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CENTER DISCUSSION PAPER NO. 550

AN APPROACH TO MODELING INSTITUTIONAL DEVELOPMENT

Xiaokai Yang

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ABSTRACT

In this paper we construct an equilibrium model to formalize Coase's idea on the function of the firm in improving transaction efficiency. The relationship between the division of labor, economic growth, and the evolution of economic institutions are investigated.

AN APPROACH TO MODELING INSTITUTIONAL DEVELOPMENT[1]

I. Introduction

This past year is the 50th anniversary of the publication of Coase's paper [1937], "The Nature of the Firm." Coase's central thesis is that differences in transaction costs lead to the emergence of firms as a replacement for some markets. The institution of the firm can be used to take advantage of long-term contracts in order to save transaction costs. He argued that the division of labor and uncertainty are not major attributes of the firm because the division of labor can be organized by the market rather than by a firm and uncertainty can be used to justify a need for risk markets rather than for firms.[2]

The relationship between the emergence of the firm and the improvement of transaction efficiency has been reconsidered in many papers on this topic. Many authors extend and refine Coase's theory, e.g. Cheung [1982] and Alchian [1972]. Cheung and Alchian hold that not only transaction costs but also the relationship between transaction costs and the division of labor is important

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[1] I would like to thank Gene Grossman, Barry Nalebuff, Edwin Mills, T. N. Srinivasan, Raaj Sah for helpfull comments. Financial Supports from the Ford Foundation and the Open Society Fund are gratefully acknowledged.

[2] Kihlstrom and Laffont's model about uncertainty and the firm [1979] can be only used to justify a need for the risk market because the authors did not explain why wage contracts are more efficient than other market contract arrangements in trading uncertainty, e.g. insurance and stock trade in the markets.

for the emergence of the firm. Cheung points out that the growth of the firm may be viewed as the replacement of a product market by a factor market, resulting in a savings in transaction costs. Alchian holds that there is a market within a firm. This market and the markets between firms and consumers may develop simultaneously.

Some economists who follow the transaction-cost approach, e.g. Williamson [1985], hold that the neoclassical framework of utility and production functions is inappropriate for describing economic institutions. In contrast to this opinion, I hold that the neoclassical framework of utility and production functions can be used to describe the evolution of institutions if the way that production function is specified is appropriately refined.

Because most economists who follow the transaction-cost approach take the gains from trade as stemming only from comparative advantages, the relationship between the evolution of the equilibrium level of division of labor and transaction efficiency cannot be well understood, although the relation between the firm and transaction costs has been discussed extensively. Such discussion will produce a partial view of the role of the firm and cannot shed light on the general relationship between the evolution of division of labor and the evolution of the institution of the firm.

In Yang [1986], the different implications of transaction efficiency for economies with and without increasing returns to specialization are indicated. For an economy with comparative advantages and without increasing returns to specialization, the utility frontier defined by the Pareto optimum is consistent with the production possibility frontier (PPF). But for an economy with increasing returns to specialization, the utility frontier may differ from the PPF because there exists a trade-off between increasing returns to speciali-

zation and transaction costs. For such an economy, an improvement of transaction efficiency will move the utility frontier closer to the PPF and move equilibrium productivity closer to that associated with the PPF. If the contract arrangement adopted by the firm can improve transaction efficiency, then such a contract arrangement may promote the equilibrium level of division of labor because this level is an increasing function of transaction efficiency. However, if the division of labor is based only on comparative advantage, then the implications of improved transaction efficiency will not have effects of this sort. Then the impacts of transaction efficiency on the evolution of institutions is limited. This improvement will not lead to the progress of productivity and the evolution of institutions and the market system.

Whereas most literature on the transaction-cost approach ignores increasing returns to scale (IRS), many excellent studies of economic growth stemming from IRS, e.g. Romer [1986], Lucas [1986], Schultz [1986], Vassilakis [1986] ignore the importance of transaction costs in an economy with IRS. The literature thus cannot highlight the relationship between the evolution of division of labor and the evolution of the institution of the firm either. It appears to me that many recent excellent works in trade theory and growth theory have brought the division of labor based on increasing returns to specialization into a central place in economics. I believe that a combination of the transaction-cost approach and the models describing increasing returns to specialization may be meaningful for such a development and may shed light on the theory on economic growth, trade, and the evolution of market and economic institutions.[3]

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[3] Helpman and Krugman [1985] pointed out the importance of transaction costs for the model with IRS. However, in their model increasing returns to spe-

In an insightful paper, Sah and Stiglitz [1986] push the notion of specialization one step further. They point out: "the past half century has been marked not only by greater specialization in production, but also by greater specialization in learning." They propose a concept "localized learning" and argue that the hours spent learning are specific for each individual. This concept may be used to distinguish increasing returns to specialization from increasing returns to scale.

Schultz [1986] and Lucas [1986] emphasize the importance of increasing returns to specialization for economic growth and note the intrinsic connection between increasing returns to specialization and so called "human capital". Schultz stresses the compatibility between increasing returns to specialization and decentralized markets. He holds that increasing returns to specialization are a general economic phenomena and the major function of specialization is to speed up the accumulation of knowledge (human capital).

In this paper, I will combine the theories proposed by Sah, Stiglitz, Lucas, and Schultz with the ideas of Coase, Cheung, and Alchian to achieve an equilibrium model based on micro-production functions with increasing returns to specialization and Cobb-Douglas utility functions. Using such a model, I will show that competitive equilibrium balances a trade-off between the economies of division of labor and transaction costs. Increasing transaction efficiency will lead to greater division of labor. The institution of the firm would increase the equilibrium level of the division of labor and productivity if it could be used to improve transaction efficiency.

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cialization are not distinguished from increasing returns to scale, so that the implications of increasing returns to specialization combined with transaction costs to institutional evolution was not addressed.

In section II, I present the model. In section III, I solve for the individual decision problems. In section IV, I solve for the equilibrium and the Pareto optimum using a multiple-step approach. In section V, I derive comparative statics of the model set out in the previous sections. Finally I make some remarks on this model.

II. The Model

Let us consider an economy with M consumers/producers. There are two consumer goods and one intermediate good (or service) in this economy. The self-provided amount of the two consumer goods are x and y respectively. By self-provided, we shall mean that quantity of a good produced by an individual for his own use. The amounts of two consumer goods sold in the market are x^s and y^s respectively. The amounts of two consumer goods purchased in the market are x^d and y^d respectively. An "iceberg" type of transaction technology is characterized by the coefficient k. Fraction k of a shipment will disappear in transaction. Thus, $(1-k)x^d$ and $(1-k)y^d$ are the amounts an individual receives from the purchases of the two consumer goods respectively.

The amounts consumed of the two goods are $x+(1-k)x^d$ and $y+(1-k)y^d$ respectively. The utility function is identical for all individuals and given by

(II-1) $$U = [x+(1-k)x^d]^{1/2} [y+(1-k)y^d]^{1/2}$$

This Cobb-Douglas utility function represents a preference for diverse consumption. The amount consumed of each good cannot be zero. A combination of diverse consumption and specialized production will base equilibrium on a trade-off between the gains from trade and transaction costs.

There is a simple iso-elasticity production function for consumer good y:

(II-2) $$y + y^s = L_y^a \qquad a > 1$$

where $y + y^s$ is the output level of good y and L_y is the hours used in producing this good.

In producing x, we need intermediate good z. The production function for x is

(II-3a) $$x + x^s = \{[z+(1-t)z^d]L_x\}^b$$

where z^d is the amount of the intermediate good purchased from the market; the fraction t of z^d disappears in transaction. Hence, $(1-t)z^d$ is the amount an individual receives from the purchase of this intermediate good. z is the amount self-provided of this good. L_x is the hours used in producing consumer good x. Later we will see that the equilibrium number of firms is greater than one in the market with firms if $1/2 < b < 1$ and this number is one if $b \geq 1$. $b > 1/2$ implies that there are increasing returns to specialization in producing x.

The production function of z is

(II-3b) $$z^s = L_z^c \qquad c > 1$$

where z^s is the amount of the intermediate good sold and L_z is the hours used in producing z

In conjuction with individual constraints on labor endowments, (II-2)-(II-3) specify a system of production functions for an individual. Assume that an individual has L units of labor, then the labor endowment constraint for each individual is

(II-4) $$L_x + L_y + L_z = L$$

where some L_i could be zero. For instance, $L_x = L_y = 0$, if an individual produces only z. This system of production functions is specified for a producer/consumer rather than for the firm. It exhibits increasing returns to specialization. According to this production function, each individual always

may choose to be self-provided in some goods. Based on the concept of localized technology proposed by Sah and Stiglitz, we assume that "L" is specific for each individual. The maximal amount of this specific L for each individual is limited. This point distinguishes increasing returns to specialization from increasing returns to scale. The Mills' production function describes a positive relation between productivity and the level of specialization.

The combination of increasing returns to specialization, exhibited by the Mills' production function, and individual preference for diverse consumption, will set up a trade-off between the gains from the division of labor and transaction costs. The market equilibrium will balance this trade-off. The improvement of transaction efficiency will raise this equilibrium level of division of labor. Such improvement may be caused either by progress of transaction technology or by institutional innovation. The latter case is where the setting of the firm may play its role.

III. Individual Optimal Decisions

I assume free entry for all individuals into any sector and a large M. These assumptions imply that individuals treat prices parametrically.

As in Yang [1986], an individual must solve for a corner solution for each structure and his decision making process consists of two steps. In the first step, all structures are enumerated. An individual solves for the efficient allocation (how much should be produced and traded of each good) for given prices and for each structure. In the second step, he decides what should be produced and what should be sold and purchased, i.e. which structure should be chosen.

Following proposition 1 in Yang [1986], for the model with increasing returns to specialization, an individual sells to the market only one type of

traded good (if any) and does not buy those goods he produces. Taking this point into account, there are seven structures which are candidates for the optimal structures.

(1) Structure (x,y,z), i.e. an individual is completely self-sufficient. The decision problem for this structure is

(III-1) Max: $U = xy$

x,y,z,L_x,L_y,L_z

s.t. $x = [zL_x]^b$, $z = L_z^c$, $y = L_y^a$ (production functions)

$L_x + L_y + L_z = L$ (endowment constraint)

Here and in the following six decision problems, we use the equivalence between maximizing U and maximizing U^2.

(2) Structure (x,z/y), i.e. an individual produces x and z, and buys y. The decision problem for this structure is

(III-2) Max: $U = xy^d(1-k)$

x,y^d,x^s,z,L_x,L_z

s.t. $x + x^s = [zL_x]^b$, $z = L_z^c$ (production functions)

$L_x + L_z = L$ (endowment constraint)

$p_x x^s = p_y y^d$ (trade balance)

where p_x and p_y are prices of x and y respectively. By Walras' law, we assume x is numeraire, $p_x = 1$ and $p_y \equiv p$.

(3) Structure (x/z,y), i.e. an individual produces x and buys z and y. The decision problem for this structure is

(III-3) Max: $U = xy^d(1-k)$

x,y^d,x^s,z^d

s.t. $x + x^s = [(1-t)z^dL]^b$ (production functions)

$x^s = py^d + qz^d$ (trade balance)

where q is the price of good z in terms of good x.

(4) Structure (z/x,y), i.e. an individual produces z and purchases x and y. The decision problem for this structure is

$$\text{(III-4)} \qquad \underset{x^d,y^d,z^s}{\text{Max:}} \quad U = x^d y^d (1-k)^2$$

$$\text{s.t.} \qquad z^s = L^c \quad \text{(production functions)}$$

$$qz^s = x^d + py^d \quad \text{(trade balance)}$$

(5) Structure (y/x), i.e. an individual produces y and buys x. The decision problem for this structure is

$$\text{(III-5)} \qquad \underset{y,x^d,y^s}{\text{Max:}} \quad U = yx^d(1-k)$$

$$\text{s.t.} \qquad y + y^s = L^a \quad \text{(production functions)}$$

$$py^s = x^d \quad \text{(trade balance)}$$

The following two structures are exactly the same as structures (x/z,y) and (z/x,y) respectively except that the transaction method differs.

(6) Structure (x/L,y), i.e. an individual becomes an employer, producing x and buying labor L and y. He purchases $M_{zx}L$ units of labor from the labor market and lets the workers specialize in the production of z. $M_{zx} \equiv M_z/M_x$ is the relative number of workers producing z to employers selling x, or the number of workers hired by the employer. The decision problem for this structure is

$$\text{(III-6)} \qquad \underset{x,y^d,x^s,z^d,M_{zx}}{\text{Max:}} \quad U = xy^d(1-k)$$

$$\text{s.t.} \quad x + x^s = [(1-t')M_{zx}z^dL]^b, \quad z^d = [(1-t'')L]^c \quad \text{(production functions)}$$

$$x^s = py^d + wM_{zx}L \quad \text{(budget constraint)}$$

where w is the wage rate in terms of good x. $1/t'$ is supervision efficiency within a firm; a fraction t' of output disappears in the production process

because of the supervision costs. $1/t''$ is transaction efficiency in labor market; a fraction t'' of labor service purchased by an employer disappears in labor trade. For simplicity, I let t' denote the transaction cost coefficient in supervising and trading labor and assume $t'' = 0$. If $b < 1$, the optimal M_{zx} is determined by the decision problem (III-6). If $b \geq 1$, the optimal M_{zx} in problem (III-6) is infinitely great. For this case the equilibrium M_{zx} is determined by free entry that maximizes the real returns to labor with respect to M_{zx}.

(7) Structure (L/x,y), i.e. an individual becomes an employee, he sells labor and purchases x and y. The decision problem for this structure is

(III-7) $$\text{Max: } U = x^d y^d (1-k)^2$$
$$x^d, y^d,$$
$$\text{s.t.} \qquad wL = x^d + py^d \quad \text{(budget constraint)}$$

From each one of these problems, I can solve for the optimal decisions including individual demand and individual supply for a given structure. Inserting the optimal decisions into utility functions, I obtain indirect utility functions, as functions of relative prices. They differ from structure to structure.

IV. Equilibrium

Due to the existence of increasing returns, there is a corner solution for each structure. By the combinations of these structures, we have several market structures. For each market structure, there is a candidate for equilibrium. Such a candidate is an analogue of a corner solution. I call it a corner equilibrium. In subsection IV.A, I solve for the corner equilibrium for each market structure. In subsection IV.B, I solve for the Pareto optimum corner equilibrium. Finally, I identify full equilibrium among these corner equilibria and prove that it is the Pareto optimum.

IV.A The Market Structures

From logically consistent combinations of the structures listed in the previous section, I can obtain four market structures. I will refer to them simply as "markets". These are

(i) Autarky. All individuals choose structure (x,y,z).

(ii) Partial division of labor in producing final goods, I refer to this market as P. This market is a combination of structure (x,z/y) and structure (y/x).

(iii) Complete division of labor without firms, I refer to this market as C. This market is a combination of structures (x/z,y), (z/x,y) and (y/x).

(iv) Complete division of labor with firms, I refer to this market as F. This market consists of structures (x/L,y), (L/x,y) and (y/x).[4]

It is easy to see that market F and market C have the same organizational structure of production and different transaction arrangements. Market F replaces the transaction of intermediate goods in the market between individuals by the transactions of intermediate goods within a firm and trades of labor in the market. As Alchian and Cheung pointed out, a firm replaces the external market for products by an internal market for intermediate service within a firm and external market for factors. In other words, people can choose alternative contractual arrangements in the external market to organize the division of labor and trade other than the wage contract associated with firms.

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[4] It could be proven that other markets, e.g. a combination of autarky structure and another market or a combination of structure (x,z/y) and market C, cannot occur in equilibrium. Therefore, we are not concerned with them. A formal proof of a proposition similar to this statement can be found in Yang [1987a].

We should explain why the wage contract supersedes other alternative contract arrangements and cannot just take the institution of the firm as given.

Let the number of individuals selling good (or factor) i be M_i; I can obtain aggregate demand (or supply) in a given market by multiplying M_i with individual demand for (or supply of) good i. Because the total number of all individuals is a constant M, we need solve only for the relative numbers of individuals choosing different structures. That is, I can solve M_s from $\Sigma M_i = M$ if I know all other M_i $(i \neq s)$.

Letting aggregate demand equal aggregate supply, we have the market clearing conditions in a given market. Free entry will make the utilities in different structures equal to one another.

For market P, for example, the market clearing condition is

(IV-1a) $$M_x x^s = M_y x^d$$

and the utility equalization condition is

(IV-1b) $$xy^d(1-k) = yx^d(1-k)$$

where M_x is the number of individuals choosing structure (x,z/y) and M_y is the number of individuals choosing structure (y/x) and $M_x + M_y = M$.

For a given market, if we have n traded goods, then we have n-1 independent market clearing conditions and n-1 relative prices of traded goods. If a market includes m structures, then we have m-1 utility equalization conditions and m-1 relative numbers of individuals choosing different structures. From direct calculation, we can show that there is a unique corner equilibrium for each one of the four markets. A corner equilibrium is defined by n-1 corner equilibrium relative prices and m-1 corner equilibrium relative numbers of individuals choosing different structures. The corner equilibria in the four markets are the candidates for equilibrium.

V.B The Pareto Optimum Corner Equilibrium

For a given market, I can construct a problem to solve for the restricted Pareto optimal allocation. By "restricted", I shall mean that the market structure is given. In this problem, I maximize the utility in a structure with respect to the quantities of all goods and subject to production functions, the balance between the total consumption and total production of each good, and the condition that the utilities in other structures are not less than some constants. By manipulating the algebra, it is easy to prove that each corner equilibrium found in the previous subsection is a restricted Pareto optimal allocation. Comparing all corner equilibrium utilities in different markets, I will identify the corner equilibrium with maximum utility. I define such a corner equilibrium as the Pareto optimum corner equilibrium. It is easy to see that this corner equilibrium satisfies the necessary conditions for the Pareto optimum. Here the Pareto optimum is defined similarly to the restricted Pareto optimal allocation, except that there is no constraint imposed on the choice of market.

From direct calculation and comparison of the corner equilibrium utilities in four markets, I can show the following proposition

Proposition 1

For $b < 1$, we have that

(1) Complete division of labor without firms (market C) is the Pareto optimum corner equilibrium if $f(t,k) < g(b, c)$ and $t < t'$, where $f(t,k) = -\ln(1-t)-\ln(1-k)^{1/2}$, $g = \ln b+(1/b-1)\ln(1-b)+c\ln(1+1/c)+b\ln(1+c)$, $\partial f/\partial t > 0$, $\partial f/\partial k > 0$, $\partial g/\partial b > 0$ and $\partial g/\partial c > 0$.

(2) Complete division of labor with firms (market F) is the Pareto optimum corner equilibrium if $f(t',k) < g(b, c)$ and $t' < t$.

(3) Autarky is the Pareto optimum corner equilibrium if $k > 1-h(a,b,c)$, where $h(a,b,c) = 4[b(1+c)]^{b(1+c)}a^{a}/[b(1+c)+a]^{b(1+c)+a}$, $\partial h/\partial a < 0$, $\partial h/\partial b < 0$, and $\partial h/\partial c < 0$.

(4) Partial division of labor (market P) is the Pareto optimum corner equilibrium if $f(t,k) > g(b,c)$, $f(t',k) > g(b,c)$ and $k < 1-h(a,b,c)$.[5]

In other words, if transaction efficiency is great, then the Pareto optimum corner equilibrium is associated with a high level of division of labor and if transaction efficiency in the labor market and supervision efficiency within firms are sufficiently greater than transaction efficiency in the market for intermediate goods, then the Pareto optimum corner equilibrium is associated with the market including firms.

IV.C Equilibrium and the Pareto Optimum.

In this subsection, I prove

Proposition 2

For the model set out in the previous subsections, the equilibrium is the Pareto optimum.

In order to establish this proposition, it suffices to

(i) show that the Pareto optimum corner equilibrium is an equilibrium; and

(ii) show that all non-Pareto optimum corner equilibria are not equilibria.

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[5] If $b \geq 1$, $f(t,k)$ and $g(b,c)$ will be changed, the major conclusion will, however, not be changed. The algebra to show this proposition is in the Appendix.

It is easy to show (i) because the Pareto optimum corner equilibrium ensures a full maximization of utility for each individual and all local equilibria satisfy all the necessary conditions for full equilibrium except for ensuring the full maximization of individual utilities.

To prove (ii), we must "break" all non-Pareto optimum corner equilibria. Assume that $f(t,k) \lessgtr g(b,c)$, i.e. the complete division of labor (market C) is an equilibrium and the Pareto optimum and other markets have non-Pareto optimum corner equilibria. For example, for local equilibrium in market P (the partial division of labor), there are corner equilibrium prices p, q and corner equilibrium utility U(P). All individuals know that they can choose any one of seven structures. Each individual can insert the corner equilibrium prices p and q of market P into indirect utilities of the structures in market C. If these utilities are greater than U(P), then individuals have incentives to break corner equilibrium in market P under corner equilibrium prices in market P.

In market C, there are three structures. The indirect utility functions in the three structures are

(IV-2a) $$U_x = G_x/pq^{2b/(1-b)}$$

(IV-2b) $$U_y = G_y p$$

(IV-2c) $$U_z = G_z q^2/p$$

where U_x, U_y, and U_z are indirect utility functions for structures (x/z,y), (y/x), and (z/x,y) respectively. G_i is constant depending on L, k, t, a, b, and c.

Let p' and q' be equilibrium prices in market C; we have utility equalization conditions in market C:

(IV-3) $$U_x(p',q') = U_y(p') = U_z(p',q') = U(C)$$

where U(C) is a constant depending on all parameters. Recalling that U(P) is corner equilibrium utility in market P; the assumption that market C is Pareto optimum corner equilibrium implies that $U(C) \rangle U(P)$.

Individuals will compare the utilities in the structures of market C under prices of market P, i.e. $U_x(p,q)$, $U_y(p)$, and $U_z(p,q)$ with U(P). If any one of the following inequalities holds, then individuals have incentives to shift to a structure of market C from market P under the prices in market P, i.e., market P is broken.

(IV-4a) $\quad U_x(p,q) \rangle U(P)$

(IV-4b) $\quad U_y(p) \rangle U(P)$

(IV-4c) $\quad U_z(p,q) \rangle U(P)$

Note, here we are in a Walrasian regime, each individual choosing a structure for given prices and not concerned with the behavior of other individuals. Because $U(C) \rangle U(P)$, one semi-inequality in (IV-4) will hold if one semi-inequality in (IV-5) holds.

(IV-5a) $\quad U_x(p,q) \geq U_x(p',q') = U(C)$

(IV-5b) $\quad U_y(p) \geq U_y(p') = U(C)$

(IV-5c) $\quad U_z(p,q) \geq U_z(p',q') = U(C)$

where the equalities are based on the utility equalization condition (IV-3). (IV-4) and (IV-5) imply that if $U_i(p,q) \geq U_i(p',q') = U(C)$, then $U_i(p,q) \rangle U(P)$ since $U(C) \rangle U(P)$. Concretely, (IV-5) is

(IV-6a) $\quad G_x/pq^{2b/(1-b)} \geq G_x/p'q'^{2b/(1-b)}$

(IV-6b) $\quad G_y p \geq G_y p'$

(IV-6c) $\quad G_z q^2/p \geq G_z q'^2/p'$

It is easy to see that in (IV-6) at least one semi-inequality must hold for any p, q and p', q'. This implies that individuals have incentives to shift to

at least one structure in market C from market P under corner equilibrium prices in P. That is, the non-Pareto optimum corner equilibrium in market P is not full equilibrium.

Repeating this procedure, we can break any of the other non-Pareto optimum corner equilibrium. Therefore, proposition 2 has been proven.

Propositions 1 and 2 imply that complete division of labor without firms (market C) is an equilibrium (and also the Pareto optimum) if transaction efficiencies 1/t and 1/k and/or the extent of increasing returns to specialization in producing intermediate goods are sufficiently great relative to the extent of increasing returns to specialization in producing final goods. If the extent of increasing returns to specialization and/or transaction efficiency are sufficiently small, then equilibrium and the Pareto optimum are autarky. For intermediate increasing returns to specialization and transaction efficiencies, the equilibrium and the Pareto optimum are the partial division of labor (market P). If transaction efficiency of intermediate goods within a firm and transaction efficiency in labor market are sufficiently great relative to transaction efficiency of intermediate goods in external market and the complete division of labor is Pareto superior to less division of labor, then equilibrium is associated with the market with firms. In other words, we have

Corollary 1

Increasing transaction efficiency and/or increasing extent of the economies of specialization will lead to a greater equilibrium (and Pareto optimal) level of division of labor. Moreover, equilibrium will be associated with the market including firms if supervision efficiency within firms and transaction efficiency in labor market are sufficiently greater than transaction efficiency in the market for intermediate goods.

This corollary has answered the question why firms substitute the external market for intermediate goods with the internal markets for intermediate goods within a firm and the external markets for labor. Furthermore, if $f(t,k) > g(b,c)$ (market P is Pareto superior to market C) and $f(t',k) < g(b,c)$ (market F is Pareto superior to market P), then the equilibrium will be market P (involving no division of labor in intermediate goods) and is not the Pareto optimum when there are no firms. The equilibrium will involve such division of labor and is Pareto optimum if firms are set up. This brings us to

Corollary 2

If transaction efficiency in labor market and supervision efficiency within firms are sufficiently greater than transaction efficiency in the market for intermediate goods and market P is Pareto superior to market C, i.e. market C (without firms) is not equilibrium, then the institutional innovation of firms will increase the level of division of labor and improve productivity and general welfare.

These two corollaries imply that the evolution of the division of labor in roundabout production (intermediate goods or services) and improvement of transaction efficiency are two sides of the rationale for the institution of the firm. Moreover, the emergence of the firm may increase the level of division of labor thereby increasing the total transaction cost although the firm will improve transaction efficiency if the benefits from the finer division of labor outweigh the increased transaction costs.

V. Comparative Statics

In this subsection, we will first discuss the comparative statics within a given market, then discuss the comparative statics across market structures.

Assume that equilibrium is associated with market F and all parameters may change under constraint $f(t',k) < g(b,c)$. Then we will obtain the comparative statics within the market by manipulating the equilibrium conditions.

(1) The ratio of intermediate products to final products characterizes the "roundaboutness" of production in an economy. This roundaboutness will increase with the extent of increasing returns to specialization. Formally, let the ratio be $R = M_z wL/(M_x x^s + M_y p y^s)$, where M_x, M_y, and M_z are the numbers of individuals choosing structures (x/z,y), (y/x), and (z/x,y) respectively. $M_z wL$ is the total value of intermediate good z and $M_x x^s + M_y p y^s$ is the total trade value of final goods. Then we have

(V-1) $\partial R/\partial b > 0$, if $3L^{1-b} > b\ln L - 1$ $R = 2b/(3-b+L^{b-1})$.

From the U. S. input-output tables, I can obtain data on the roundaboutness. These data indicate a significant increase in the roundaboutness over time. The ratio of values of intermediate goods to consumer goods are .44 in 1947, .54 in 1958, .55 in 1961, .57 in 1963, .62 in 1967 (see Department of Commerce [1975]).

(2) Assume that good z is a machine or other capital good; the capital-labor ratio in our model increases as transaction efficiency is improved. Let this ratio $S = M_z wL/ML$; we have

(V-2) $\partial S/\partial t' < 0$, $\partial S/\partial k < 0$, $\partial S/\partial c > 0$, $\partial S/\partial b > 0$

where $M_z wL$ is the total output value of intermediate (capital) goods, ML is the total quantity of labor, and

$$S = [b^{1+b}(1-b)^{1-b}(1-t)^{b}\ (1-k)^{b/2}L^{b(c+1)-1}]/[3-2b+b(1-k)^{1/2}].$$

(3) The number of workers hired by an employer, $M_{zx} \equiv M_z/M_x$ increases as the extent of increasing returns to specialization, "b" and transaction efficiency, 1/k, i.e.

(V-3) $M_{zx} = b(1-k)^{1/2}/(1-b)$ and $\partial M_{zx}/\partial b > 0$, $\partial M_{zx}/\partial k < 0$.

The algebra to show (II-7)-(II-9) is in the Appendix. For different markets, I can solve for corner equilibrium ratios of intermediate products to final products, corner equilibrium ratios of capital to labor, and of trade volume to income. By comparing these ratios in different markets and using the corollaries 1 and 2, we can obtain other results on the comparative statics across market structures.[6] From direct calculation, we can show that the three ratios will increase as the market evolves from autarky to the developed division of labor and this evolution may be induced by an improved transaction efficiency and/or an increased extent of increasing returns to specialization. The emergence of firms will be related to this evolution of market structure if the institution of the firm can be used to improve transaction efficiency.

If I specify production functions for many intermediate activities, then equilibrium may be associated with new firms specializing in finer subprofessions of intermediate activities if the gains from finer division of labor and from the decrease in transaction costs among subprofessions within such firms equal the increase in transaction costs between such firms and other firms at the margin. The institutional and technical innovations facilitating the improvement of transaction efficiency will shift equilibrium to a increasingly finer division of labor in intermediate activities. Such evolution of market structure and the institution of the firm will increase the capital-labor ratio in the whole economy. Therefore, the increase in the capital-labor ratio is not only a matter of technical conditions and available inputs, but also a matter of the evolution of the market and firm structure.

VI. Remarks on the Model

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[6] More general analysis on the comparative statics across markets can be found in Yang [1986].

Such a model has several merits.

(1) Primary production functions are relevant to individuals and each individual is able to produce any good. The prices are determined by the number of individuals choosing different structures, while free entry prevents any individual from manipulating these numbers. Therefore, there is no monopoly power in the market even though the equilibrium number of actual producers for a good may be small if the equilibrium is associated with a high level of division of labor. In other words, increasing returns to specialization is compatible with a Walrasian regime. In our model, a decentralized market can integrate increasing returns to specialization (internal to individuals) into the economies of the division of labor (external to individuals).

Moreover, Mills' production function is relevant to the relation between productivity and economic organization rather than to technology itself. This production function distinguishes increasing returns to specialization from the increasing returns to scale and the gains to trade based on comparative advantages. Therefore, our model based on the Mills' production function can be used to highlight the relation between the evolution of economic institution, the division of labor, and economic growth.

(2) For market F the individual production functions in structures $(x/L,y,z)$ and $(L/x,y)$ are aggregated into a production function of the firm. This aggregate production function looks like the conventional production function associated with U-shaped average cost curves (if $b < 1$) or that with global increasing returns to scale (if $b \geq 1$). However, the conventional production function is irrelevant to the decision problem of the optimal level of self-sufficiency and in fact our individual production function differs from the production function associated with U-shaped average cost curves or that

with global increasing returns to scale. Our model can be used to explain a simultaneous evolution of the division of labor, the market, and the firm. The evolution looks like a shift of the structure of production functions since new traded goods, new professions, and new firms will come to being and productivity will be improved as the division of labor and market evolve.

From direct calculation, we can show that the trade volume of final goods in the market is greater in market F than in market P if $f(t',k) < g(b,c)$. This implies that the evolution of the division of labor from market P to market F not only increases the exchange volume of intermediate service (or goods) within a firm, but also increases the trade volume of final goods in the market. This supports Alchian's idea about a simultaneous development of the firm and market.

In the equilibrium of market F, the number of workers hired by an entrepreneur is M_z/M_x, an increasing function of transaction efficiency 1/k, where M_z is the number of workers producing z in firms and M_x is the number of employers. This implies that an improvement of transaction efficiency will increase the equilibrium level of division of labor, thereby increasing the equilibrium number of workers hired by an entrepreneur and the equilibrium scale of the firm.[7]

For great supervision efficiency within a firm and transaction efficiency in the market for labor, relative to transaction efficiency in the market for intermediate goods, propositions 1 and 2 tell us that equilibrium is associated with the institution of the firm. However, these two propositions mean

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[7] In Vassilakis [1986], a model with increasing returns to scale is used to justify the increase in the worker-employer ratio based on the evolution of the division of labor.

that equilibrium will shift to corner equilibrium with the market for intermediate goods from one with firms if transaction efficiency in the market for intermediate goods is sufficiently improved relative to supervision efficiency within firms and transaction efficiency in labor market. In other words, whether individual professions are integrated into a firm or a firm disintegrated into separate professions depends upon the difference between transaction efficiencies in markets F and C.

(3) In this paper I adopt a multiple-step approach to solving for the equilibrium. This approach is flexible enough to accommodate different hierarchical structures of the firm and transaction network. For example, I can specify a transaction network associated with piece rate contracts in the firm and a transaction network associated with subcontract arrangements in the market, then I solve for two corner equilibria. The corner equilibrium utilities in the two market structures will be different because of the different transaction efficiencies of these transaction networks. Investigating the comparative statics, I can see under what condition equilibrium will shift from a corner equilibrium to another one. Also, this multiple-step approach can be used to extend the model in this paper to contain many final and intermediate goods and many roundabout professions in the division of labor.

This multiple-step approach simulates a searching process for the Pareto optimum by a trial-and-error method. In reality, this process not only searches for a Pareto optimal allocation of resources for a given market structure, but also searches for a Pareto optimal structure of the firm and market.

If we interpret z as the management services required in producing good x and assume that the individual producing z may set up a firm by hiring the

individuals producing x, then we can show that equilibrium will be associated with the institution of the firm when the transaction efficiency in labor trade is sufficiently greater than the transaction efficiency in trade of management services.

The model of this sort differs from that without management services. In the model without management service, goods are tangible commodities. But management services in the revised model is intangible knowledge property, which is usually in the form of know-how. For such models, we will have problems of information.

Indeed, in the model without management problem, there implicitly is a problem of information. In our model, the original system of production functions is identical for all individuals. However, if people specialize in the production of different goods and/or have different levels of specialization, productivities of various goods will differ from individual to individual in equilibrium, i.e. there are comparative advantages in production based on increasing returns to specialization.[8] Such comparative advantages based on increasing returns to specialization imply that an individual specializing in a certain production process knows more about this process than the individuals specializing in other production processes. In fact, the gains from trade in such a model are based on the difference in knowledge possessed by individuals

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[8] When there is no increasing returns to specialization, if production function is identical for all people, productivities of all goods in equilibrium will be identical for all people. The discussion on the distinction of comparative advantage based on increasing returns to specialization from the comparative advantage based on constant returns can be found in Yang [1987a].

specializing in different professions. However, in the model without management problem, individuals do not directly trade knowledge. They trade tangible goods or service which embody the specific information on how to efficiently produce them (implicitly represented by prices). In the revised model, individuals may directly trade management knowledge in the market place. But the intangible commodity, like all other commodities of this sort has serious problem of transaction. First, it is extremely difficult to delimit the rights to contract for such intangible commodities because of prohibitively great cost of keeping an owner's exclusive property rights over such commodities. Second, the costs of enforcing the payments from those individuals having used management knowledge to the owner of the knowledge are extremely great because of the existence of "spill-over".[9]

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[9] There are three ways to address the problem of intangible commodity: (1) There is no market for the intangible commodity because the rights to contract on the commodity cannot be delimited. (2) There is no market for the intangible commodity because pricing costs (costs of metering the quantity traded, costs of finding price, and costs of collecting payment) are prohibitively great. (3) In the market, allocation of the intangible commodity is not efficient because of externalities. Essentially, these three ways are closely related to one another. For example, we can say that the rights to contract cannot be delimited because of great pricing costs. Or we can say that there are externalities because there is no the market for the intangible goods (pollution or some knowledge), while the lack of the markets is due to transaction costs that are too large. The relation and distinction among these three methods needs to be clarified in further research.

In other words, pricing costs of management knowledge in a market are so high that a market for management services is sometimes almost infeasible. Hence, using the revised model it is easy to show that the equilibrium in the division of labor between producing intangible management knowledge and tangible goods involves the institution of the firm and a market for labor rather than a market for management service. The function of the institution of the firm is thus to replace the market for management knowledge or other intangible commodities (e.g. organizational structure of large corporation itself is a kind of property) with the market for labor or other tangible commodities (e.g. other factors or the large corporation itself) in order to avoid extremely great transaction costs in the developed division of labor between the production of intangible property and the production of tangible commodity.[10]

Such replacement is a common economic phenomenon. For example, TV stations replace trading of information between TV program producers and their audience with trading among advertisement agents, the TV stations, and the customers of the TV program and goods advertised by the agents. This is because pricing efficiency in the latter trade is much greater than in the former trade. It is expensive to monitor who watches which TV program and to collect payments from each viewer. Therefore, the latter trade may be Pareto superior to the former though everybody knows that the latter trade causes some distortion by forcing the audience to watch advertisements that they might prefer not to see.

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[10] The market for labor has a similar (moral hazard) problem: transaction costs to specify the quality of labor, i.e. effort, are great. Hence, the institution with relatively less serious problem of transaction cost will be prefered.

In other words, the institution of the firm may be used to efficiently protect intangible knowledge property and improve its pricing efficiency. In particular, the trade of the firms themselves (e.g. sale of a large corporation) can efficiently delimit the exclusive rights to contract over intangible property of management knowledge.

According to the theory produced by a model of this sort, any tax on trade (domestic and international) is harmful to economic growth and general welfare. Such a tax will decrease transaction efficiency and thereby decrease the equilibrium level of division of labor. But this theory by no means implies that all governments that taxing their residents are irrational. The theory in this thesis can in fact be used to justify taxation. Because governments produce many intangible commodities and the transaction efficiency for such commodities is extremely low, we need taxation to finance the production of such intangible properties.

If the firm is not available as an institution and the market for management services involves transaction costs that are too great, then there does not exit an equilibrium with a complete division of labor. The individuals who produce goods and need the management knowledge will be free riders and nobody will be willing to specialize in management. So called "market failure" will occur. In this sense, the institution of the firm can be used to overcome this "market failure." However, the firm is a type of market system. It replaces the market for management services by the markets for factors and internal market within firms. In this sense, the function of the firm is to replace deficient markets by efficient ones.

Indeed, there is an almost unlimited number of feasible institutional arrangements if the products are many and the division of labor in roundabout

activities is developed. The function of a decentralized market in searching for the efficient institutions and market structures may be much more important than its function in allocating resources within a certain institution and market structure.

Conclusions

In this paper, we formalize Coase's notion of the role of the firm. The basic approach here is a typically neoclassical one of utility and production functions. However, in specifying production function, we emphasize the concept of localized technology, proposed by Sah and Stiglitz [1986]. A production function is specified for individuals and labor is specific for each individual. For traditional production functions, employers just put labor and other factors into "production functions" and obtain output from such black boxes. What is the internal organization of the black box, what implications does the internal organization have for the traditional theory of equilibrium, and why does an economy evolve from autarky without firms to one with the developed division of labor within firms and among the firms? The model in this paper allow us to open the black box and to answer these questions.

In our model, the function of the firm is not only to put input factors into the black box of the production function and to pick up outputs from the black box, but also to organize the individuals' production functions into a combined one, which may have greater productivity than the combination of these individual production functions in the market without firms. This is because the institution of the firm may be used to improve transaction efficiency, thereby increasing the equilibrium level of the division of labor.

Based on the theory of firms formalized in this paper, we can show that all the results concerning trade and economic growth derived from the models with increasing returns to specialization in Yang [1986] and [1987] continue to hold when firms are introduced.

Combining the approach in this paper with the approach to the dynamic model in Yang [1987b], we can show that the division of labor evolves over time even if there is not exogenous progress in transaction efficiency. Whether this evolution involves the institution of the firm depends on the relative extent of increasing returns to specialization in trading labor to that in trading intermediate goods.

The most important result of this paper concerns two functions of the free market system (free price system and free enterprise system) beside its function in allocating resources for a given level of division of labor (market structure) and a given institutional arrangement. The first one of these two functions is to search for the efficient level of division of labor (market structure). The second one is to search for the efficient institutional arrangements.

Accordingly, we find three types of distortions that can result from inappropriate government intervention: (i) The distortion of resource allocation for given levels of division of labor and institutional arrangement. This is the major concern of the traditional microeconomics. (ii) The distortion of organizational structure. (iii) The distortion of institutional arrangements. For example, if a government places a tax on business sales at proper rates such that relative prices do not deviate from efficient ones, then the tax will not cause allocative distortion. However, such a tax will increase transaction costs in the market for management services, thereby causing the

equilibrium to have a lower level of division of labor than without such a tax. Moreover, such a tax favours the institution of the firm and the market for labor over the market for management services. Hence, the equilibrium institutional arrangement may deviate from the efficient one if the efficient one is in fact the market for management services.

Appendix The Algebra to Show Proposition 1 and Comparative Statics

In this appendix, I first present the algebra to solve for corner equilibria in four markets one by one. Then I present the algebra of comparative statics in market F.

(1) First, I consider marekt A. This marekt consists of one structure (x,y,z). The decision problem for this structure is given in (III-1). The optimal decisions of (III-1) are

(1-1) $L_x = bL/(bc+b+a)$ $L_y = aL/(bc+b+a)$ $L_z = bcL/(bc+b+a)$

$z = L_z^c$ $x = (zL_x)^b$ $y = L_y^a$ $U_A = xy$

(2) In marekt P there are two structures (x,z/y) and (y/x). The decision problem for structure (x,z/y) is given in (III-2). The optimal decisions in this structure are

(2-1) $L_x = L/(c+1)$ $L_z = cL/(c+1)$ $x = x^s = py^d = (L_xL_z^c)^b/2$ $U_x = xy^d(1-k)$

where p is the price of y in terms of x.

The decision problem for structure (y/x) is given in (III-5). The optimal decisions in this structure are

(2-2) $L_y = L$ $y = x^d/p = L^a/2$ $U_y = yx^d(1-k)$

Let $U_x = U_y$, I obtain the utility equalization condition in market P which gives corner equilibrium price

(2-3) $p = c^{bc}L^{bc+b-a}/(c+1)^{bc+b}$

Inserting (2-3) into U_x or U_y, I find the real returns to labor in market P

(2-4) $U_p = [L/(c+1)]^{bc+b} c^{bc} (1-k) L^a/4$

(3) In marekt C, there are three structures (x/z,y), (z/x,y), and (y/x). The decision problem for structure (x/z,y) is given in (III-3). The optimal decisions in this structure are

(3-1) $x = py^d = q(1-b)z^d/2b \quad z^d = [b(1-t)^b L^b/q]^{1/(1-b)} \quad U_x = xy^d(1-k)$

where q is the price of z in terms of x.

The decision problem for structure (z/x,y) is given in (III-4). The optimal decisions in this structure are

(3-2) $x^d = py^d = qL^c/2 \quad U_z = x^d y^d (1-k)^2$

The optimal decisions in structure (y/x) are given by (2-2). Let $U_x = U_y = U_z$, the utility equalization conditions give the corner equilibrium prices in marekt C.

(3-3) $p = L^{bc+b-a}(1-k)^{b/2} b^b (1- b)^{1-b} (1-t)^b$

$q = L^{b-c+cb}(1-k)^{(b-1)/2} b^b (1- b)^{1-b} (1-t)^b$

Inserting (3-3) into U, I find the real returns to labor in market C

(3-4) $U_C = L^{bc+b+a}(1-k)^{b/2+1} b^b \ (1-b)^b (1-t)^b/4$

Note, here I assume that b ‘ 1.

(4) In marekt F, there are three structures (x/L,y), (L/x,y), and (y/x). The decision problem for structure (x/z,y) is given in (III-6). The optimal decisions in this structure are

(4-1) $M_{zx} = [wL/bL^{bc+b}(1-t')^b]^{1/(b-1)}$

$x = py^d = [L^{bc+b}(1-t')^b M_{zx}^b + wM_{zx}L]/2 \quad U_x = xy^d(1-k)$

where M_{zx} is the relative number of employees to employers and w is the price of labor in terms of x.

The decision problem for structure (L/x,y) is given in (III-7). The optimal decisions in this structure are

(4-2) $x^d = py^d = wL/2 \quad U_L = x^d y^d (1-k)^2$

The optimal decisions in structure (y/x) are given by (2-2). Let $U_x = U_y = U_L$, the utility equalization conditions give the corner equilibrium prices in marekt F.

(4-3) $\quad p = wL^{1-a}(1-k)^{1/2} \qquad w = b^b(1-b)^{1-b}(1-t')^{b(b-1)}(1-k)^{(b-1)/2}L^{bc+b-1}$

Inserting (4-3) into U, I find the real returns to labor in market F

(4-4) $\quad U_F = b^b(1-b)^{1-b}(1-t')^{b(b-1)}(1-k)^{1+b/2}L^{bc+b-1}/4$

Comparing U_A in (1-1), U_P in (2-4), U_C in (3-4), and U_F in (4-4), I obtain proposition 1.

Next, I present the algebra of comparative statics in market F. According to (II-7), the roundaboutness in market F is defined as

(5-1) $\quad R = M_z wL/(M_x x^s + M_y p y^s) = M_{zx} wL/(x^s + M_{yx} p y^s)$

where M_i is the number of individuals producing good i and M_{ij} is the relative number of individuals producing good i to individuals producing good j. The numerator of (5-1) is the total value of intermediate products and denominator is the total value of consumer goods. Here, w and p are given by (4-3). Inserting w given by (4-3) into M_{zx} given in (4-1), I find

(5-2) $\quad M_{zx} = b(1-k)^{.5}/(1-b)$

From the marekt clearing condition for good y

(5-3) $\quad M_x y_x^d + M_z y_L^d = M_y y^s$

where y_i^d is the quantity of y demanded by individuals producing good i, the quantity and y^s are given by the individual optimal decisions, I find

(5-4) $\quad M_{yx} = (1-t')^b L^{bc+b-a} M_{zx}^b / p$

Inserting the value of p in (4-3) and the value of M_{zx} in (5-2) into (5-4), I can obtain the value of M_{yx}.

Inserting the values of w, p, and M_{ix} into (5-1), I find

(5-5) $\quad R = 2b/(3-b+L^{b-1})$

It is not difficult to drive (II-7) from (5-5).

According to (V-2), the capital-labor ratio is defined as

(5-6) $S = M_z wL/ML = M_z wL/(M_x+M_z+M_y)L = M_{zx} w/(1+M_{zx}+M_{yx})$

where numerator is the total value of capital (intermediate) goods and the denominator is the total amount of labor. w is given by (4-3), M_{zx} and M_{yx} are given by (5-2) and (5-4) respectively. Therefore, I can derive S in (V-2) from (5-6), (4-3), (5-2), and (5-4).

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