\frac{p_3(t-1)/t_{13}}{r_1(t)}.
\end{aligned}$$

From the constraints in (1), we have

$$\begin{aligned}
&x^1_{\mathrm{m}}(t) + z^1_{\mathrm{m}}(t) = \beta\,p_1(t), \\
&x^2_{\mathrm{m}}(t) + y^2_{\mathrm{m}}(t) = \beta\,q_2(t), \\
&x^3_{\mathrm{m}}(t) = \beta\,p_3(t)/t_{13}.
\end{aligned}$$

The above conditions together with market clearing conditions imply that for any $\xi, \eta \in (0,1)$, a profile such that

$$\begin{aligned}
&p_1 = \frac{M}{\beta},\ p_2 = \frac{t_{12}M}{\beta},\ p_3 = \frac{t_{13}M}{\beta}, \\
&q_1 \in \left(\frac{t_{13}}{t_{23}}\frac{M}{\beta}, t_{12}\frac{M}{\beta}\right),\ q_2 = \frac{M}{\beta},\ q_3 = t_{12}t_{13}\frac{M}{\beta}, \\
&r_1 = \frac{t_{13}M}{\beta},\ r_2 \in \left(\frac{t_{12}}{t_{13}}\frac{M}{\beta}, t_{23}\frac{M}{\beta}\right),\ r_3 = \frac{M}{\beta}, \\
&x^1_2 = \xi\frac{\beta}{t_{12}},\ y^1_2 = (1-\xi)\beta,\ z^1_2 = 0, \\
&x^1_{\mathrm{m}} = \eta M,\ y^1_{\mathrm{m}} = 0,\ z^1_{\mathrm{m}} = (1-\eta)M, \\
&x^2_3 = \frac{\beta}{t_{13}},\ y^2_3 = 0,\ z^2_3 = 0, \\
&x^2_{\mathrm{m}} = \xi M,\ y^2_{\mathrm{m}} = (1-\xi)M,\ z^2_{\mathrm{m}} = 0, \\
&x^3_1 = \eta\beta,\ y^3_1 = 0,\ z^3_1 = (1-\eta)\frac{\beta}{t_{13}}, \\
&x^3_{\mathrm{m}} = M,\ y^3_{\mathrm{m}} = 0,\ z^3_{\mathrm{m}} = 0, \\
&k^1 = k^2 = k^3 = \beta, \\
&m^1 = m^2 = m^3 = 0,
\end{aligned}$$

constitutes a stationary monetary equilibrium, in which all trading posts in town 1 are active, and trading post $\{0,2\}$ in town 2, and trading post $\{0,1\}$ in town 3 are active. ▮

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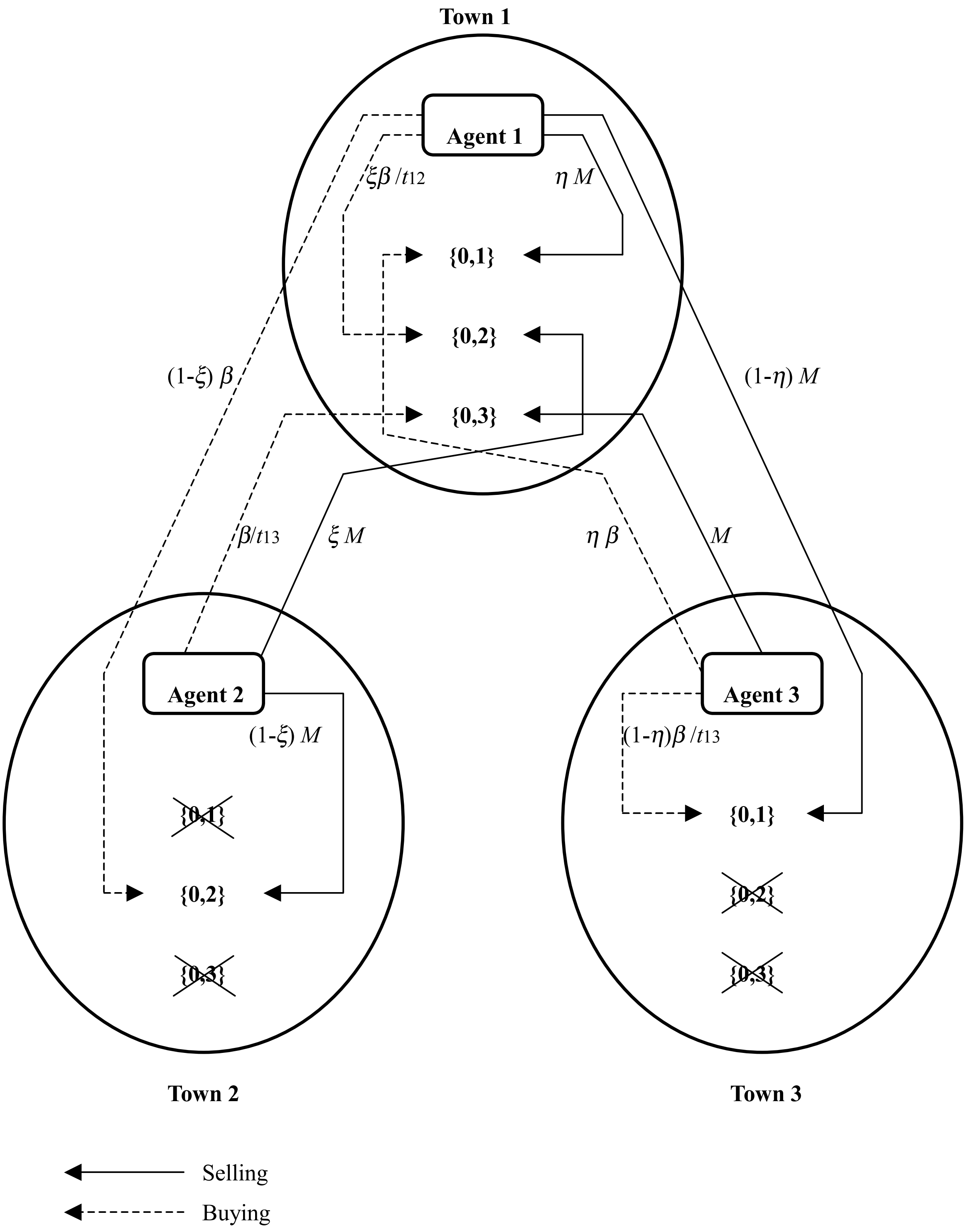
Town 1
Agent 1
$\xi\beta/t_{12}$
ηM
{0,1}
{0,2}
{0,3}
$(1-\xi)\beta$
$(1-\eta)M$
β/t_{13}
ξM
$\eta\beta$
M
Agent 2
Agent 3
$(1-\xi)M$
$(1-\eta)\beta/t_{13}$
{0,1}
{0,2}
{0,3}
{0,1}
{0,2}
{0,3}
Town 2
Town 3
Selling
Buying

Figure 1.