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Inframarginal analysis of division of labor A survey

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Abstract

This paper provides an updated survey of the rapidly growing literature on inframarginal analysis of division of labor, tracing the development of this literature since its emergence in the 1970s and exploring the linkages between this literature and classical ideas on division of labor and contemporary work from other research programs. The paper also outlines the basic inframarginal economics and illustrates its wide applications by reviewing recent work in a wide range of research fields including international trade, e-business, theory of the firm, contract and property rights, public economics, economics of the state, economics of urbanization, and macroeconomics.

1. Introduction

This paper provides an updated survey of the rapidly growing literature on inframarginal analysis of division of labor, tracing the development of this literature since its emergence in the 1970s and to explore the linkages between this literature and classical ideas on division of labor and contemporary work from other research programs. The paper also outlines the basic inframarginal analytical framework and illustrates its wide applications by reviewing recent work in a wide range of research fields including international trade, e-business, theory of the firm, contract and property rights, public economics, economics of the state, economics of urbanization, and macroeconomics.

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2. What is inframarginal economics?

2.1. Marginal and inframarginal decisions

We categorize business decisions into two classes: marginal decisions of resource allocation and inframarginal decisions of economic organization. Marginal decisions involve the extent to which resources are allocated to a pre-determined set of activities. Inframarginal decisions are about what activities to engage in (or whether or not to engage in an activity).

To illustrate, before a student enrolls in a university, he needs to choose his major (field of study). If he chose economics as his major, then typically he would take microeconomics and macroeconomics classes rather than chemistry or physics classes. His choice of major and the associated choices of courses to take are inframarginal decisions since they involve deciding *what* activities to engage in (which is a series of yes-no decisions or corner decisions). Once he has chosen his major and classes, he then decides how to allocate his time to the chosen courses. These allocation decisions are marginal decisions since they involve deciding the *quantity* of resources devoted to each activity given the activities that have been chosen.

In the context of social division of labor, inframarginal decisions are perhaps more important than marginal decisions. If each individual chose to be self-sufficient (which is an inframarginal decision that says yes to production of all essential consumption goods and no to all trade activities), there would be no trade connection between individuals and no social division of labor. If each individual chose to specialize in producing a single good and to buy all other goods that he consumed (which is an inframarginal decision), then the network of division of labor would be very large. There are many intermediate network sizes of division of labor between the two extremes. As an individual becomes more specialized, he must have more trade connections with other specialists to obtain goods that he needs but does not produce. Thus, an individual's (inframarginal) specialization decision determines his trade connections with others, and all individuals' specialization decisions jointly determine the network size and pattern of social division of labor. For this reason, we refer to individuals' (inframarginal) specialization decisions as inframarginal network decisions.

2.2. Inframarginal analysis and Smithian framework

Inframarginal analysis is concerned with optimal inframarginal network decisions and the outcome of these decisions. The optimization of inframarginal network decisions involves both total cost benefit analysis across different network patterns of specialization and trade connections as well as marginal analysis of resource allocation for a given network pattern.

In mathematical terms, inframarginal analysis includes all non-classical mathematical programming (linear and non-linear programming, mixed integer programming, dynamic programming, and control theory) that allows corner solutions. Inframarginal analysis was developed by mathematicians in the 1950s and has been applied to economics by Koopman, Arrow, and other economists in the 1950s and 1960s.[1] Inframarginal economics is a combination of inframarginal analysis and a Smithian framework of consumer–producers.

[1] Coase (1946, p. 173) noted "a consumer does not only have to decide whether to consume additional units of a product; he has also to decide whether it is worth his while to consume the product at all rather than spend his money in some other direction". He applies this inframarginal analysis to criticize the marginal cost pricing rule

Yang and Ng (1993) call it the "new classical framework". The two terms will be used interchangeably in this paper. Also, inframarginal economics and new classical economics are interchangeably used. We will discuss why inframarginal analysis is not enough and the Smithian framework is essential for studies of network effects of division of labor in Section 3.3. Inframarginal economics emerged in the 1980s and focuses on individuals' inframarginal decisions. The outcome of inframarginal networking decisions forms the topological properties of an organism, which can be represented by a graph consisting of vertices (or nodes, points) and edges (or lines, curves). All information about marginal decisions of resource allocation form non-topological properties of an organism and can be represented by weights attached to edges and vertices of the graph. A weighted directed graph (or digraph) can describe topological as well as non-topological properties of an economic organism. Marginal analysis focuses solely on non-topological properties of economic organisms, while inframarginal analysis focuses on topological properties of economic organisms, taking into account non-topological properties as well.

3. Economic analysis of division of labor

3.1. Classical literature

Well before the publication of Smith's (1776) Wealth of the Nations, classical thinkers had studied the division of labor.[2]

Plato (380 B.C., pp. 102–106) considered the welfare implications of division of labor and the linkage between the division of labor, the market, and money. Petty (1671, pp. 260–261) noted the productivity enhancing property of specialization in cloth-making and shipping and later Petty (1683, pp. 471–472) also observed that cities could promote the division of labor by reducing transaction costs. Tucker (1755, 1774) examined the productivity implications of the division of labor and the relationship between a greater variety of goods, higher degree of production roundaboutness, and a higher level of division of labor.

A number of thinkers, notably Diderot (1713), the anonymous author of *Consideration on the East-India Trade* (1701, p. 91), Maxwell (1721, p. 33), and Josiah Tucker, recognized the three advantages of the division of labor (improving the skill of individual workers, saving the time and effort spent on switching from one task to another, and facilitating the invention of machinery) and the role of the market and population size in stimulating specialization. Anne–Robert–Jacques Turgot (1751, p. 242–243) observed the linkage between the development of division of labor and an increased living standard for even the humblest member of society and increased inequality of income distribution. Turgot (1766, pp. 44–46, 64, 70) further noted the linkage between the division of labor, the introduction of money, the extension of commerce, and the accumulation of capital.

(1946) and Pigou's marginal analysis of externality. Buchanan and Stubblebine (1962) coined term inframarginal analysis. Koopman (1957) and Arrow et al. (1958) are among those economists who initiated formal inframarginal analysis in economics.

[2] A collection of classic literature on division of labor, "Readings in the Division of Labor", edited by Monchi Lio and Guangzhen Sun, is scheduled to be published by World Scientific Publishers in 2004.

The most influential classical work on the division of labor is, of course, Adam Smith's *Wealth of Nations* first published in 1776. Smith (1776) systematically investigated the implications of division of labor for wealth creation and prosperity of nations. One of Smith's well-known insights was that the division of labor is limited by the extent of the market which, in turn, is affected by transportation efficiency (Chapter 3 of book I). He proposed a theory of capital in which capital is a vehicle for increasing division of labor in roundabout productive activities (p. 371). In addition, he observed that economies of specialization and division of labor may exist even if all individuals are ex ante identical and that the differences in productivities between various specialists are consequences rather than causes of the division of labor (p. 28).

Smith also contended that the industrial sector benefited more from specialization (relative to the seasonal adjustment costs associated with specialization) than the agricultural sector, which was the main reason for the productivity differences between the two sectors. This theory explains economic structure by the different balance points in trading off economies of division of labor against coordination cost of the division of labor, instead of by tastes, income, or exogenous technical conditions. An extension of theory implies that a decline in income share of the agricultural sector occurs not because of a change in tastes, in income, or in exogenous technical conditions, but because the agricultural sector has a higher coordination cost of the division of labor compared to the benefits derived from the division of labor, and it can improve productivity only by importing an increasingly larger number of industrial goods whose production takes advantage of a high level of division of labor in the manufacturing sector where transaction costs are more likely to be outweighed by economies of division of labor.

The classical insights on the division of labor were appreciated by Marshall and presented in his influential textbook *Principles of Economics* (1890, Chapters 8–12 of book IV). Marshall, however, was not able to present these classical insights in a mathematical framework due to a lack of mathematical tools at the time. The economic theory that Marshall was able to present in a consistent mathematic framework concerned the marginal analysis of demand and supply and of resource allocation (Yang and Ng, 1993). Marshall's mathematical framework of resource allocation enjoyed enormous success and popularity, establishing neoclassical economics which became mainstream neoclassical microeconomics. Unfortunately, neoclassical mainstream economics includes little classical economic thinking on the division of labor, and the core of classical economic thinking on the division of labor has been neglected. As Buchanan (1994, p. 6) observes, "with one part of his mind always in classical teachings, Marshall recognized that this genuinely marvellous neoclassical construction requires that the Smithean proposition on labor specialization be abandoned". Also, Marshall's partial equilibrium analysis is incapable of formalizing the general equilibrium flavour of network effects of division of labor reflected in the Smith–Young theorem (see Section 3.2.1 below).

3.2. Modern literature

Partly due to the overwhelming influence of Marshall's neoclassical economic theory with a focus on the marginal and partial equilibrium analysis of the problem of resource allocation, there has been a relative sparsity of modern literature on the implications of

division of labor and the associated problem of economic organization. Following the success of Samuelson's textbook *Economics* (1948), which has little discussion of classical insights on the division of labor, the dominance of neoclassical economics was further entrenched. Nevertheless, the importance of a theory on the division of labor is not in dispute, as many would agree with Houthakker's (1956, p. 182) view that "there is hardly any part of economics that would not be advanced by a further analysis of specialization". In addition, some distinguished economists have expressed concern over the glaring omission of formal theory on the division of labor in mainstream economics. As Stigler observed (1976, p. 1029–1210):

> The last of Smith's regrettable failures is one for which he is overwhelmingly famous – the division of labor. How can it be that the famous opening chapters of his book, and the pin factory he gave immortality, can be considered a failure? Are they not cited as often as any passages in all economics? Indeed, over the generations they are. The failure is different: almost no one used or now uses theory of division of labor, for the excellent reason that there is scarcely such a theory . . . there is no standard, operable theory to describe what Smith argued to be the mainspring of economic progress. Smith gave the division of labor an immensely convincing presentation – it seems to me as persuasive a case for the power of specialization today as it appeared to Smith. Yet there is no evidence, so far as I know, of any serious advance in theory of the subject since his time, and specialization is not an integral part of the modern theory of production, which may well be an explanation for the fact that the modern theory of economies of scale is little more than a set of alternative possibilities.

Despite the lack of research into the division of labor by mainstream economists, there have been some notable contributions to the understanding of the driving forces and implications of the division of labor as well as to the development of techniques necessary for studying the division of labor in an internally consistent mathematical framework. It is convenient to discuss the diverse literature under the following headings: (1) Allyn Young's work, (2) early models of economies of specialization, and (3) modeling of endogenous specialization.

3.2.1. Allyn Young's work

As noted earlier, Smith contended that the division of labor is determined by the extent of the market. Young (1928, p. 539, 534) expanded Smith's insight and suggested that "[n]ot only the division of labor depends upon the extent of the market, but the extent of the market also depends upon the division of labor" and that "[d]emand and supply are two sides of the division of labor". We refer to Young's statements above as the "Smith–Young theorem".

The Smith–Young theorem implies circular causation between the division of labor and the extent of the market. Such circular causation is a common feature of network effects (for instance, the value of a telephone set to a user is dependent on the number of telephone users within the network, and the number of users is dependent on the value of telephone set to each user.) In this sense, the Smith–Young theorem is about network effect of division of labor. It implies that individuals' decisions to choose their levels of specialization are determined by the benefits of division of labor, which are, in turn, dependent on the number of participants in the network of division of labor (the extent of the market). In the meantime,

the number of participants in the network is determined by all individuals' specialization decisions.

Circular causation is also a typical feature in general equilibrium models. In a conventional general equilibrium model, the optimum quantities demanded and supplied are dependent on market prices while market prices are determined by all individuals' decisions of quantities of demand and supply. Hence, the Smith–Young theorem captures some important linkages between the division of labor, network effects and general equilibrium.[3]

Young used three concepts to describe the economies of specialization:

(1) *Individuals' level of specialization*. An individual's level of specialization increases as he narrows his scope of activities.
(2) *The length of a roundabout production chain*, or the roundaboutness of production.
(3) *The number of intermediate goods in each link of the chain*.

The three concepts are distinct from the concept of economies of scale in the neoclassical framework. As Young explains (p. 539), "[t]he mechanism of increasing returns is not to be discerned adequately by observing the effects of variations in the size of an individual firm or of a particular industry, for the progressive division of labor and specialization of industries is an essential part of the process by which increasing returns are realized. What is required is that industrial operations be seen as an interrelated whole".

Young's work represents a significant contribution in theory of the division of labor. It also foreshadows two promising lines of research into the division of labor. The first is to formalize the concept of division of labor that includes individuals' specialization, production roundaboutness, and variety of occupations and goods. The second is to model how the size and features of the market network are determined by impersonal networking and specialization decisions in a decentralized system.

3.2.2. Early models of economies of specialization

Studing the trade-off between economies of specialization and transaction costs, Houthakker (p. 182) noted that if transaction costs are high, then the economies of specialization will be outweighed by transaction costs associated with specialization, and the equilibrium level of division of labor and aggregate productivity will be low. Consequently, the extent of the market will be small and market demand and supply will be low. As the trading efficiency is improved, the equilibrium level of division of labor and productivity will increase, and the extent of the market and demand and supply in the market place will also increase.

Houthakker's concept of economies of specialization is different from the neoclassical concept of economies of scale of a firm. Houthakker observed, "[w]e have increasing returns to the extent that if several activities are replaced by a single one, there is less need for (internal) coordination and switching time and more scope for acquiring experience. The

[3] Young's criticism of the notion of static general equilibrium does not mean that he rejected the notion of general equlibrium, but rather it means we need a notion of dynamic equilibrium to describe spontaneous evolution in division of labor (see Section 4.3.2). He called the dynamic general equilibrium "moving equilibrium". Indeed, comparative statics of general equilibrium may, to a certain extent, capture the essence of his moving equilibrium.

output of the single activity may thus be raised above the combined outputs of the several activities" (p. 182).

Houthakker recognized that the formal analysis of the division of labor "involves the use of methods that are rather unlike those by which the classical questions of economics are discussed. These classical questions are treated with the aid of traditional calculus methods, but the latter are not suited to deal with indivisibility. It is in fact from indivisibility that the division of labor takes its start, and the basic indivisibility is that of the individual" (p. 182).

Falling short of developing a mathematical model, Houthakker used a graph (reproduced below) to illustrate the economies of specialization assuming production technologies with fixed learning costs.

Suppose there are two ex ante identical individuals. The production functions for the two goods and the endowment constraint are

$$x_1 = \text{Max}\{0, L_1 - A\}; \qquad x_2 = \text{Max}\{0, L_2 - A\}; \qquad L_1 + L_2 = 1$$

where x_i is the quantity of good i produced, L_i is the quantity of labor allocated to produce good i, A is a fixed learning or training cost in an activity and total amount of labor is one for each person.

In Fig. 1, without specialization, the aggregate production schedule for the two persons when each of them produces two goods is DI. With specialization (i.e., at least one person producing a single good), the aggregate PPF is MCAKBJL. It is obvious that the aggregate PPF with specialization is higher than that without specialization.

Based on Fig. 1, we can make the following observations:

(1) The division of labor involves both specialization and diversification. At points L and M, the two individuals specialize in producing the same good, and there is no division of labor. At point K, segments CA, BJ (excluding points C and J), the individuals specialize in different goods, and there is a division of labor between them.
(2) There is an ex post difference in productivity between ex ante identical individuals if they choose different levels of specialization. We refer to this ex post difference

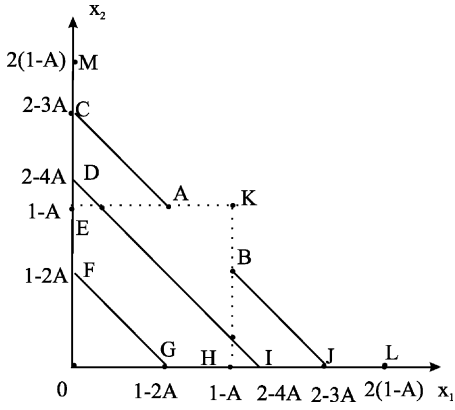

Fig. 1. Network effects of division of labor generated by fixed learning costs.

in productivity as endogenous comparative advantage that arises from an individual's decision to specialize.

(3) The network effect of division of labor can be formalized as a general equilibrium phenomenon based on the trade-off between economies of division of labor and transaction costs. If the benefit of division of labor outweighs the total transaction cost, then division of labor will occur in general equilibrium, and production takes place at MCAKBJL instead of DI. The difference between MCAKBJL and DI is a measure of the positive network effect of division of labor (in terms of aggregate productivity).

Another important early paper on economies of specialization is by Stigler (1951). Like Houthakker, Stigler used a graph to show that a firm's productivity increases as it narrows its range of production activities. He demonstrated that a firm's cost function will endogenously and discontinuously change as the firm makes different decisions about its level of specialization. Stigler's work followed Marshall's approach of separating the analysis of demand from the analysis of decision making regarding the level of specialization, but emphasized increasing returns to specialization rather than Marshall's concept of external scale economies.

3.2.3. Modeling an individual's decision of his level of specialization

As noted in earlier, modeling an individual's decision of his level of specialization is an important project on the research agenda implicitly set by Young. Rosen and Becker are two pioneers in this line of research.

Rosen (1978) extended the Ricardo model to include many goods and many individuals. Using a managerial decision model and applied linear programming to examine individuals' specialization decisions which involve corner solutions, he showed that economies of division of labor are endogenously determined by individuals' decisions on their levels and patterns of specialization. As individuals choose different levels and patterns of specialization, resource allocation may jump from one transformation curve to another, generating changes in productivity (see Fig. 1 in Rosen, 1978, p. 236). The more the interactions occur among individuals, the larger the scope for productivity improvement. This is a social complementarity which Rosen calls "superadditivity".

Superadditivity is different from economies of scale or technical complementarity that relates to economies of scope. Economies of scale and economies of scope relate to pure technical relationships between outputs and inputs and are independent of the degree of interpersonal and social interdependence. In contrast, superadditivity is intimately dependent on interdependence between individuals that is a result of the individuals' specialization decisions. Since the aggregation of individuals' decisions can generate many possible patterns of division of labor, and each of the patterns is associated with a certain size of network of exchanges, Rosen's superadditivity is a concept that captures the essence of the Smith–Young conjecture about the interdependence between the extent of the market and the division of labor.

Becker (1981) developed a model to endogenize individuals' decisions on specialization within a family. The solution of this model involved inframarginal analysis of many corner and interior solutions. The positive interaction between labor and human capital allocated to produce a certain good leads to complete specialization for all members of the family

except one when an integer condition for the numbers of different specialists is not satisfied. Becker's model endogenizes the pattern of specialization within a family and comparative advantages as a result of specialization (endogenous comparative advantage). It also formalized the classical idea that an advantage of specialization is the avoidance of duplicated learning and training costs.

Following Becker's (1981) idea of modelling learning costs, Rosen (1983) developed a model to explain individuals' specialization pattern. In his model, there is a learning cost associated with activity i ($i = 1, 2$). An individual chooses his time (t) allocation to maximize the net benefit specified as $V = w_1k_1t + w_2k_2(1 - t) - C(k_1, k_2)$, where k_i is learning and training level in activity i, C is the total learning and training cost, $1 - t$ is the amount of time allocated to activity 2, and w_i is a given benefit coefficient for activity i.

Since V is linear in t, the optimum value of t may involve a corner solution. Rosen used marginal analysis to solve for the two corner solutions that involve specialization in different activities and the interior solution, then compared total benefit-cost across all possible solutions. The result is that non-specialization is optimal if and only if economies of technical complementarity between two learning activities outweigh economies of specialization generated by a higher utilization level of a particular learning and training investment. This result again shows that social complementarity is different from technical complementarity. If $\partial^2 C/\partial k_1 \partial k_2 = 0$, which means no technical complementarity exists, two individuals can still take advantage of social complementarity by specializing in different activities.

Another important work on individuals' level of specialization is by Becker and Murphy (1992). The Becker–Murphy model investigates the relationship between the division of labor, coordination costs and human capital. It is a decision model where the optimum level of division of labor is determined by the condition that the benefit and cost of the division of labor are equalized at the margin. In this model, if coordination costs increase more rapidly than economies of division of labor as the number of different professions increases, then the optimum level of division of labor will evolve as the human capital parameter and/or the coordination cost coefficient change.

The Becker–Murphy model shows that the efficient level of division of labor is determined not only by the population size that is usually considered as the extent of the market, but also by the efficient balance between economies of division of labor and coordination transaction costs. This suggests that the concept of extent of the market needs to be more accurately defined. There are three aspects of the extent of the market: population size, the number of goods, and the number of traded goods relative to the number of all goods. Generally, a large population size means more scope for the division of labor and a larger market. A greater number of goods can also mean a larger market; if each individual buys all goods that he consumes, then the number of consumption goods determines his trade volume which, in turn, affects the extent of the market. Many new trade and growth models (see, for example, Dixit and Stiglitz, 1977; Ethier, 1982; Grossman and Helpman, 1989) have modelled the extent of the market by endogenizing the number of goods. However, these models do not endogenize the third aspect of the extent of the market which is determined by individuals' levels of specialization. If individuals' levels of specialization are not endogenized, then population size becomes the ultimate driving force of the number of goods, division of labor, and productivity. This result is inconsistent with evidence of a negative correlation between the population size and productivity in some less developed

economies. The Becker–Murphy model shows that even if the population size is fixed, a trade-off between economies of specialization and coordination costs can endogenize the level of division of labor: the driving force behind the division of labor can be falling coordination costs.

Other representative papers that model individuals' decisions of specialization include Baumgardner (1988a), Kim (1989), Locay (1990), and Tamura (1992).

Baumgardner (1988a) developed a partial equilibrium model with a given demand function for a continuum of service types to explain why physicians in a large city are more specialized than those in small towns. In this model, the analysis of demand is separated from the endogenization of individuals' levels of specialization as there is a dichotomy between pure consumers and producers. Global economies of scale lead to monopoly power and the market will trade-off the distortions caused by monopoly power, against economies of scale to determine the equilibrium range of services provided by each monopolist producer. As the population size increases, the scope for balancing the trade-off is enlarged, so that more economies of scale will be exploited by narrowing down each producer's range of activities. Hence, a larger population in the city enables a higher level of specialization than small towns.

Kim developed a model with many consumer-workers. A point on the circumference of a circle represents the characteristics of a worker which differ from those of other workers. Each worker can invest in two kinds of human capital, one can be used to reduce the matching cost with a potential employer by expanding the worker's characteristics, and the other can improve productivity. Each worker will trade-off the benefit from higher productivity against the matching cost to choose his investment in the two types of human capital. For a given pattern of each worker's human capital, the structure of a firm is determined by the trade-off between productivity gains from a narrower range of activities and the matching cost caused by the narrower range of activities of the firm. In this structure, all firms are evenly located on the circle, so that the average distance between each worker's range of characteristics and his employer's range of activities is minimized. As population size increases, the scope for the market to trade-off economies of specialization against matching costs is enlarged, so that the equilibrium level of specialization of each firm, the number of differentiated firms, and the wage rate increase.

Locay (1990) developed a model with many consumer–producers. Each person consumes only one particular good that is different from goods consumed by other consumers. The consumption goods and producer goods are structured in layers. On the top is a producer good that is essential for production of all producer goods at the second layer. Each producer good is essential for the producer goods that are in its span at a lower layer. Hence, the demand for the higher layer producer goods is greater than that for the lower layer producer goods. Goods can be produced within a firm or within a household. As labor is pooled together in a firm, productivity is increased even if the level of specialization of all workers within the firm is fixed. The disadvantage of production within a firm is a higher monitoring cost than household production. When this trade-off is made by a competitive market, the goods at top layers are more likely to be produced within firms due to a greater extent of the market for top layers goods, while the goods at lower layers are more likely to be produced by households. Increased population will enlarge the scope for the market to trade-off economies of scale against monitoring costs within a firm, and at equilibrium

more goods would be produced within firms. Locay's model endogenizes the extent of the market as determined by households' level of self-sufficiency, which is dependent on the population size. If one regards monitoring cost as a type of transaction costs, and introduces a monitoring cost coefficient to the model, the model can explain the extent of the market and households' level of self-sufficiency by the coefficient even in the absence of any changes in the population size.

Tamura (1992) develops a dynamic version of the Becker–Murphy model. Economies of specialization due to a higher utilization rate of training and learning investment are specified to endogenize the interval of activities of each individual specialist. He specifies a CES production function and the trade-off between current and future consumption to tell an endogenous growth story. However, the novelty of endogenization of specialization is lost in his dynamic macroeconomic model, due to aggregation. This model cannot predict evolution of individuals' specialization and of division of labor in society. Coordination cost is specified as an aggregate function of the population size. No trade-off between economies of specialization and transaction (or coordination) costs exists. Each specialist's interval of activities is directly determined by the population size. This is a setback from the Becker–Murphy model which can explain individuals' levels of specialization by the trade-off between economies of specialization and coordination costs even if the population size is fixed.

3.3. Literature of inframarginal economics

The beginning of the literature of inframarginal economics can probably be traced to Yang (1984), and the literature developed rapidly during the 1990s. Yang and Ng (1993) covers many early new classical models. Yang and Ng (1998) survey the literature, and Yang (2001) provides an updated survey.

Yang (2001, Chapter 1) uses the following figures to illustrate the difference between the Smithian framework and Marshall's neoclassic framework. Fig. 2 depicts the neoclassical framework where consumers (1 and 2) and firms (producing goods *x* and *y*) are separated. Consumers buy goods from the firms, thus their levels of self-sufficiency are pre-determined, and the institutions of the market and the firm are exogenously given. Within this framework, different levels of specialization by consumers may produce the same equilibrium outcome. For instance, suppose each consumer has one unit of labor which he sells to either or both firms. Two scenarios are possible. In scenario 1, consumer 1 and 2 each sells one unit of labor

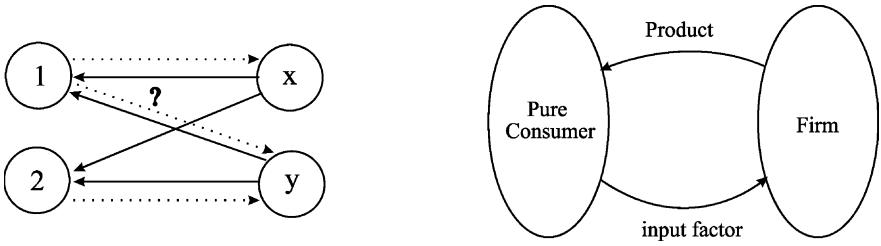

Fig. 2. Neoclassical analytical framework.

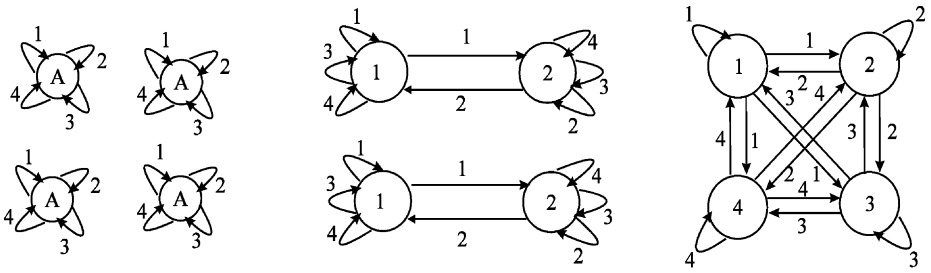

Fig. 3. New classical analytical framework.

to firm *x* and *y*, respectively; and in scenario 2, each consumer sells 0.5 unit of labor to each firm. In scenario 1, each individual is specialized whereas neither is specialized in scenario 2. Yet, within the neoclassical framework, both scenarios result in the same equilibrium output for the firms as total inputs the firms employ are the same, so the level of individual specialization does not make any difference to productivity. This is in sharp contrast to the classical economic thinking which regards the level of specialization and social division of labor as a driving force behind productivity progress. Inframarginal economics attempts to formalize the classical thinking and to put the division of labor at the core of the subject of economic inquiry.

Fig. 3 illustrates the new classical analytical framework. In each panel, there is an economy with four consumer–producers, each of whom consumes four goods and can choose to produce one, two, three, or four goods.

In panel (a), each consumer–producer is self-sufficient in all goods, thus there is no market and no market transaction costs. In this organizational structure, each person's level of specialization is low, as is his productivity. The economy consists of four separate units.

In panel (b), each consumer–producer produces only three goods, and obtains the fourth good through trade. There are two markets, and some transaction costs are incurred. Compared to the structure depicted in panel (a), this structure entails the division of labor and higher productivity. Compared to autarky, this structure has (1) a higher degree of specialization and diversity as two different specialists have emerged from the division of labor; (2) a higher level of production concentration as the number of producers for each good has decreased from four to two; and (3) a higher degree of integration as the economy now comprises two separate local business communities instead of four, consequently, the degree of interaction between individuals, the degree of each person's trade dependence, the degree of commercialization have all increased.

In panel (c), each individual is completely specialized in producing a single good. There are markets for all four goods. As a result, an individual's level of specialization, production concentration, the degree of market integration, the degree of trade dependence and commercialization, productivity, and aggregate transaction costs are all higher than in panel (b).

Given that there is a trade-off between transaction costs and economies of division of labor, in a static model, as transaction costs of a unit of goods traded fall, the economies of division of labor will more likely to outweigh the aggregate transaction costs caused by

the division of labor. As a result, the economy will evolve from autarky in (a) to partial division of labor (b), then to complete division of labor (c). In a dynamic equilibrium model such evolution of division of labor may occur in the absence of exogenous improvements in transaction efficiency (Yang, 2001a, 2001b, 2001c).

The main features that distinguish the Smithian framework from the neoclassical one can be summarized as follows.

Firstly, in the Smithian framework, there is no ex ante dichotomy between pure consumers and firms. Individuals' make infra-marginal decisions about their level and pattern of specialization; their optimal decisions are corner solutions. In the neoclassical framework, consumers and firms are separated. Consumers choose their consumption patterns and their allocation of endowments; their optimum choices are usually interior solutions; corner solutions are exceptional. It might be argued that the consumer–producer framework makes the algebra much more complicated than that in the neoclassical framework; and that the framework appears to be suited for an economy characterized by prior industrial revolution home production. However, as shown in the graphs, the framework of consumer–producers is essential for defining equilibrium labor allocation of each person. Moreover, if labor trade and a roundabout production chain are introduced into new classical models, a very complicated social production involving firms may occur and home production does not take place in equilibrium as division of labor evolves to a very high level (Yang and Ng, 1995) and Shi and Yang, 1995)

Secondly, in the Smithian framework, transaction cost (transaction efficiency) has important implications for the network properties of the equilibrium structure. As transaction efficiency improves, the equilibrium network size of division of labor is enlarged, aggregate productivity and social welfare increase, and total transaction costs increase.

Thirdly, in the Smithian framework, productivity is determined by individuals' specialization decisions and is described using the concept of economies of specialization and network effect of the division of labor. In the neoclassical framework, productivity positively relates to scale of a firm. As shown by Liu and Yang (2000) in a new classical model, the level of division of labor is positively related to the average size of firms if division of labor evolves within each firm and negatively related to the latter if division of labor evolves among increasingly more specialized firms.

Fourthly, in the Smithian framework, the institution of the firm is not given; it emerges from the division of labor only if individuals have decided to use labor markets to coordinate the division of labor. Production functions are specified for each consumer–producer for all possible production activities. A firm cannot simply pool all employees' labor into its own production function; rather the production function of a firm is a combination of production functions of all employees and the employer. This implies that the aggregate production set may be non-convex even if all individuals' production sets are convex. As a result, general increasing returns and network effects of division of labor are compatible with a competitive market. As shown by Yang (2001, Chapter 11), neoclassical marginal cost pricing holds only for non-traded goods; it does not hold for traded goods whose prices are determined by a total-cost benefit analysis in a Smithian framework. This formalizes Coase's critique of marginal cost pricing. Cheng et al. (2000a) have shown that even if in a Ricardian model with constant returns to scale technology, marginal cost pricing may not hold within a consumer–producer framework.

In the next section, we survey the literature on the division of labor within the new classical analytical framework.

4. Inframarginal analysis of division of labor

4.1. Basic approach

In this subsection, we describe the basic approach of inframarginal analysis of division of labor using the model developed by Yang (1991).

Yang (1991) started with the assumption of ex ante identical individual consumer–producers who have the same utility function and production functions for each good. The production functions exhibit economies of specialization; as an individual devotes a larger share of his labor to producing a good (i.e., as his level of specialization increases), his productivity in that good increases. Since each individual has a fixed labor endowment, the economies of specialization are individual-specific, and increasing returns are localized; consequently simply pooling labor without an increase in individuals' levels of specialization cannot increase their productivities.

An individual's decision is presented by a non-linear programming problem; each individual is assumed to maximize his utility by choosing his quantities of goods produced, traded, and consumed, as well as level and pattern of specialization, subject to the production functions, endowment constraint, and the budget constraint. An individual's specialization decision can be thought as choosing a profile of zero and positive values of the decision variables associated with each good: whether or not to self-provide, to sell or to buy. That is, there are three decision variables for each good: quantity self-provided, quantity sold, and quantity purchased. For a model with m goods, there are 2^{3m} combinations of zero and positive values of 3 m decision variables.

The large number of combinations of choices makes the individual's decision problem difficult to solve, especially when there are more than three goods. To solve this problem, Yang (1991) applied the Kuhn–Tucker theorem and proved that if there are economies of specialization and transaction costs, a consumer–producer never simultaneously sells and buys the same good, never simultaneously buys and produces the same good, and sells at most one good. This proposition was generalized by Wen (1998) for a general specification of quasi-concave utility function and separable production functions with economies of specialization, and non-increasing transaction cost coefficient functions. Later, Yao (2002a, 2002b) found that this proposition may not hold in the case with linear production functions with fixed learning costs. He proved that although selling two goods or more is possible, the optimal outcome for an individual can be achieved by selling at most one good. Diamantaras and Gilles (in press) extend theorem of optimum configuration to the case with a trade-off between income and leisure. Yao (in press) extends this theorem to the case with two factors of production.

The theorem of optimum configuration significantly narrows the number of candidates for the optimal decision. For instance, in a model with three goods, the candidates are reduced from $2^9 = 512$ to 10. We refer to the combination of zero and non-zero variables that is compatible with the theorem of optimum configuration as a configuration and an

aggregation of configurations that is compatible with the market clearing conditions for traded goods as a structure.

General equilibrium is defined as a state of the economy that satisfies the following conditions: (1) each individual maximizes her utility with respect to configurations and quantities of each good produced, traded, and consumed for a given set of relative prices of traded goods and numbers of individuals selling different goods, and (2) the set of relative prices of traded goods and numbers of individuals selling different goods clear the markets for traded goods and equalize utility for all individuals.

To solve for the general equilibrium, Yang (1991) used a two-step approach. First, for each structure, "corner equilibrium" prices and utilities are calculated using the market clearing conditions and utility equalization conditions. Secondly, the corner equilibrium in which individuals derive the highest utility is selected as the general equilibrium. The two-step approach has been followed by many subsequent models in the new classical economic literature, and the validity of this approach was proved by Sun (1999). However, there are some notable limitations with the two-step approach, notably its reliance on the assumption of ex ante identical individuals and the possibility of missing some structures. To overcome these limitations, Sun (2003) proposed a general method to identify the general equilibrium structure. The gist of this method is as follows: for any given prices (p, w), where p is the price vector $p = (p_1, \ldots, p_m)$ and w the wage vector $w = (w_1, \ldots, w_n)$, each individual maximizes utility for his potential configuration(s). For each configuration the individual's indirect utility can be calculated as a function of the given prices, and the individual chooses the configuration that gives him the highest utility. Clearly, which configuration pattern brings about the highest real income depends on the relative prices. The price set can therefore be partitioned into several sub-sets in each of which a particular configuration (i.e., specialization patterns) brings about the highest real income. This, together with the market clearing condition (and utility equalization if applicable), then allows the identification of subsets of parameters in which a particular structure of specialization occurs in equilibrium.

There are two types of comparative statics of the general equilibrium. The first type involves shifts between general equilibrium structures as parameters in the model reach certain critical values. With the general equilibrium structural shift, demand and supply functions and indirect utility function will (often discontinuously) shift.[4] The second type of comparative statics of the general equilibrium involve continuous changes in equilibrium relative prices, quantities, and other endogenous variables in response to continuous changes of the parameters within each parameter subset that defines equilibrium structures. The second type of comparative statics reveal resource allocation implications for a given network pattern of division of labor and is the same as those in the neoclassical framework. The first type of comparative statics based on inframarginal analysis focuses on implications of the network pattern of division of labor. They can be used to explain changes in the patterns of social division of labor. In Yang (1991), the comparative statics of the first type imply that the efficient pattern and level of division of labor is determined by the efficient trade-off between transaction cost and the positive network effect of the division of labor. If transaction efficiency is low, the positive network effect of the market is outweighed

[4] The discontinuous jump of the supply function is consistent with Stigler's (1951) conjecture that a change in the level of division of labor will lead to discontinuous change of the cost function.

by transaction costs, so autarky or low levels of division of labor occur in equilibrium. If transaction efficiency is improved, the efficient and equilibrium level of division of labor and related efficient size of market network will increase.

4.2. Theoretical research

Much theoretical research to date has been devoted to establishing fundamental theorems such as the existence of general equilibrium and the first and second welfare theorems within the Smithian framework. The representative work in this area is by Sun et al. (1999), Sun et al. (this issue), and Sun et al. (2003).

Sun et al. (1999) are the first authors to establish the existence theorem and the first welfare theorem for a general class of general equilibrium models with endogenous structure of division of labor and ex ante identical consumer–producers.

Sun, Yang, and Zhou have applied Hildenbrand's (1974) approach to large economies with local increasing returns to synthesize the Arrow–Debreu model of resource allocation (which focuses on interactions between prices and quantities of goods (non-topological properties of organisms) and recent literature of strategic networking decision making[5] (which focuses on networking decisions and ignores interactions between quantities, prices, topological properties of organisms, and networking decisions). They have established the first existence theorem and the first and second welfare theorems for a general class of models with ex ante different consumer–producers. Their paper allows constant returns as well as increasing returns and has used the measurement theory, while Sun, Yang, and Yao's existence theorem does not need measurement theory. Neither model includes producer goods.

Sun (2003) has established the first existence and first welfare theorems for a class of general models with ex ante different consumer–producers, and consumer and producer goods.

Together these papers have extended some fundamental theorems of neoclassical economics to a general class of models with impersonal networking decisions and endogenous structure of division of labor within the Smithian framework. They have shown that there exist well-defined equilibrium patterns of division of labor in the economy which are Pareto optimal even if there are network effects of division of labor, local increasing returns in production, and transaction costs. This result also implies that network effects generated by impersonal networking decisions are compatible with competitive markets. The most important function of the market is to coordinate individuals' networking decisions and to utilize network effects of division of labor, and this function is carried out by the price system which carries all information about non-topological properties (quantities consumed and produced or resource allocation) of economic organisms as well as information about topological properties (such as the degree of connectedness and integration, degree of separation which is the average topological distance between each pair of vertices, clustering coefficient, and asymmetry between the core and periphery) of economic organisms. A crucial assumption made in the papers is that the set of consumer–producers is a contin-

[5] Katz and Shapiro (1985, 1986), Jackson and Wolinsky (1996), and Dutta and Mutuswami (1997).

uum. This assumption needs to be relaxed in future research which may predict equilibrium unemployment caused by integer problem.

Of course there are other significant lines of theoretical research within the new classical analytical framework besides those related to the fundamental theorems in neoclassical economics. Notably, Yang and Yao (2001) drew insights from Ng and Yang (1997) and developed a Walrasian sequential equilibrium model to study social experiments and entrepreneur discovery. The model predicts that as the society experiments with network patterns of division of labor sequentially, it gradually acquires organization information. The experiment process is decentralized and limited by individuals' bounded rationality. During the process, each individual does not know others' choices and characteristics in detail, but all individuals collectively learn the information on the efficient pattern of division of labor carried by price signals. In this sense, the degree of information asymmetry in a Walrasian sequential equilibrium mode is much higher than in game models with incomplete information. The paper proves the existence of equilibrium for a general class of well-closed Walrasian sequential equilibrium models and provides a new approach to studying individual adaptive decisions with bounded rationality, social, endogenous, and fundamental uncertainty, and entrepreneurial discovery.

Another example of theoretic research is by Li and Sun (2003) who developed ways of measuring the level of division of labor and economies of division of labor. They showed that the level of division of labor can be defined by the spectrum of a matrix of all individuals' labor allocations among all production activities in society. Since the spectrum consists of the eigen-values of the matrix, the level of division of labor needs to be defined by many variables. Yang (2001) has shown that the economies of division of labor is a general equilibrium concept and cannot be well defined before a general equilibrium pattern of division of labor is solved. This further demonstrates that the concept of economies of division of labor is different from that of economies of scale which can be well-defined before equilibrium is solved.

4.3. Applied research

Inframarginal economics and the concept of general equilibrium based on inframarginal analysis focus on problems of economic organization rather than those of resource allocation. This new prospective has stimulated research in a wide range of economic fields, including trade, economic growth and development, urbanization, theory of the firm and property rights, e-commerce, money and capital and business cycles, and has provided an overarching framework for these seemingly disconnected fields of research (Smythe, 1994; Ben-Ner, 1995). In the rest of this section, we briefly survey recent applied work in a number of areas, namely, theory of trade, theory of economic growth and development, theory of the firm, property rights, uncertainty, and e-commerce, theory of urbanization and industrialization, theory of money, capital and business cycles, and political economics and public economics.

4.3.1. Theory of trade

A notable feature of the new classical trade theory is that it is able to endogenize the emergence of trade from no trade, and to explain the equilibrium trade patterns and the evolution of trade patterns. As the main determining factor of equilibrium trade pattern is the trade-off

between economies of specialization and transaction costs, the rationale behind domestic trade and international trade is fundamentally the same, although there are additional factors of consideration in international trade, such as tariffs and domestic trade policies.

Early work in new classical trade theory is represented by Yang and Shi (1992) and Yang (1996), who developed several models with the CES utility function to endogenize individuals' levels of specialization and the number of goods. There are two tradeoffs in the model: the trade-off between individual's preference for consumption variety and his cost of managing consumption variety, and the trade-off between economies of specialization and transaction costs. The model shows that if the transaction cost coefficient is large, economies of specialization are outweighed by transaction costs, and individuals will choose autarky which means there is no demand and supply in the market place. Autarky implies a very narrow scope for trading off consumption variety against the associated costs because of each person's limited time. As a result, the number of goods in equilibrium is small. As the transaction cost coefficient falls, each individual will choose a higher level of specialization, and there will be greater scope for trading off economies of specialization and preference for consumption variety against management costs of consumption variety. The equilibrium level of specialization, the number of traded goods, and the equilibrium number of all goods, the extent of the market, variety of occupations and economic structure, the extent of endogenous comparative advantage, production concentration, and commercialization, productivity and trade dependence all increase concurrently as division of labor develops. Lio and Liu (2003), Barro (1997), North (1958), North and Weingast (1989), Gallup and Sachs (1998), Sachs and Warner (1995), Easton and Walker (1997), Gwartney et al. (1996), Frye and Shleifer (1997), and Yang et al. (1992) have found empirical evidence for this prediction. Different authors use different measures of trading efficiency in their studies. For instance, North uses indices of freight fee, Sachs and Warner use quality of institution, Barro uses rule of law, Gallup and Sachs use CIF/FOB margin and proportion of the population within 100 km of the coast, Easton and Walker use economic freedom, and Yang et al use an index of transaction efficiency in specifying and enforcing property rights.

A common feature of the new classical trade models and the new trade models is that they both endogenize the number of all consumption goods, productivity, and trade dependence (ratio of trade volume to income). However, new classical trade models also endogenize the degree of market integration (or degree of globalization) and individuals' levels of specialization, but the new trade models do not. In Dixit-Stiglitz type new trade models, each consumer must buy all goods from monopolist producers. This together with productivity gains from a large economy imply that an integrated world market is preferred to separate local markets and would always occur in equilibrium. Thus, the Dixit–Stiglitz type models are unable to endogenize the degree of market integration. In contrast, in new classical trade models, the degree of market integration is endogenized because the extent of market increases as trading efficiency is improved. To the extent that domestic trade involves lower unit transactions cost, domestic trade would occur before trading efficiency is high enough to sustain international trade. For the same reason, domestic trade would occur only when transaction costs are sufficiently low to be outweighed by economies of specialization within the domestic economy. Below that transaction costs threshold, the domestic economy would consist of separate "local communities". With continuous improvements in transaction efficiency, an integrated national market emerges from separate

local business communities, followed by international trade with several separate international trade blocks, and finally ending up with the integrated world market. The evolution path of integrated world market was modelled by Ng (1998), who highlights the trade-off between economies of specialization and transaction costs as being the common rationale for domestic and international trade.

More recent research has attempted to study some "traditional" models and issues of international trade within the new classical analytical framework.

Cheng et al. (2000a) developed a 2×2 Ricardian model within the Smithian framework and extended it to a 2×3 model. They showed that the model has a unique general equilibrium except for some razor edge cases and that comparative statics of the general equilibrium can be used to explain the evolution of trade patterns. As transportation efficiency is improved, the general equilibrium market structure changes from autarky to partial division of labor, then to complete division of labor. If partial division of labor is the general equilibrium market structure, the country producing both goods would benefit from imposing a tariff whereas the country producing a single good would prefer unilateral free trade. In a 2×3 model with three countries, the country which does not have a comparative advantage relative to the other two countries, and/or which has low transaction efficiency may be excluded from trade.

Shi and Zhang (in press) identified a technical omission by Cheng et al. (2000a), and suggested once the omission has been rectified, the results of the original model remain valid and the model can explain a dual structure in the domestic economy.

Cheng et al. (2000) applied inframarginal analysis to the Ricardian model to study the evolution of trade policy regimes. The model identifies the conditions for trade negotiations that could result in zero tariff and the conditions for the co-existence of unilateral tariff and unilateral laissez faire trade policies. This work has been further developed by Yang and Zhang (2003) who applied inframarginal analysis to the Ricardian model with endogenous as well as exogenous comparative advantages to study the interplays between trade policy regime, dual structure, income distribution, and network size of division of labor.

Cheng et al. (2000b, 2004) conducted inframarginal analysis of the HO model and test the validity of core trade theorems. The papers demonstrate that the HO theorem can be refined to account for the impact of transaction costs and technological difference, and that the factor price equalization theorem, the Stolper–Samuleson theorem and the Rybczynski theorem do not always hold. Tombazos et al. (2003) have extended this research to the case with mobile capital.

Other contributions to the new classical trade theory include work by Sachs et al. (2002) which applied inframarginal analysis to the Dixit–Krugman model to explain the evolution of trade pattern determined by the interplay between endogenous and exogenous comparative advantages in technology, endowments, and transaction efficiencies. In addition, Yang (2003) and Li (2001) applied inframarginal analysis to investigate the relationship between the division of labor, international trade and foreign direct investment.

4.3.2. Theory of growth and development

One of the most cited piece of work to date on theory of the growth within the Smithian framework is by Yang and Borland (1991), though it is perhaps the least interesting among new classical models.

Prior to Yang and Borland's (1991) paper, all new classical models of economic development were static in the sense that although the evolution of the levels and patterns of division of labor is modelled, the evolution is driven by changes in exogenous variables such as transaction efficiency coefficient. An important contribution of Yang and Borland (1991) is that they developed a dynamic general equilibrium model of specialization which formalized Young's conjecture that a "moving equilibrium" may capture the spontaneous evolution of division of labor and the accompanying change in the extent of the market.

The Yang and Borland (Y–B) model applies control theory (dynamic inframarginal analysis) to solve for the dynamic general equilibrium based on corner solutions. The model specifies three types of learning by doing. The first is learning by doing in autarky in the absence of the division of labor and its evolution. This type of learning by doing contributes to the growth of per capita real income but the growth rate declines over time.

The second type is specialized learning by doing based on the division of labor. Their model specifies a mechanism of spontaneous evolution of the division of labor which generates endogenous growth. Individuals' specialized learning by doing combined with increasing levels of division of labor accelerate the society's learning process and its rate of human capital accumulation. Intuitively, in the absence of the division of labor, an individual would spread his time on learning more activities, and his speed of learning for a given activity declines. In contrast, as the level of division of labor increases, the individual's learning becoming more specialized and his speed of learning a given activity increases. Over time specialized learning by doing through increasing division of labor increases the speed of learning for society as a whole and can lead to accelerated economic growth or "economic miracles" referred to by Lucas (1993). It should be noted that as the division of labor evolves, individuals' productivity increases, so is their reliance on the network of specialization in the economy. This increased reliance on society is an important feature of the specialized learning by doing through social division of labor which is different from the standard formulation of learning by doing (independent of the division of labor) investigated by Arrow (1962).

The third type of learning by doing is based on a high level of division of labor in the absence of the evolution of division of labor. This type of learning by doing leads to positive growth but the growth rate declines over time.

The logic of the Y–B model is straightforward. The basic assumptions of the model are: (1) there are productivity gains from specialized learning by doing, (2) transaction costs are positive, and (3) individuals are consumer–producers who prefer diverse consumption. At $t = 0$, each individual has not benefited from specialized learning by doing, so his productivity is low and he cannot afford the transaction costs associated with the division of labor; thus autarky is chosen. As time goes by, each individual accumulates experience in producing each and every goods, and his productivity goes up so that he can afford some transaction costs and therefore a low level of level of specialization. The specialized learning by doing accelerates the accumulation of professional experience, and each individual's productivity in his professional activity increases further. Consequently he can afford higher transaction costs and will choose a higher level of specialization, and so on, until the potential for further evolution of division of labor has been exhausted. In this process, the growth rate of per capita real income declines in autarky, then increases (takeoff) as the division of labor evolves to a critical level, and declines again (but is always positive) as the potential

for further evolution of division of labor has been exhausted. The evolution of division of labor will increase the extent of the market (measured by the product of per capita effective market demand and population size), the degree of market integration, the income share of transaction costs, each person's productivity in his profession, and so on.

As noted earlier, a contribution of the Y–B model is that it formalizes Young's conjecture about the relationship between the evolution of division of labor and evolution of the extent of the market as two sides of the same coin. In addition, the model may be used to explain the convergence and divergence of growth rates between developed and less developed economies. One may consider a developed economy as one that starts the evolution process earlier than a less developed economy because of a lower transaction cost parameter (due to, say, favourable geographical location). If the developed economy enters the takeoff stage when the less developed economy is still in autarky, then the growth rates between the two economies will diverge. But as the developed economy begins to exhaust its potential for further evolution of division of labor, and the less developed economy has eventually entered the takeoff stage, then the growth rates between the two economies will converge. Chen et al. (1999) have found empirical evidence for the sequential divergence and convergence, which rejects a monotonic divergence predicted by Romer (1986, 1990) and Lucas (1988) and a monotonic convergence predicted by Barro and Sala-i-Martin (1991, 1992) and Tamura (1991, 1992). North (1986) has found empirical evidence for a positive correlation between income share of the transaction sector and per capita real income predicted by the Y–B model.

Wen (1997) has extended the Y–B model by introducing the effects of public finance on trading efficiency. This model is used to investigate the coevolution of optimum fiscal policy, trading efficiency, and the division of labor. Zhang (1997, 1998) has extended the Y–B model to investigate the effects of monetary and fiscal policies on the coevolution of division of labor and of the extent of the market (aggregate demand). His models have shown that since aggregate demand is endogenized as an aspect of the level of division of labor, the inframarginal approach can be used to investigate many macroeconomic phenomena.

Apart from individuals' specialized learning by doing, another important aspect of economic development is learning by experimenting. Ng and Yang (1997) were the first to develop a Walrasian sequential equilibrium to investigate the function of the market in experimenting with various patterns of division of labor. Their model has been further developed by Yang and Yao (2001) as mentioned earlier in the sub-section on theoretic research. In their model, individuals are assumed to experiment with one pattern of division of labor in each period and apply dynamic programming to maximize expected total discounted utility taking into account updated information in each period. There is a trade-off between information gains from experimentation and the cost of acquiring price information. The sequential equilibrium depends upon four parameters: the pricing cost coefficient, the transportation cost coefficient, the degree of economies of specialization, and the discount rate. The smaller the two types of transaction cost coefficients and the discount rate and/or the greater the degree of economies of specialization, the more social experiments will be undertaken, the more information will be acquired through the price system, and the faster the evolution of division of labor and productivity will be. The Yang and Yao model is more realistic than standard dynamic general equilibrium models in that the former allows for adaptive behaviour of individuals. Given its realism and tractability, a sequential model

may prove to be a powerful tool to study social experiments and the evolution of division of labor and accompanying changes in the economic structure. Technically, the notion of Walrasian sequential equilibrium can be used to create dynamic versions of static models of endogenous specialization in a much more manageable way than other dynamic general equilibrium models of endogenous specialization.

Wen and King (2004) have introduced primary resources into a general equilibrium model of endogenous specialization. They have shown that aggregate productivity and level of division of labor are determined positively by trading efficiency (because of the trade-off between economies of division of labor and transaction costs), and negatively by per capita endowment of primary resources. This is because shortage in primary resources will force individuals to choose a higher level of division of labor in order to utilize interpersonal complementarity to accommodate harsh condition caused by the shortage. Their model can explain four scenarios of economics development: (a) positive effect of high trading efficiency dominates negative effect of a great per capita primary resource endowment on the equilibrium level of division of labor (e.g., in the USA, Australia, and Canada), thereby generating a high level of division of labor; (b) high trading efficiency and a small per capita primary resource endowment (e.g., in Japan, the UK, and Hong Kong) generating a high level of division of labor; (c) negative effect of low trading efficiency dominates positive effect of a small per capita primary resource endowment on the equilibrium level of division of labor (e.g., in pre-reform India and China, and some African countries), thereby generating a low level of division of labor; (d) low trading efficiency and a great per capita primary resource endowment (e.g., in some south American countries) generating a low level of division of labor.

4.3.3. Theory of the firm, property rights, insurance, and e-commerce

Since the economic decision makers within the Smithian framework are consumer–producers, the firm is not exogenously given. Rather, the firm would emerge only endogenously when the trade in labor proves more advantageous than the trade in goods.

The pioneering research on the theory of the firm within the Smithian framework was conducted by Yang (1988) and Yang and Ng (1995). The Yang and Ng (1995) model starts with the assumption of individual consumer–producers who consume a final good, cloth, the production of which requires an intermediate good, management service. There is a trade-off between economies of specialization and transaction costs for individuals' decision making. If a unit transaction cost coefficient is large, autarky occurs in equilibrium, and no firms and market will emerge. If the unit transaction cost coefficient is small, the equilibrium structure involves the division of labor.

With the division of labor, there are three structures associated with different methods for defining residual rights and organising transactions. In Structure 1, there are specialist cloth makers and specialist management services providers. The two groups of specialists exchange their good/service in the market. There is no firm nor labor market, and the residual rights to returns and control are symmetrically distributed between the two groups of specialists. In Structure 2, cloth producers hire management service specialists through the labor market and produce cloth, and the firm emerges. The cloth makers are employers and management services specialists are employees. The right of controlling employees' labor and the right to the firm's residual returns are held by cloth makers. In Structure 3,

management service providers hire cloth makers to produce cloth in the firm. Management service providers hold the right to the firm's residual returns and the right of control over cloth makers' labor.

Both Structures 2 and 3 involve a labor market but not a market for the intermediate input, management services; the firm replaces the market for intermediate goods with the market for labor. However, Structures 2 and 3 have different firm ownership structures.

If transaction efficiency associated with trading management services is lower than that for trading labor, the firm will be a more efficient institution than the market for management services for organising the division of labor between cloth makers and management service providers. If transaction efficiency associated with hiring cloth makers is lower than that for hiring management service providers (because it is costly to measure the output of management service providers and monitor their work efforts), then hiring cloth makers will be more efficient than hiring management service providers, and the equilibrium structure will be Structure 3 as division of labor can be more efficiently organized in Structure 3 than in Structure 2.

In Structure 3, the price for management services is indirectly determined by the residual return of the firm. The asymmetric structure of residual rights allows specialization in management services but avoids the cost of directly pricing output and input in providing the services. This transaction cost saving promotes the division of labor. Moreover, as management service providers can get the full price of their services through residual claims, their intellectual property is protected and their incentive to specialize in intellectual property production preserved.

The Yang–Ng model explains the emergence of the firm and ownership structure of the firm from the division of labor without having to rely on assumptions such as uncertainty, and incomplete contracts, thus formalising the transaction cost theory of the firm developed by Coase (1937) and Cheung (1983). The model also predicts that the equilibrium size of the firm may decrease as division of labor evolves if the relative transaction cost coefficient of labor to goods rises or if more intangible intellectual properties need to be protected by different types of firms. This prediction captures Young's idea (1928, p. 539) that "[t]he mechanism of increasing returns is not to be discerned adequately by observing the effects of variations in the size of an individual firm or of a particular industry, for the progressive division of labor and specialization of industries is an essential part of the process by which increasing returns are realized. What is required is that industrial operations be seen as an interrelated whole". The theory of irrelevance of the size of firm is supported by empirical evidence (Liu and Yang, 2000; Yang and Zhang, 2003a, 2003b; Zhang and Zhao, 2003).

The Yang–Ng model was regarded as a breakthrough in modelling theory of the firm, and a number of extensions have been made. For instance, Yang (2001) introduces two sided moral hazard and the trade-off between moral hazard and measurement and enforcement costs of contract into the Yang-Ng model to simultaneously endogenize transaction costs and emergence of the firm from the division of labor. He has absorbed the critique of Hart, Grossman, and Moore's theory of incomplete contract (see Hart, 1995) by Maskin and Tirole (1999a, 1999b), Milgrom and Roberts (1992), and Holmstrom and Roberts (1998). Yang emphasizes that it is relative enforcement cost of labor and goods rather than absolute transaction cost that determines the equilibrium structure of residual returns and control rights. Different from the Grossman–Hart–Moore model, incomplete labor contract

is essential for theory of the firm. Though, Yang's theory is similar to theory of the firm developed by Holmstrom, Milgrom, and Roberts, the former can be used to investigate implications of incomplete contract and the institution of the firm for the network size of division of labor, but the latter cannot.

Borland and Yang (1995) developed a dynamic version with the CES production function of the Yang–Ng model. Zhao (1999) developed a Walrasian sequential equilibrium model to explain the emergence of the firm when bounded rationality and social, endogenous, and fundamental uncertainty are present. Sun (2000) extends the model to the case with m goods, and using data from Australia, the UK, China, Hong Kong, Singapore, and Korea, Yang and Zhang have shown that there is no monotonic positive correlation between per capita real income and average size of firms.

Closely related to theory of the firm, theory of property rights has also been a fertile area for research using the new classical analytical framework. The pioneering work in this area was done by Yang and Wills (1990). The Yang-Wills model introduces risk into the basic new classical model to investigate the implications of transaction risk for the division of labor and property rights.

The logic of the Yang–Wills model is as follows. Assume that due to anticipated opportunistic behaviour or uncertainty in transaction, there is a risk associated with each transaction. As the level of division of labor increases, the chain of series connections between different specialists becomes longer, and as a result the compounded risk for coordination failure in the network of division of labor increases more than proportionally. The risk of coordination failure can be mitigated in two ways.

The first is supplier competition: each buyer has access to different specialist suppliers, so that the threat of competition discourages the incumbent supplier from behaving opportunistically. Competition between many suppliers raises the reliability of each purchasing contract. However, a larger number of suppliers of the same good means that a smaller number of different types of specialists and therefore a lower level of division of labor for a given population size. Also, there is additional transaction costs involved in maintaining relationships with many potential suppliers of the same good.

The second is to allocate more resources to specification and enforcement of each contract so that the risk of breaching each contract can be reduced, thereby reducing welfare losses caused by the compounded risk of coordination failure. If we interpret the welfare loss as an endogenous transaction cost, the reduction in the endogenous transaction cost is achieved through an increase in the exogenous transaction costs associated with specification and enforcement of contracts. That is, apart from the trade-off between economies of specialization and coordination risks, there is a trade-off between exogenous and endogenous transaction costs. If the exogenous transaction cost coefficient associated with "deepening" a relationship is large, "classical contracts" with many potential trading partners may prevail in equilibrium. If the exogenous transaction cost coefficient associated with "widening" relationships is large, "relational contracts" without potentially alternative trading partners may prevail in equilibrium (Williamson, 1975).

The Yang–Wills model formalizes Cheung (1970, 1983) and Coase's (1960) insight that the essence behind the notion of (endogenous) "externality" is the trade-off between exogenous and endogenous transaction costs. Endogenous transaction costs can be reduced by an increase in exogenous transaction costs for better specifying and protecting property

rights. If the trade-off is recognized, many seemingly inefficient contractual arrangements are the outcomes of an efficient balance of this trade-off. As the Yang–Wills model shows, with the improvement of transaction efficiency, the equilibrium level of division of labor and the risk of coordination failure may increase side by side. The equilibrium degree of unreliability and the associated costs may be thought as the equilibrium extent of externalities. Eliminating all the "externalities" is certainly not efficient. This is referred to as the theory of "endogenous externality".

Following Yang and Wills (1990), other authors have introduced risk and uncertainty into the Smithian framework. Lio (1996, 1998) developed a model with uncertainty, insurance, and moral hazard in the Smithian framework and showed that insurance can promote the division of labor and productivity. He also demonstrated that incomplete insurance can alleviate problems of moral hazard although it increases endogenous transaction costs as well. Furthermore, he showed that as the risk for each transaction is reduced, the aggregate risk of coordination failure of a larger network of division of labor will increase. This result has important implications for analyzing positive and negative network effects of globalization and new economy. Yang and Yeh (2002) investigated the effect of moral hazard on the division of labor and the extent of the market. Yang (2000) introduced moral hazard into the Yang and Ng (1995) model to investigate the role of incomplete labor contracts in the emergence of the firm. More recently, Sun (2002) developed a model that investigates the impact of knowledge and transaction uncertainty on the division of labor. His model shows that both knowledge and transaction uncertainty have a profound influence on individuals' specialization choices. Increased knowledge tends to promote specialization, but higher levels of specialization also tend to increase transaction costs of which uncertainty is an important element. Thus, the improvement in specialization due to increased knowledge is reduced by increased uncertainty. In this sense, the division of labor is limited by uncertainty. This strand of the literature relates to the literature of endogenous externality. Formal models in the literature are developed by Milgrom and Roberts (1992), Holmstrom and Roberts (1998), and others. The new classical models of endogenous externality are distinguished from other formal models of endogenous externality by their predictive power on the effects of the trade-off between endogenous and exogenous transaction costs on the general equilibrium network size of division of labor.

E-commerce is another growing area of research within the Smithian framework. There is a large literature in the neoclassical tradition that attempts to explain various e-commerce phenomena using marginal analysis. Indeed some economists believe that e-commerce phenomena that are emerging with the rapid development of information technology can be adequately explained by neoclassical theory – "technology changes, economic laws do not" (Shapiro and Varian, 1999). In contrast, researchers who study e-commerce within the Smithian framework consider that since e-commerce concerns networking decisions, inframarginal analysis of networking decisions is essential to understanding the nature of e-commerce phenomena. Not surprisingly, the two different approaches lead to different explanations for some common e-commerce phenomena. We illustrate the differences with two examples.

The first is the phenomenon associated with the development of information technology: while new technology increases the trading efficiency and reliability of each transaction, the income share of transaction costs and the risk of coordination failure of a large network

of division of labor are increasing. This phenomenon is recognized in the neoclassical literature, but no systematic analysis has been performed to explain it.

Yang and Wills (1990) and Lio (1998) offer an explanation for this phenomenon. As the transaction cost coefficient is reduced by new technology, the scope for trading off economies of division of labor against transaction costs is enlarged, so that the equilibrium network size of division of labor increases. However, the increased network size implies increased interconnections among specialists. If there is a transaction risk for each trade connection, the aggregate risk of coordination failure of the trade network will increase exponentially despite a lower risk of coordination failure for each trade connection. However, as long as the benefit from increased division of labor outweigh the costs associated with the increased risk of coordination failure, the network size of division of labor will increase and so will the aggregate risk of coordination failure and the income share of transaction costs.

Another example is the practice of bundling. There is a large literature on bundling within the neoclassical tradition (see, for instance, Adams and Yellen, 1976; Whinston, 1990; Bakos and Brynjolfsson, 2000a, 2000b). The models in this literature typically assume that each consumer has a constant valuation for a good and that different consumers have different valuations. Since consumer valuations are not observable, differential prices cannot be set on the basis of differential valuations. Under these assumptions, bundling is used by a monopolist firm as a method for exercising indirect price discrimination (assuming resale is not possible).

These bundling models do not quite catch the features of bundling by internet service providers; in particular it does not seem to explain free services in a bundle. ISPs often provide many services, some of which are charged positive prices and others are provided free of charge. Indeed, a zero price for some services in a bundle can be observed in conventional markets. For instance, many services stations sell petrol at a competitive price and provide air pump service free of charge. Intuitively, charging a positive price for air pump service involves a large transaction cost (relative to value of the service). This transaction cost can be avoided if the service is provided free of charge, but the cost of the services are included in the price of petrol. The way of (implicit) bundling of petrol and air pump service may cause some distortion to the extent that some customers may use the air pump without buying petrol from the same service station. However, as long as, the transaction costs savings outweigh the costs associated with the price distortion, competitive pressure would ensure that the implicit bundling practice prevails in equilibrium.

Li (2003) developed a model that formalizes the intuition behind the implicit bundling practice observed in e-commerce and in traditional markets. Different from the neoclassical literature on bundling, Li's model focuses on individuals' impersonal (as opposed to strategic) networking decisions. That is, an individual makes decisions using infra-marginal analysis in a competitive environment where nobody can manipulate prices. In Li's model, individuals' impersonal network decisions in a competitive environment with free entry lead to the emergence of implicit bundling with zero prices of some goods within a bundle.

Li (2003) models an implicit bundle of automobiles and Internet services (for purchasing automobiles on-line) provided by an automobile manufacturer (GM). Since internet services are costly to price, GM can implicitly bundle automobiles and internet services by providing free internet services and adding the operation cost of internet services to the price of auto-

mobiles. If the bundling practice saves more transaction costs to customers than the added costs to automobile prices, GM will have an advantage over its competitors in attracting customers, and its competitors will be pressured to offer similar bundled services. Note that Li's model does not require any of the standard assumptions of a neoclassical bundling model, such as monopoly power and constant and independent valuations of goods. Even if all individuals have ex ante identical utility function, bundling may still prevail in equilibrium and enable the production and trade of goods whose pricing involves high transaction costs.

Shi and Zhang (2002) have extended Li's model to the case with buyers choosing the bundling ratio. Also, Yang (2003b) and Shi and Yang (1998) have developed two models which predict two seemingly contradictory internet phenomena: the degree of separation (average topological distance between each pair of vertices) and the clustering coefficient (the reciprocal of degree of clustering) decrease as globalization and new economy develop (Barabasi, 2002). Their models show that as trading efficiency improves, the level of division of labor evolves. This will increase equilibrium degree of market integration (decrease in degree of separation) and the increase the equilibrium number of layers of hierarchical wholesales and retail network (which implies a decrease in the clustering coefficient). Sachs et al. (2000) and Zhang (2003) have developed two cobweb models of endogenous specialization. Their models show that due to the trade-off between the benefit of sensitivity of the feedback and stability when there is a time lag between price signals and decisions, higher trading efficiency and more sensitive feedback may make an economy converge to its equilibrium state before a feedback sensitivity threshold is reached. Beyond this threshold, the sensitive feedback and high trading efficiency generated by liberalization reforms or new computer technology may cause chaos or a breakdown in the price feedback mechanism so that individuals will be forced to choose autarky or a low level of division of labor. Globalization and new economy make the efficient trade-off much more difficult and complicated.

4.3.4. Theory of urbanization and industrialization

The paper by Yang and Rice (1994) may be thought as the beginning of research on urbanization within the Smithian framework. The Yang–Rice model specifies different transaction cost coefficients for the manufacturing and agricultural sectors. The transaction cost differential can lead to a differential in the level of specialization and productivity between the two sectors; and as a result a dual structure of urban and rural sectors emerges. In the Yang–Rice model, transaction costs play a key role in explaining the emergence of the urban sector, this is somewhat similar to the models by Fujita and Krugman (1995), but a distinct feature of Yang–Rice model is its focus on the economies of division of labor rather than economies of scale within a firm.

More recently, Sun and Yang (2002) applied inframarginal analysis to study the relationships among the division of labor, agglomeration and land rentals. An interesting aspect of their model is that it predicts that the degree of urbanization, degree of industrialization, the average size of firms, and aggregate productivity can be positively or negative correlated. This is contrary to the Fujita–Krugman model that predicts a monotonically positive correlation between the variables. Zhang and Zhao use data of seven OECD countries to test the Sun–Yang and Fujita–Krugman models. They have found empirical evidence to reject the prediction by the Fujita–Krugman model (i.e., there is a positive correlation between the average size and degree of urbanization when the fixed cost coefficient and population size

increase over time) and to support the prediction of the Sun–Yang model of urbanization (i.e., the correlation between average size of firms and urbanization can be either positive or negative). The data show no monotonically positive correlation between average size of firms and urbanization when the fixed cost coefficient and population increase over time. Baumgardner (1988b) has also found empirical evidence for a positive correlation between physicians' levels of specialization and urbanization, supporting the Sun–Yang model.

Much research effort has gone into studying diverse issues in the field of industrial organization as well. Yang and Ng (1993, Chapter 14) investigated the relationship between the level of division of labor and the number of layers in the efficient hierarchy of transactions. Yang (2003b) developed a general equilibrium model of hierarchy. His model shows that as transaction efficiency improves, the division of labor in producing goods and transaction services evolves to a higher level. With that evolution, professional middlemen and a decentralized hierarchical structure of wholesale and retail network would emerge, while the equilibrium number of layers of the hierarchical network increases.

A notable contribution to inframarginal analysis of industrial organization is the paper by Shi and Yang (1995). The authors developed a model to investigate both horizontal and vertical division of labor in a hierarchical structure of production and to formulate a theory of industrialization based on complex trade-offs between economies of specialization, input complementarity, roundabout production, and transaction costs.

The Shi–Yang model introduces a hierarchical production structure with multiple layers, where the division of labor can occur horizontally (within a layer) or vertically (between layers.) A greater degree of horizontal division of labor may generate more opportunities for vertical division of labor, which implies more variety of specialized equipment and machines and higher productivity, but more transaction costs.

If transaction efficiency is extremely low, then the gains to horizontal and vertical division of labor are outweighed by transaction costs. The equilibrium structure will be autarky where each individual self-provides all producer goods and consumer goods. There is a trade-off between economies of specialization and increasing returns to a variety of producer goods. If a large number of producer goods are produced in autarky, a person's level of specialization in producing each good must be low, and more gains to specialization would be foregone. To capture the economies of specialization, an individual will devote his labor to a small number of activities directly related to final consumption. This means that equilibrium hierarchical structure would involve a small number of layers and a small number of producer goods at each layer.

As transaction efficiency improves, an individual can choose to be more specialized and transact with other individuals. New layers in the hierarchy of goods and new producer goods at each layer in the hierarchy may emerge. The emergence of new production layers and new producer goods is accompanied with the introduction of new technologies and new industries, which characterizes the process of industrialization.

Thus, the Shi–Yang model predicts concurrent increases in individuals' level of specialization, the number of links in the roundabout production chain, and the number of producer goods at each link. This endogenizes the three aspects of the division of labor described by Smith (1776) and Young (1928), namely, individuals' level of specialization, the length of the roundabout production chain, and the number of producer goods in each link of the chain. It is also worth noting that in the Shi–Yang model, as transaction efficiency improves,

new ex post production functions emerge, the level of division of labor increases, and the equilibrium evolves to a new structure. The model therefore exhibits the characteristics of a complex system as defined by Krugman (1994) which involves the emergence of new phenomenon, the evolution of economic structure and self-organization.

The Shi–Yang model has later been extended by Shi and Yang (1998) to study the dividing line between a hierarchical organization within a firm and a hierarchical trade network in the market.

4.3.5. Theories of money, capital and business cycle

Borland and Yang (1991) were the first to develop a model within the Smithian framework to investigate the emergence of money. In their model, they assume a single consumption good whose production requires an intermediate good which is in turn produced with another intermediate good.

When transaction efficiency is low, there is no division of labor, and the equilibrium structure will be autarky where no money is required. As transaction efficiency improves, there will be partial division of labor and in equilibrium there will be trade between input producers and final goods producers, again no money is required. As transaction efficiency further improves, the level of the division of labor will involve transactions between three different groups of specialists. Since there is no "double coincidence of wants" between each pair of specialists, the transactions cannot take place without a medium of exchange. If an enforceable credit system exists, transactions will be carried out through credit. In the absence of an enforceable credit system, the medium of exchange will be commodity money which has the lowest transaction costs.

Compared to the work by Kiyotaki and Wright (1989, 1991, 1993), the Borland–Yang model have truly endogenized the emergence of money by showing the transition from an economy with no money to one that uses money as a medium of exchange. In addition, the Borland-Yang model has shown that specialization is a necessary but not sufficient condition for the emergence of money. They have shown that use of commodity money will increase total transaction cost as it enlarges the network size of division of labor and raises aggregate productivity.

Different from the Borland–Yang model in which the emergence of money requires a sufficiently long chain of roundabout production, Cheng (1998, 1999) developed a model with only a single intermediate good to study the origin and the value of money. In her model, the commodity associated with the lowest unit transaction cost will be chosen as commodity money as the division of labor evolves to a sufficiently high level. Her model also showed that the value of commodity money depends on both the commodity's consumption use and its use as a medium of exchange, and that under certain conditions the use of money substitute is welfare enhancing.

Classical economists such as Adam Smith, John Mill, Karl Marx and Alfred Marshall believe that capital is a means for increasing the level of division of labor in roundabout productive activities. This aspect of classical theory of capital is formalized by Yang (1999).

The Yang (1999) model assumes an economy with many ex ante identical consumer–producers who can produce a single consumption good food, with either labor alone or with labor and tractors. There are economies of specialized learning by doing in production and a fixed learning cost. The fixed learning cost associated with producing

a tractor is significantly high such that a tractor cannot be produced until the learning cost incurred by an individual has exceeded a threshold value. The individuals can choose to be self-sufficient or specialize and trade with other individuals. There are transaction costs associated with trading activities. There are multiple consumption and production periods. The setting of the Yang model implies that it is a dynamic model with trade-offs among economies of specialized learning by doing, economies of roundaboutness, transaction costs, and fixed learning costs.

If the transaction cost is high, the equilibrium structure is autarky. As transaction efficiency improves, if the economies of specialized learning by doing and the economies of roundabout production are significant, the equilibrium will involve the division of labor. If the fixed learning cost in producing tractors is small, the production of a tractor can be funded through self saving. Otherwise, if the learning cost is so large that the production of a tractor cannot be completed within one consumption period, the production of a tractor will need to be supported by a loan, which works as follows. In period 1, a specialist farmer produces food using his labor only and makes a loan in terms of food to a specialist tractor maker. In period 2, the tractor maker sells the tractor to the farmer at a price that equals the value of his food consumption in period 2 plus the loan amount. With this arrangement, per capita consumption of food in period 1 is lower than otherwise but the increase in production in period 2 more than compensates the loss of consumption in period 1 if transaction efficiency coefficient and economies of specialized learning by doing and roundaboutness are sufficiently large.

The Yang (1999) model highlights the role of capital in fostering roundabout production and the division of labor. It also suggests that investment per se may not improve productivity; what is required is that the investments are made in an environment with high trading efficiency and the investments are devoted to improving specialized learning by doing and roundabout production. The model generates empirical implications that there is no monotonically positive correlation between investment rate and growth rate since trading efficiency is crucial for lucrative investment which is used to develop a finer division of labor in roundabout production. This is verified by empirical evidence provided by Jones (1995a 1995b), which conclusively rejects the AK model predicting such a positive correlation, and R&D based endogenous growth models predicting a positive correlation between growth rates and the size of the R&D sector.

In a model similar to Yang (1999), Yang and Ng (1993, Chapter 18) investigate the relationship between the division of labor in producing durable goods, unemployment, and business cycles.

The Yang and Ng (1993) model assumes that an individual can produce a non-durable consumer good (food) and a durable producer good (tractor). A tractor is indivisible and lasts 2 years. Each individual uses only one tractor to produce food at any point in time. There are economies of specialized learning by producing any good. It is assumed that an individual will forget his experience in an activity if he shifts to another activity. There is an entry cost (learning cost) into each activity.

The model considers three possible organizational structures of production and consumption. The first is autarky where each person self-provides tractor and food. He makes a tractor first and then uses the tractor to produce food in the first year and produces only food using the tractor in the second year. There is no business cycle or unemployment.

The second structure involves partial division of labor between farmers and tractor makers. Farmers remain specialized all the time, but tractor makers make tractors in the first and switch to producing food in the second. There is no business cycle or unemployment.

The third involves complete division of labor between specialist farmers and tractor makers. Tractor makers make tractors in the first year and are unemployed in the second year. The aggregate output is higher in the first year than that in the second year. Thus, there is a 2-year business cycle, and unemployment occurs in the second year.

The first two structures do not involve business cycles or unemployment but incur the costs of shifting from making tractors to producing food. If this cost and the economies of specialized learning by doing are sufficiently great, the structure with complete division of labor and associated business cycles and unemployment will be Pareto superior to autarky and the partial division of labor structure and will be the equilibrium structure.

Thus, the Yang and Ng (1993) model is able to endogenize regular and efficient business cycles in contrast to many other mainstream macroeconomic models.[6] The Yang and Ng (1993) model has recently been further developed by Du (2003) who considers the effect of overlapping generations on smoothing out business cycles.

4.3.6. Public economics and political economics

The broad areas discussed so far concern, inter alia, the interaction between the division of labor and the (mostly competitive) market mechanism. Inframarginal economics has also been applied successfully to other areas involving politics and policies.

For instance, Chu and Wang (1998) and Ng and Ng (2001b) introduced externalities into models of endogenous specialization to investigate the effects of externalities on the extent of the market and network size of division of labor. Ng and Ng (2001a) studied the relationship between specialization, network externality and work ethics; and Ng and Yang (2000) studied the impact of taxation using the inframarginal analysis.

Fang and Zhu (1999), Yao (2002b) and Sachs et al. (2000) applied inframarginal analysis to study transitional economies. Their work shed lights on the issues of political economy, implicit and explicit corruption during economic transition.

Li (2001) developed an equilibrium model with endogenous division of labor to study the emergence and the function of the state. His work has been extended by Liu and Yang (2001) and Li et al. (in press) to explain the effect of political monopoly on the extent of the market, economic development and income distribution.

5. Concluding remarks

The core methodology of the inframarginal economics literature reviewed in this paper uses mathematical programming to describe self-interested behaviour and the notion of general equilibrium to describe the outcome of interactions between self-interested decisions. Mainstream economists may consider this literature as being non-mainstream, whereas evolutionary economists and economists of the Austrian School may consider it to be of too mainstream.

[6] See, for instance, Weitzman (1982) and Mankiw (1985) for microeconomic explanations of business cycles.

As argued by many mainstream economists, the notion of general equilibrium does not necessarily imply market clearing, decisions based on perfect rationality, static equilibrium, or deterministic regularities. General equilibrium as a consequence of interactions between self-interested decisions may generate equilibrium shortage, spontaneous evolution in endogenous variables, and chaos (Rosen, 1997; Yang, 2001; Yang and Yao, 2001).

In the inframarginal economics literature, Walrasian sequential equilibrium can be used to formalize the ideas on social, endogenous, and fundamental uncertainties, entrepreneurial discovery, adaptive decisions based on bounded rationality, and other notions developed by evolutionary economists as well as those of the Austrian School. Moreover, general equilibrium as a consequence of interactions between decisions is characterized by a circular causation, all individuals' self-interested decisions about which goods to trade determine the prices of which goods can be seen in the market, while prices that can be seen in the market determine which goods individuals will trade. All individuals' participation decisions in the market are dependent on the number of participants in the market, while the size of the market network is determined by all individuals' participation decisions (Smith–Young theorem). The function of the market price mechanism is to coordinate impersonal networking decisions to utilize the network effects of division of labor. This function of the market and price system in acquiring organization information via social experiments is much more sophisticated and more powerful than marginal analysis of resource allocation predicts.

The inframarginal economics literature has absorbed many ideas from traditional and modern economic thinking and has the advantage of mainstream formalism. We hope the new ideas and the formalism can forge a new mainstream synthesis.

In the past two decades, inframarginal economics has attracted the attention of an increasing number of economists, and the inframarginal framework has been applied to a wide range of economic topics. This is in part because inframarginal economics can provide an overarching framework to explain many economic phenomena starting from simple assumptions.

To date, two textbooks (Yang, 2001, 2003a) have been published that provide systematic and comprehensive materials for teaching inframarginal economics. With further dissemination of research and better co-ordination of future research efforts of an increasing number of researchers, it is to be expected that inframarginal economics would experience faster development and at the same time be subject to wider scrutiny. It will continue drawing ideas and techniques from other research programs and approaches, and resurrect the spirit of classical mainstream economics in a modern body of mathematical formalism.

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