Specialization and Division of Labor: A Survey

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Abstract

The paper first briefly reviews the classical literature on specialization. The classical research approach to the study of specialization that was followed by Adam Smith, Allyn Young, and Houthakker is distinguished from neoclassical economics structured by Marshall. The modern literature on specialization and division of labor is then surveyed in detail. Three lines of research are identified. One is associated with neoclassical trade theory which assumes constant returns to scale in production and explains the pattern of specialization and division of labor by exogenous comparative advantage between countries. The second line is associated with new trade and growth models which endogenize one aspect of the division of labor, the number of goods, by formulating a tradeoff between economies of scale and economies of variety of consumption or producer goods. The third line is associated with models that endogenize all aspects of the division of labor: individuals' levels of specialization, the length of a roundabout production chain, and the number of goods in each link of the chain. In particular, the implications of new classical economics and inframarginal analysis for the resurrection of the spirit of classical economics in a modern body are explored.

1. Classical Literature on Specialization and Division of Labor

The purpose of the paper is to survey the literature on specialization and the division of labor in society. In the introductory section the classical literature on specialization is briefly reviewed. The neoclassical literature on specialization and new trade and growth theory based on marginal analysis will be reviewed in section 2. The formal decision models that apply inframarginal analysis to endogenize individuals' levels of specialization and the equilibrium models that apply marginal analysis to endogenize individuals' levels of specialization will be surveyed in section 3. New classical equilibrium models of specialization based on corner solutions and inframarginal analysis will be surveyed in section 4.

Houthakker [1956, p. 182] expressed the belief that "Most economists have probably regarded the division of labor, in Schumpeter's words, as an `external common place,' yet there is hardly any part of economics that would not be advanced by a further analysis of specialization." This implies that the analysis of specialization and division of labor is not merely one of many fields of economics, but rather is at the core of classical mainstream economics. But Stigler [1976, pp. 1209-1210] noted the absence of formal theory of division of labor in the modern mainstream economics: "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 the theory of division of labor, for the excellent reason that there is scarcely such a theory. … But 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 the 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."

The focus of classical economics was on the implications of specialization and division of labor for economic growth and welfare. Plato [380BC, pp. 102-6] considered welfare implication of division of labor and specialization and the connection between the division of labor, the market, and money. Xenophon also examined the connection between cities and the division of labor (see Gorden [1980, p. 41]). William Petty [1671, I, pp. 260-61] noted that specialization contributes to skillful clothmaking and pointed out that Dutch could convey goods cheaply because they specialized each ship for a specific function. In another place, Petty gave a more striking example of the division of labor in the manufacture of a watch. He indicated [1683, pp. 471-2] that cities can promote the division of labor by reducing transaction costs. Joseph Harris [1757] and Josiah Tucker [1756, 1774] referred directly to the productivity implications of the division of labor, the possibility for the subdivision of labor, and the intimate relationship between a greater variety of goods, production roundaboutness, and a higher level of division of labor.[1] Before Adam Smith, three advantages of the division of labor (improving the skill, or human capital in modern terms, of individual workers, saving the time and effort involved in having to switch from one operation to another, and facilitating the invention of machinery) and the role of the market and population size in permitting specialization were spelt out by French *Encyclopedia*, Anonymous author [1701, p. 591], Henry Maxwell [1721, p. 33], and Josiah Tucker [1755, 1774]. Also, Anne-Robert-Jacques Turgot [1751, 242-3] had linked the development of division of labor with the concurrent increases in inequality of income distribution and in living standard for even the humblest member of society. He associated the division of labor with the introduction of money, the extension of commerce, and the accumulation of capital [1766, pp. 44-6, 64, 70].

Smith [1776] called public attention to the central role of specialization and division of labor in economic analysis by systematically investigating their implications for economic growth and prosperity. Among other contributions, he proposed the conjecture that the extent of the market is determined by transportation efficiency [1776, pp. 31-32] and the proposition that the division of labor

[1] See Groenewegen [1987], Meek and Skinner [1973] and Rashid [1986] for more details of this classical literature.

is limited by the extent of the market [1776, chapter 3 of book I]. He proposed a theory of capital that takes capital to be a vehicle for increasing division of labor in roundabout productive activities (p. 371). He proposed what is now referred to as the concept of endogenous comparative advantage which implies 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).

He explained the difference in productivity between the agricultural sector and industrial sector as determined by the relative difference in the benefits of specialization compared to the seasonal adjustment cost caused by specialization 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 the 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. These goods are produced by 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.[2]

David Ricardo [1817] pursued an alternative line of studies of specialization and division of labor. He emphasized exogenous comparative advantage and what is referred to by Rosen [1978] as superadditivity which implies a type of interpersonal or social complementarity of production that generates a higher transformation curve for the division of labor than that for non-specialized production. Here, exogenous comparative advantage is defined as ex ante differences in tastes, technology, and factor endowments between individuals or countries that generate gains to trade.[3] In this paper, "ex ante" means "before individuals make decisions" and "ex post" means "after individuals have made decisions and the economy has settled down in equilibrium".

According to Rae [1834, pp. 164-5, 352-7], an increase in the utilization rate of tools and materials is a far more significant advantage of the division of labor than time saved. Charles Babbage [1832, pp. 170-74] indicated that the division of labor can be used to save on fixed learning cost by avoiding duplicated learning and training. Hegel [1821, p. 129], Babbage [1832, pp. 173-4], and Ure [1835, p. 21] had indicated that the division of labor simplifies work of each specialist, so that the work can be replaced with machines. Karl Marx [1867, Vol. 1, chapters 13-15] drew the distinctions between simple cooperation without the division of labor and cooperation based on the division of labor, between the division of labor in production and the division of labor in transacting activities, and between the division of labor within a firm and the division of labor in the market. Amasa Walker [1874, p. 39] called attention to the implications of the division of labor in schools, lectures, churches, and journals, and stated that division of labor facilitates the invention of tools, machines, and technology [1874, pp. 36-37]. He discussed the tradeoff between the benefits of the division of labor and related costs caused by a tension between specialization and seasonal changes in demand (p. 41). He conjectured that division of labor will increase when the benefits outweigh the costs.[4]

It is interesting to note that the classical economists did not use the concept of economies of scale or increasing returns to scale. The concepts that they used are specialization, division of labor, and related benefits and costs. A careful reading of Alfred Marshall [1890] and Allyn Young [1928] indicates that the subtle distinction between the concepts of economies of specialization and economies of scale was crucial for the subsequent development of economics.[5]

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[2] This theory of Smith is formalized by Shi and Yang [1995]. Some empirical implications of the Smith conjecture is investigated by Kaldor [1967].

[3] In trade theory, comparative advantage is relevant to only ex ante differences in technology and endowments.

[4] In George Stigler et al [1995], some topological indices are estimated to analyze the asymmetric nature of the network hierarchy of exchanges based on the division of labor between journals that specialize in different fields of economics.

[5] According to Groenewegen [1987], the works of N. Senior [1836, pp. 74-5, 181-2], John Stuart

Marshall [1890] tried to formalize classical economic thinking within a mathematical framework. His principles textbook consists of two parts. One (chapters 8-12) is full of classical insights into the economic implications of specialization and division of labor without mathematical formalization. The other is the marginal analysis of demand and supply within an internally consistent mathematical framework. The second part successfully formalized the relatively unimportant part of classical economic thinking on the problem of resource allocation. Here, the problem of resource allocation is to find the efficient relative quantities of different goods and the efficient relative quantities of factors allocated to produce the different goods for a given degree of scarcity (or a given transformation function) and a given pattern and level of division of labor. The problem of organization by contrast is to find the efficient level and pattern of division of labor in order to expand the production possibility frontier (or to reduce scarcity) against transaction costs for a given relative quantities of different goods consumed and produced. As Yang and Y-K. Ng [1993] show, the absence of formalization of classical economics on problems of economic organization in Marshall's work was because the formalization must involve corner solutions, but the technique for handling corner solutions and related inframarginal analysis was not available until the 1950s. Here, a corner solution to an optimization problem is a solution that involves upper and/or lower bound values of some decision variables. Inframarginal analysis is defined as total benefit-cost analysis across corner solutions in addition to marginal analysis of each corner solution[6].

The success of the second part of Marshall's principles textbook is based on an unrealistic dichotomy between pure consumers and pure producers (firms) which is essential for avoiding corner solutions. This dichotomy makes Marshall's marginal analysis incapable of explaining the emergence of firms, business cycles, cities, money, middlemen, and a hierarchical structure of transactions from division of labor and incapable of explaining the evolution of the extent of the market, productivity, comparative advantages, trade dependence, and many other interesting and important economic phenomena.

However, Marshall's formalization of the resource allocation problem established mainstream of economics in the following sense. Marshall's mathematical structure of marginalism gives teaching a well organized structure. Within this structure, not only can different generations of economists and students share a common dictionary, but also teachers can set good questions and exercises in classrooms and in examinations to which a unique correct answer is expected. What teachers teach on the blackboard can be exactly duplicated by many students. This common mainstream facilitates the division of labor between different generations of economists and between different fields of economics. Unfortunately, the mainstream does not carry the core of classical economic thinking on problems of specialization and the division of labor. As Buchanan [1994, p. 6] observes, "with one part of his mind always in classical teachings, Marshall recognized that this genuinely marvelous neoclassical construction requires that the Smithean proposition on labor specialization be abandoned." As an unexpected consequence of Marshall's success in formalizing problems of resource allocation, the core of classical economics concerning specialization and division of labor has been forgotten.[7] but according to Young [1928, pp. 538-40], the "possibility of economic progress" could not be fully understood without this core.

Samuelson's principles textbook [1948] was another dividing line. This textbook consists of microeconomics that is Marshall's marginal analysis of demand and supply and macroeconomics that

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Mill [1848, p. 13], Fawcett [1863], and Nicholson [1893] started the process that replaces the concept of economies of division of labor with the concept of economies of scale.

[6] Buchanan and Stubblebine [1962] propose this concept. The application of inframarginal analysis to a decision problem can be found from Kendrick [1978], Little and Mirrless [1980], and Rosen [1983]. The application of inframarginal analysis to general equilibrium models can be found from Yang [1991], Yang and Wills [1990], Yang and Borland [1991], Yang and Shi [1992], and Yang and Ng [1993]. Koopman [1957] suggests that the concept of production function should be replaced with the notion of activity analysis when inframarginal analysis is conducted.

[7] As a result, economists' research on specialization and division of labor since Marshall is not as much as sociologists' research on the topic, represented by Emile Durkheim [1933].

incorporates Keynesian economics which tries to explain many economic phenomena that Marshall's economics cannot predict. Since the 1950s when Samuelson's textbook became a prototype for principles textbooks in economics, there has not been a place for problems of specialization and division of labor in principles textbooks. Each principles textbook spends just one paragraph to pay symbolic respect to classical economic thinking concerning specialization and division of labor. No formal models of Smith's endogenous comparative advantage are developed to endogenize individuals' levels of specialization in the textbooks although they cover formal models of Ricardo's exogenous comparative advantage.

Marshall's neoclassical framework is characterized by the dichotomy between pure consumers and firms, the replacement of the concept of economies of specialization with the concept of economies scale, and marginal analysis of demand and supply.[8] The debate on external vs. internal economies of scale and on other issues within the framework clarified some confusion. But as Buchanan [1994, p. 7] indicates, "Allyn Young sensed that the focus of economists' attention was shifting too readily and too rapidly toward clarification of analysis within neoclassical structure and away from classical emphasis." Young [1928] is the paper most cited by the modern literature of specialization and is regarded by Rosen [1983, p. 44] as "the zenith of the analysis of the connection between specialization and economic development." Young emphasized the concepts of specialization, roundaboutness, and division of labor, and criticized the concept of economies of scale or increasing returns to scale which had been already very popular in economics teaching and research due to the success of Marshall's principles textbook of neoclassical economics. He argued [1928, 531] that "the view of the nature of the processes of industrial progress which is implied in the distinction between internal and external economies is necessarily a partial view. Certain aspects of those processes are illuminated, while, for that very reason, certain other aspects, important in relation to other problems, are obscured." Hence, it seemed to Young that the concept of external economies of scale is a misrepresentation of classical concept of economies of specialization and division of labor. Since Young and Marshall, the research of specialization has developed along two lines. One is associated with Marshall's concept of (external or internal) economies of scale and with his marginal analysis, and the other follows Young's concept of economies of specialization and division of labor.[9]

Young's concept of "social increasing returns" is very similar to Buchanan's [1994] concept of "generalized increasing returns" and to Rosen's [1978] concept of "superadditivity", which will be defined in section 3. Young stated several times that the increasing returns with which he was concerned are not caused by the scale of a firm or an industry. According to him, they are generated by specialization and the division of labor rather than by economies of scale.[10] He used three concepts to describe the division of labor. The first is individuals' specialization. An individual's level of specialization increases as he narrows down his scope of activities. The second is the length of a roundabout production chain, or so-called roundaboutness. The third is the number of intermediate goods in each link of the chain. Certainly, the three concepts are related to and distinct from the concept of economies of scale. Indeed, Young's concept of social increasing returns based on specialization and division of labor is equivalent to the modern concept of a positive network effect of division of labor.[11]

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[8] The modern Arrow-Debreu model of general equilibrium, which is featured with the first two properties of Marshall's framework, has generalized and consolidated Marshall's framework. Arrow and Debreu use the concept of non-convex production set to generalize the concept of economies of scale.

[9] Economies of scale and economies of division of labor may coexist. But the latter is much more important than the former, since the latter enhances the capacity of society in acquiring information and knowledge by exploiting interpersonal complementarity, while the former is a pure technical concept that may have nothing to do with endogenous technical progress generated by the knowledge acquisition process of society.

[10] Young (p. 533) even argued that the use of the notion of large-scale-production misses the phenomenon of economies of division of labor.

[11] Young [1928, p. 539] spelled this out as follows. "The mechanism of increasing returns is not to be discerned adequately by observing the effects of variations in the size of an individual firm

The Young conjecture [1928, p. 539, p. 534] consists of the following three statements. "The securing of increasing returns depends on the progressive division of labor"; "Not 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";[12] "Demand and supply are two sides of the division of labor".[13] The Young conjecture represents the view that takes economies of division of labor as a network effect.

Young suggested that the extent of the market is determined not only by population size, but also by purchasing power, which is determined by productivity, which is in turn dependent on the extent of division of labor. He then went on to argue that the circle that the division of labor depends upon the extent of the division of labor implies that a dynamic mechanism generates progressively increasing division of labor and the extent of the market. On the other hand, this circle implies that the size of the market network and the degree of division of labor are simultaneously determined. Suppose there are three ex ante identical individuals who prefer diverse consumption and specialized production in producing each of three goods x, y, and z. If an individual chooses to completely specialize in producing x, then he will demand y and z. If he chooses partial specialization in producing x and y, then he has no demand for x and y from the market and he will demand z. But if two individuals choose self-sufficiency, then the other cannot choose specialization. This implies that each person's decision on his level of specialization not only determines his productivity, but also determines the extent of the market for others' produce, thereby setting a constraint for others' decisions on their levels of specialization and productivity. Hence, the Young conjecture explores a typical feature of network effects of the division of labor and related market.[14] He implicitly, therefore, set up a research agenda to use economic models to explain how the size of the market network based on specialization and division of labor is determined in a decentralized system. Another more explicit target set by Young is to formalize the concept of economies of division of labor which includes economies of individuals' specialization, economies of roundaboutness, and economies of the variety of producer goods. On the basis of the formalization, a dynamic equilibrium model may be able to simultaneously explain the three aspects of the division of labor.

Although Young's approach represented a more promising research line than Marshall's neoclassical framework, he did not, unfortunately, formalize his ideas within a well organized mathematical structure. However, he was sure that neoclassical marginal analysis is not suitable for his research agenda (p. 534). Certainly, Marshall's concepts of demand and supply are substantially different from Young's. The essence behind Marshall's concepts of demand and supply is a tradeoff between quantities of different goods in raising utility and a tradeoff between quantities of factors allocated to produce a certain level of output. The market trades off one against the other to achieve an equilibrium. The equilibrium relative prices and relative quantities of goods and factors are explained by relative tastes, relative technologies, and relative quantities of different factor endowments and their initial distribution among individuals. Marshall's story has no implication for how demand relates to the level of division of labor.

Due to the dichotomy between pure consumers and firms, Marshall's neoclassical model does not have any tradeoff that can be used to endogenize the level of specialization for individuals and the level of division of labor for society. In other words, each pure consumer in Marshall's model has to buy all goods that he consumes and he cannot survive in the absence of exogenously given firms and market. Hence, this model cannot explain why and how an economy evolves from an autarkic state where each

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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."

12 Roumasset and Smith [1981] provide evidence for the proposition that individuals' levels of specialization determine the extent of the market.

13 This relates to Say's law. Yang and Ng [1993, chap. 18] show that a new classical dynamic equilibrium model may generate efficient business cycles and unemployment even if Say's law holds.

14 The concept of network effect here is consistent with Katz and Shapiro's [1985, 1986] definition, which implies that performance of a network depends on the number of participants and that a participant's decision depends on his expectation of other participants' decisions.

individual self-provides all goods he consumes to a completely commercialized state, and why and how firms emerge and develop as division of labor evolves. When Young developed his analysis of demand and supply on the basis of the investigation of the division of labor, he explicitly criticized marginal analysis of demand. He stated "The apparatus of supply and demand in their relation to prices does not seem to be helpful for the purpose of an inquiry into these broader aspects of increasing returns [1928, p. 533]. Young inquires how individuals choose among different patterns and levels of division of labor to reduce scarcity or to improve productivity. Demand and supply are determined by the pattern and level of division of labor. Marshall's marginal analysis is devised to address the question of how the market sorts out the relative quantities of goods consumed and produced for a given degree of scarcity and a given pattern of organization within firms and between pure consumers and firms. Hence, Young's economics is referred to as economics of organization and Marshall's economics is referred to as economics of resource allocation by Yang and Y-K. Ng [1993].

Houthakker [1956, p. 182] develops Smith's proposition that the extent of the market is determined by transportation conditions to suggest that a tradeoff between economies of specialization and transaction costs can be used to explain the level of division of labor. If the transaction cost coefficient for one unit of goods is very large, then economies of specialization are outweighed by transaction costs caused by the division of labor, and the equilibrium level of division of labor will be very low. In this case the extent of the market is small and market demand and supply are zero. As the transaction cost coefficient falls, the efficient level of division of labor and productivity will increase, so that the extent of the market and demand and supply in the market place will increase.[15] This is a promising direction toward the formalization of Young's concepts of demand and supply. However, Houthakker argues (p. 182) "such an analysis (of specialization) 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."[16]

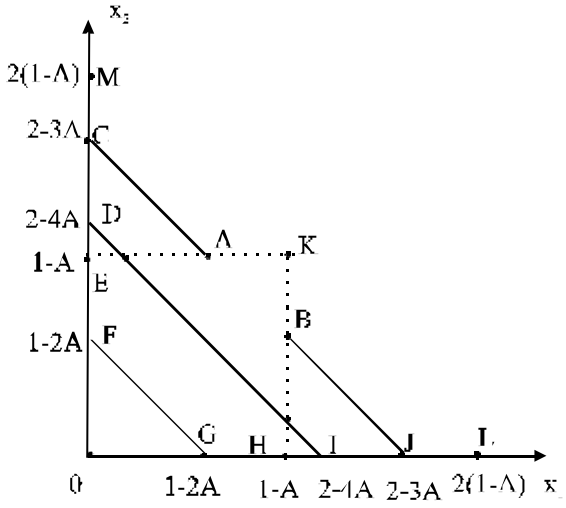

Figure 1: Economies of Division of Labor Generated by Fixed Learning Costs

Houthakker draws the distinction between economies of specialization and economies of scale when he discusses the necessity of a new analytical approach. "We 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 output of the single activity may thus be raised above the combined outputs of the several activities."

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15 Rosen [1983, p. 48] also states that market constraints on specialization must arise from transactions costs that limit the size of a person's market.

16 This is an indirect criticism of those models with a continuum of individuals or of variety of goods.

Houthakker [1956] uses a graph to illustrate the distinction between Smith's concept of economies of division of labor and Ricardo's concept of comparative advantage. Suppose there are two ex ante identical individuals with the same production functions for two goods and the same endowment for labor: $x_1=L_1-A$, $x_2=L_2-A$, and $L_1+L_2=1$, 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. Then, an individual's transformation curve is ecdf in Fig 1. Each individual's PPF is EFGH. The aggregate transformation curve for the two persons when each of them produces two goods is segment DI. The aggregate transformation curve for the division of labor which implies at least a person producing only one good is MCAKBJL. It is obvious that the aggregate transformation curve for the division of labor is higher than the aggregate transformation curve for autarky even if the two persons are ex ante identical or even if no Ricardian comparative advantage exists. This shows that Smith's concept of economies of division of labor may be more general than Ricardo's concept of comparative advantage. Yang and Borland [1991] refer to Smith's comparative (and absolute) advantage as endogenous comparative advantage and refer to Ricardo's comparative advantage as exogenous comparative advantage.[17]

Two points from Houthakker's graph deserve particular attention.[18] (1) Specialization and diversification are two sides of the division of labor. Point G represents the situation where two persons specialize in producing good y, but no division of labor exists. Also, at point H there is specialization but no division of labor. Point D, segment BC excluding point B, and segment EF excluding point F are associated with division of labor as well as specialization.[19] (2) An ex post difference in productivity between sellers and buyers emerges from ex ante identical individuals only if they choose different levels of specialization in producing a good. If each of the two persons spends the same amount of labor in producing each good, then ex post productivity is the same for them, so that no endogenous comparative advantage exists. This implies that the existence of endogenous comparative advantage depends upon individuals' decisions on their levels of specialization.[20]

Houthakker complained that the evolution of specialization and division of labor in an economic system seems more significant and important than the evolution of species, but research of the former in economics is far behind studies of the latter in biology. This complaint still has important implication for current economic research.

Another important paper that followed up Young's research line was Stigler [1951]. Like Houthakker, Stigler used a graph to emphasize the distinctive feature of specialization that a firm's productivity increases as it narrows down its range of production activities. He demonstrated that a firm's cost function will be endogenously and discontinuously changed by its decision on the level of specialization. The discontinuous change in the cost function that is caused by a change in a firm's level of specialization is similar to the inframarginal analysis developed by Rosen [1983] and Yang [1991]. However, Stigler still followed Marshall's approach of separating the analysis of demand from the analysis of decision making regarding the level of specialization. He emphasized internal increasing returns to specialization against Marshall's concept of external economies of scale. When discussing the

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17 Also, Arrow [1979, p. 154, p. 162] has spelled out the distinction between Smith's endogenous comparative advantage and Ricardo's exogenous comparative advantage and the tradeoff between economies of specialization and communication costs.

18 A similar graph for non-linear production functions can be found from Yang [1994a] or from Yang and Ng [1993, chap. 2]. Houthakker's original graph is drawn in an Edgeworth box with different origins for two individuals.

19 Many economists (for instance, Arrow [1979]) regard specialization as equivalent to division of labor. Though the two go together in many situations, they are not equivalent.

20 Our survey does not cover many formal models in the literature of transaction costs. Most of the formal models assume exogenous comparative advantages to generate the tradeoff between the exogenous comparative advantages and ex ante or ex post transaction costs. Hence, the endogenization of individuals' levels of specialization is not the focus in the models although inframarginal analysis is used in some of the models, for instance, in S. Grossman and Hart's model [1986] and in Hart and Moore's model [1990].

problem of vertical integration, he mixed up the concept of economies of specialization with the concept of economies of scale, departing from Young's research line.

The literature on specialization has developed along three lines since Stigler and Houthakker. The first line has developed formal models based on Ricardo's concept of exogenous comparative advantage and on Marshall's framework with a dichotomy between pure consumers and firms and marginal analysis of demand and supply, focusing on the division of labor between countries rather than on the endogenization of individuals' levels of specialization. This turned out to be a field called the theory of international trade. Dixit and Norman's textbook [1980] is representative of this research line. The second line has developed formal models using the concept of economies of scale and Marshall's framework to endogenize one aspect of Young's concept of division of labor: the number of consumption and producer goods. Representative works along this line are Dixit-Stiglitz [1977], Ethier [1982], Krugman [1979], Judd [1985], Romer [1986], and Grossman-Helpman [1989, 1990]. The third line has endogenized individuals' levels of specialization and the level of division of labor for society as a whole, following Smith, Young, and Houthakker's ideas. Some of the formal models apply inframarginal analysis to endogenize the level of division of labor and explain other economic phenomena by the level and pattern of division of labor. Section 2 reviews the major works along the first two research lines. Then sections 3 and 4 survey the third line of research.

2. Exogenous Comparative Advantage and Economies of Scale

2.1. Neoclassical Trade Theory

Ricardo's model is a razor edge between increasing returns and diminishing returns from which either Young and Houthakker's ideas can be formalized or Marshall's line can be pursued. In his model production technology has constant average as well as marginal productivity of factor(s). Hence, it is not easy to apply marginal analysis to Ricardo's model. For instance, if two agents (individuals or countries) have the following production functions, endowment constraints, and tastes: $x_1=3L_{1x}$, $y_1=2L_{1y}$, $L_{1x}+L_{1y}=1$, $x_2=2L_{2x}$, $y_2=L_{2y}$, $L_{2x}+L_{2y}=1$, $u_i=X_i^I Y_i^{1-I}$, where x_i and y_i are respective output levels of the two goods for agent i, L_{ij} is agent i's amount of labor allocated to produce good j, u_i is agent i's utility level, and X_i and Y_i are respective quantities of the two goods consumed by agent i. In this model, agent 2 has no absolute advantage, but has a comparative advantage in producing good x. Equilibrium may involve one combination of several corner and/or interior solutions. Each agent must do inframarginal analysis to choose one from several corner and interior solutions.[21] Cheng, Sachs, and Yang [2000] have shown that there is a unique general equilibrium in this model and it will discontinuously jump across several corner equilibria as parameters reach some critical values. As transaction conditions are improved, the equilibrium network size of division of labor enlarges, resulting in increases in aggregate productivity. This formalizes the notion of generalized and social increasing returns in the absence of economies of scale. Trade economists however were not used to inframarginal analysis. As Dixit and Norman [1980, p. 38] observe, "The Ricardo model is unsuitable for comparative statics. The phenomenon of multiple output choices with non-differentiable revenue functions makes it difficult to apply most standard techniques of analysis. For analyses which need single valued supply choices, therefore, attention has shifted to a post-Ricardian model. We have several goods produced using only one variable factor (the Ricardo-Viner model) or several factors (neoclassical trade model), but the factor(s) has diminishing returns in each use. Price change then cause a smooth shift of the factor from one use to another."

From here, neoclassical trade theory has gone on to focus on models with constant returns to scale (diminishing returns to each factor). Trade economists have shown remarkable insistence in the marginal technique in handling the neoclassical trade models. These models cannot explain the emergence of international trade from individuals' decisions on their levels and patterns of specialization. The dichotomy between pure consumers and firms in neoclassical trade theory implies

[21] Buchanan and Stubblebine [1962], Coase [1946, 1960], Lievowitz and Margolis [1994] and other economists argue that many so called problems of coordination, multiple equilibria, and network externalities are generated by the assumption that individuals cannot do total benefit-cost analysis across corner solutions and they naively stick to marginal analysis of a globally non-optimum corner solution.

that the rationale for international trade differs from the one for domestic trade. Domestic trade is essential even in the absence of exogenous comparative advantage (the differences in technology, endowments, and tastes) between individuals, and of economies of scale because pure consumers cannot survive in the absence of domestic trade. But the driving forces of international trade are these elements. Also, international trade cannot be endogenized in two senses. First, trade is generated by exogenous comparative advantage which decision makers cannot alter. Second, international trade is always better than autarky if any of these elements is present. Differing degrees of involvement of countries in international trade cannot be explained by individual agents' decisions. Wong and Yang [1996] show that even if the tradeoff between economies of scale and transaction costs is introduced into a neoclassical trade model, the degree of involvement in trade cannot be explained by the transaction cost coefficient, as long as the coefficient is between 0 and 1 and the differential in the coefficient between international trade and domestic trade is not very large.

2.2. New Trade and Growth Theory

Since the end of the 1970s, a new trade and growth theory has been developed to formalize the concept of gains to trade that are generated by economies of scale. In Dixit and Stiglitz's classic paper [1977], a tradeoff between distortions caused by global economies of scale and pure consumers' preferences for diverse consumption is formulated to explain productivity, percapita real income, and the number of goods by the size of an economy. The CES utility function in the D-S model implies that each good is not a necessity individually and utility increases with the number of consumption goods. A larger size of an economy generates more scope for trading off economies of scale for consumption variety, so that productivity and percapita real income increase as the size of the economy increases.[22] The implications of the model for trade theory, which are explored by Krugman [1979], are straightforward. Opening up of international trade will improve productivity, raise percapita real income, and reduce the distortion caused by the monopoly power because the size of the pooling economy in an integrated world market is always larger than that for individual countries.[23]

As Krugman shows [1979, 1980], gains to trade exist even if all countries are ex ante identical. Trade between identical countries might be more than trade between differentiated countries. This was an important step towards the formalization of Smith's concept of endogenous comparative advantage along the line suggested by Houthakker. Ethier [1982] extends the Dixit-Stiglitz model to the case with the CES production function. The Ethier model formulates a tradeoff between productivity gains in producing final goods from a variety of producer goods and global economies of scale in producing the producer goods. As the size of an economy increases, the scope for the market to trade off one for the other is enlarged, so that total factor productivity and percapita real income increase and distortions are reduced.

Following Judd [1985] who has developed a dynamic version of the Dixit-Stiglitz model, Romer [1986a] develops a dynamic version of the Ethier model, by replacing the concept of internal economies of scale with the concept of external economies of scale and by assuming perfect competition instead of monopolistic competition. This model formalizes one aspect of Young's concept of division of labor, that is, the number of producer goods. Also, this model formalizes Young's conjecture that a dynamic mechanism generates spontaneous evolution of the number of producer goods and productivity. However, none of the new trade and growth models has endogenized the level of specialization for individuals. In the models, each consumer has to buy all goods that he consumes, each firm completely specializes in producing one good, and an intermediate level of specialization never occurs in equilibrium, so that the level of specialization for each individual cannot be explained. Romer's story runs as follows. There is a tradeoff between economies of scale and economies of complementarity between different intermediate goods in raising the productivity of final goods. In addition, another tradeoff exists between current consumption which can be increased by reducing saving and future

[22] Y-K. Ng's model [1977, 1980] is similar to the Dixit-Stiglitz model in specifying a monopolistically competitive regime, but is used for macroeconomic analysis.

[23] However, Krugman uses the Dixit-Stiglitz formula for the own price elasticity of demand which implies that opening up of international trade will not reduce prices and related distortions. Yang and Heijdra [1992] show that if a correct formula for the elasticity is used, the implication of international trade for reducing the distortions can be explored.

consumption which can be increased by a higher saving level that increases the quantity of a primary factor which can be employed to increase the number of intermediate goods and thereby the productivity of final goods. A competitive market trades off the conflicting forces to achieve a dynamic equilibrium that generates long-run growth and spontaneous evolution of the number of intermediate goods. The dynamic equilibrium is not Pareto optimal due to external economies of scale. In another model, Romer [1990] extends this analysis to endogenize innovation based on imperfect competition.

Grossman and Helpman [1989, 1990] have developed a dynamic version of the Dixit-Stiglitz model and a dynamic version of the Ethier model, keeping the original flavor of internal economies of scale and monopolistic competition. Their story is similar to Romer's story, but distortions are caused by monopoly power instead of external economies of scale. The model can generate endogenous evolution of productivity and the number of goods.[24] All of the new trade and growth models are featured with (static or dynamic) marginal analysis, economies of scale, and dichotomy between pure consumers and firms.[25] Hence, this is a development within Marshall's neoclassical framework.[26]

3. Specialization and Division of Labor

3.1. The Return to the Endogenization of Individuals' Levels of Specialization

The first effort to bring formal economic research back to the original ideas of Smith, Young, and Houthakker might be attributed to Rosen [1978] and Becker [1981]. Rosen extends the Ricardo model to the case with many goods and many individuals. He applies linear programming rather than marginal analysis to handle the problem of corner solutions. Different from the neoclassical economists, he concentrates attention on the implications of corner solutions for endogenization of individuals' levels and patterns of specialization instead of getting around corner solutions. He uses a managerial decision model to clarify several important problems which are essential for the endogenization of individuals' levels of specialization and the level of division of labor in society. He shows that economies of division of labor that are endogenously determined by individuals' decisions on their levels and patterns of specialization look like external economies of scale, but may exist in the absence of economies of scale. Economies of division of labor is not a technical concept because the linear programming model can be used to show that the elasticity of substitution between factors in an ex post production function generated by individuals' decisions of their levels and patterns of specialization is different from the elasticity of substitution for the corresponding ex ante production function. Hence, economies of division of labor is a concept that explains productivity by the degree of interpersonal or social interdependence. Suppose there are exogenous comparative advantages among many individuals, then there are many possible transformation curves. 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]). This means that more interaction and interdependence among individuals yields greater scope for productivity improvement. This is an interesting type of social and interpersonal complementarity. Rosen calls such social complementarity "superadditivity" which differs from economies of scale and from technical complementarity which relates to economies of scope. Economies of scale and economies of scope relate to pure technical

[24] For more detailed review of this literature, please see, for instance, Grossman and Helpman [1995] and Romer [1994].

[25] Here, dynamic marginal analysis refers to the calculus of variations. The first order condition for the interior solution, the Euler equation, in a dynamic model implies that accumulated discounted marginal benefit equals instant marginal cost of investment. This is an analogue of the equalization condition between marginal benefit and marginal cost in static models. The control theory is sufficient but not necessary for managing the new growth models. The dynamic inframarginal analysis involves dynamic corner solutions (bang-bang control), the control theory, or dynamic programming (see Yang and Borland [1991] and Borland and Yang [1995]).

[26] As soon as economists have realized the implications of economies of scale and CES function for the endogenization of aggregate demand, the Dixit-Stiglitz model is applied to macroeconomic analysis. See Blanchard and Kiyotaki [1987] and Rotemberg [1987].

relationships between outputs and inputs and are independent of the degree of interpersonal and social interdependence.

There are two types of technical complementarity. One is studied by Milgrom and Roberts [1994] who consider to what degree a factor complements another in producing goods for a given number of factors and goods. The second is studied by Dixit-Stiglitz, Ethier, Judd, Romer, and Grossman and Helpman who investigate the implications of the complementarity between goods when the number of goods is endogenized. Rosen's superadditivity differs from both types of technical complementarity that are independent of individuals' decisions on their levels and patterns of specialization. The distinction between the interpersonal superadditivity of Rosen and technical complementarity can be used to draw the distinction between economies of division of labor, which relates to Rosen's superadditivity, and economies of scope which is equivalent to technical complementarity. Since various combinations of corner solutions generate many possible patterns of specialization and division of labor, each of the patterns is associated with a certain size of network of exchanges. Hence, Rosen's superadditivity is a typical and important network effect. The essence of the Smith-Young conjecture about the interdependence between the extent of the market and the division of labor relates to the nature of the network effects of division of labor.

As shown in Cheng, Sachs, and Yang [2000], if transaction costs are introduced into the Rosen model, a tradeoff between exogenous comparative advantage and transaction costs might be used to endogenize not only the pattern of division of labor, but also the level of division of labor and the related size of the network of exchanges. Rosen's work is an important step toward shifting economists' attention from the marginal analysis of interior solutions to the endogenization of individuals' levels and patterns of specialization and related inframarginal analysis of corner solutions.

Becker [1981] develops a model to endogenize individuals' decisions on specialization within a family. This model is solved using inframarginal analysis of many corner and interior solutions. The positive interactions between labor and human capital allocated to produce a certain good generates a pattern of complete specialization for each member of the family except one who will not completely specialize when an integer condition for the numbers of different specialists is not satisfied. Although this model is not explicitly specified as a dynamic decision model, and human capital plays a role similar to the one of the difference in endowment between agents in neoclassical models, it focuses attention on the endogenization of individuals' patterns of specialization and emphasizes the role of endogenous comparative advantage. This might be taken to be a starting point for formalizing Smith and Babbage's idea that the division of labor can be used to avoid duplicated fixed learning and training costs.[27]

Rosen was aware of the limitation of exogenous comparative advantage in his 1978 paper. He develops a model based on endogenous comparative advantage to explain individuals' levels of specialization [1983], following Arrow [1979, p. 154], Becker [1981], and Barzel and Yu's [1981] ideas that the division of labor can increase utilization rate of a fixed learning and training investment. In his decision model, an agent maximizes the difference between benefits and costs of learning, that is $V= w_1k_1t+w_2k_2(1-t)-C(k_1, k_2)$, with respect to t which is the time allocated to produce good 1 and k_i which is learning and training level in activity i, where C is the total learning and training cost, 1-t is the amount of time allocated to produce good 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 uses marginal analysis to solve for the two corner solutions which represent specialization in different activities, and the interior solution which represents non-specialization, and then compares total benefit-cost across all possible solutions. The result is that non-specialization takes place 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. Rosen uses this model to emphasize again that interpersonal complementarity may exist in the absence of technical complementarity. If $\partial^2C/\partial k_1\partial k_2=0$, then technical complementarity does not exist, but two individuals can be better off by completely specializing in different activities and by utilizing the social complementarity.

[27] Also, Schultz [1993] has explored the intrinsic connection between human capital and specialization.

The economies of specialization in Rosen's model are individual-specific, so that increasing returns are localized. This implies that substantial economies of specialization may be compatible with a competitive market. Many economists claim that Smith's notion of economies of scale is incompatible with the invisible hand.[28] However, Smith never used the concept of economies of scale which is imposed on him by others. Smith's concept of benefits from specialization and division of labor can be more accurately represented by the concept of economies of specialization or economies of specialized learning by doing that are individual-specific. It is not obvious why such localized increasing returns are necessarily incompatible with a competitive market. When two individuals engage in the division of labor, economies of specialized learning by doing will not go beyond the scale of each individual's working time. This implies that pooling two persons' labor together will not generate so great economies of scale that correspond to the size of the pooling labor although the social and interpersonal superadditivity (or complementarity) can be exploited by the division of labor between the two persons. Hence, economies of scale derived by pooling labor together within a firm and economies of division of labor based on specialization and interpersonal superadditivity are two distinct concepts. The distinction is very subtle, but very important. As Young argued, the replacement of Smith's concept of economies of division of labor with Marshall's concept of economies of scale obscures the distinction, thereby misleading economics.

Yang [1984, pp. 425-31, 1985, pp. 272-91] develops a model to endogenize individuals' levels of specialization and the level of division of labor in society by abandoning the dichotomy between pure consumers and firms. In this model, each individual is a consumer-producer who prefers diverse consumption and specialized production because of economies of specialization. A tension between specialized production and diverse consumption for each consumer-producer generates a tradeoff between economies of specialization and transaction costs. A central planner may trade off economies of specialization against transaction cost to achieve the efficient level of division of labor by equalizing marginal benefit of the division of labor and marginal transaction cost. Since this is a planning model, marginal analysis can be used for decision making, and corner solutions which may emerge from a decentralized market are avoided. In terms of mathematics, the Becker and Murphy model (B-M model) [1992] is very similar to this model if the coordination cost in the B-M model is interpreted as transaction costs in the Yang model. Both are decision models where the optimum level of division of labor is determined by the equalization condition between marginal benefit and marginal costs of the division of labor. Also, endogenous comparative advantages are a driving force in both models. If the transaction or coordination cost increases more rapidly than economies of division of labor do as the number of different professions increases, then the comparative statics of the optimum implies that division of labor will evolve if the degree of economies of specialization (in the Yang model) or a human capital parameter (in the B-M model) and/or the transaction or coordination cost coefficient change. A difference between the two models is that each person's level of self-sufficiency and the number of transactions are endogenized in the Yang model, but not in the B-M model. Also, the Yang model is featured with the indivisibility of the individual, while a continuum is assumed to describe the division of individuals among different activities in the B-M model. The differences are important for the subsequent development of the literature on specialization.

The B-M model is a very important step toward formalizing ideas of Smith, Young, and Houthakker. This model shows that the efficient level of division of labor is determined not only by the population size which is usually considered as the extent of the market, but also by the efficient balance between economies of division of labor and coordination or transaction costs. Also, Becker and Murphy recognize the implications of Smith's conjecture that transportation conditions determine the extent of the market which in turn determines the level of division of labor. They discuss the implications of coordination costs for urban economics and suggest the possibility of developing a dynamic model to explain evolution of division of labor through interactions between human capital and economies of specialization.

The B-M model reminds us that the concept of extent of the market needs to be refined. There are three aspects of the extent of the market: population size; the number of goods; and the number of traded goods compared to the number of all goods. Certainly, the population size is a determinant of the extent

[28] See, for example, Kim [1989] and Sah and Stiglitz [1986].

of the market. If there is only one person in the world, the extent of the market is zero and the division of labor is impossible. The second aspect of the extent of the market relates to the number of goods. If each individual buys all goods that he consumes, then his number of consumption goods determines his trade volume which in turn affects the extent of the market. All new trade and growth models (Dixit-Stiglitz, Krugman, Ethier, Judd, Romer, Grossman-Helpman) have endogenized the extent of the market by endogenizing the number of goods. However, the new trade and growth models have not endogenized the third aspect of the extent of the market which is determined by individuals' levels of specialization or their degrees of self-sufficiency. If individuals' levels of specialization are not appropriately endogenized, then in the static models the ultimate driving force of productivity, the number of goods, and division of labor is the population size. This result is inconsistent with evidence of a negative correlation between the population size and productivity in some less developed economies. The B-M model shows that even if the population size is fixed, a tradeoff between economies of specialization and coordination costs can endogenize the level of division of labor, while the driving force for the division of labor can be a falling coordination or transaction cost coefficient.

Since the middle of the 1980s, the endogenization of individuals' levels of specialization has been developing along two distinctive lines. One line is to endogenize individuals' levels of specialization on the basis of the neoclassical dichotomy between pure consumers and pure producers or to endogenize individuals' levels of specialization by assuming economies of scale. Baumgardner [1988], Kim [1989], Locay [1990], and Tamura [1992] are representative of the studies. Another line is to follow Yang's 1985 model. The rest of this section surveys the models of the first type. The second type of models will be surveyed in the next section.

3.2. Equilibrium Models of Specialization

The Baumgardner model [1988] represents an important effort to endogenize individuals' levels of specialization within Marshall's framework. This is a partial equilibrium model with a given demand function for a continuum of service types. The analysis of demand is separated from the endogenization of individuals' levels of specialization, a typical Marshallian way of formalism. The dichotomy between pure consumers and producers implies that marginal analysis is a major analytical instrument and inframarginal analysis is not needed. Global economies of scale in producing each type of service entails monopoly in the market for the range of service provided by each producer who will differentiate his range of service from all others' ranges of services. 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 tradeoff is enlarged, so that more economies of scale will be exploited by narrowing down each producer's range of activities. Here, the population size is interpreted as the extent of the market. The model is used to explain why physicians in a large city are more specialized than those in small towns. Becker and Murphy [1992] have, however, argued that a higher level of specialization is generated by a lower coordination cost in a large city rather than by a larger population size. Young's idea that demand and supply are two sides of the division of labor and that the extent of the market and division of labor are two sides of the same coin is yet to be formalized.

Kim [1989], following Lancaster [1980] and Grossman and Shapiro [1982], specifies 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. Hence, there are exogenous absolute advantages between workers. But a matching cost between specialist workers and firms counteracts economies of division of labor which are generated by the exogenous absolute advantages. Each worker can invest in two kinds of human capital with known costs. One type of human capital can be used to reduce the matching cost with a potential employer by expanding the worker's characteristics, and the other type can improve productivity. Each worker will trade off the benefit from higher productivity against the matching cost to choose a pattern of two kinds of human capital. For a given pattern of each worker's human capital, free entry in the market will trade off the productivity gains from a narrower range of activities of each firm against the matching cost caused by the narrower range of activities of the firm, thereby determining a structure of firms. 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. Also, this structure of firms is characterized by the range of each firm's activities and the number of firms. 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. As Weitzman [1994] shows, models of this type are dual to the Dixit-Stiglitz model [1977]. Hence, another interpretation of the Kim model is that a tradeoff between economies of specialization and productivity gains of input variety in the market determines the equilibrium number of firms and their output levels. However, Kim assumes a Nash bargaining game rather than the regime of monopolistic competition. Since each consumer-worker's welfare depends only on his wage, the tradeoff between diverse consumption and increasing returns does not exist. This implies each person's level of self-sufficiency and the extent of the market in the sense of Young's definition is not endogenized.

Locay's model of specialization [1990] is closer to classical notions of specialization and division of labor than both Baumgardner's and Kim's models. Locay assumes that there are many consumer-producers and that endogenous comparative advantages exist in producing goods. Each person consumes only one particular good that is different from goods consumed by other consumers. In producing consumption goods, a long roundabout production chain is needed. The consumption goods and producer goods are structured in a hierarchy. On the top of the hierarchy is a producer good that is essential for production of all producer goods at the second layer. Each of the producer goods at the second layer is connected by a span to the several producer goods at the third layer. Each producer good is essential for the production of the producer goods that are in its span at a lower layer. For instance, steel can be used to produce all kinds of machines, but a particular harvester can be employed only to produce wheat. Hence, the demand for the upstream producer goods at the top of the structure is greatest and the demand for the downstream goods at the bottom of the structure is smallest due to specialized preferences of consumers. The extent of the market for producer goods at different layers decreases as the production process descends from upstream to downstream.

The production of each good can be organized within a firm or within a household. Economies of scale rather than economies of specialization are assumed. That is, 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. This tradeoff between economies of scale and monitoring cost implies that the production within a firm is superior to household production only if the extent of the market for a good is sufficiently great such that economies of scale outweigh the increased monitoring cost within a firm. When this tradeoff is balanced by a competitive market within the hierarchical structure of goods, those upstream goods are more likely to be produced within firms due to a greater extent of the market for upstream goods, while those downstream goods are more likely to be produced by households due to a smaller extent of the market for downstream goods. A larger population size will enlarge the scope for the market to trade off economies of scale against monitoring costs within a firm. Hence, the equilibrium dividing line between household production and the production within firms will move in favor of the production within firms as the population size increases.

Locay’s model mixes the concept of economies of scale with the concept of economies of specialization. The hierarchical structure that is based on preferences for specialized consumption is quite artificial. As in all models with the tradeoffs involving economies of scale, the driving force of specialization in this model is the population size. This model successfully formalizes Stigler's thought about specialization and the extent of the market. It endogenizes the extent of the market as determined by households' level of self-sufficiency, which is dependent on the population size. In a sense, the monitoring cost within a firm can be considered as a type of transaction costs. Hence, this model also touches on Smith’s conjecture that transaction efficiency determines the extent of the market which in turn determines the level of division of labor. If a monitoring cost coefficient is specified, the Locay 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 tradeoff 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 tradeoff 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 B-M model which can explain individuals' levels of specialization by the tradeoff between economies of specialization and coordination costs even if the population size is fixed. Tamura specifies a continuum of activities to get around the issue of indivisibility. But this specification makes his model incapable of endogenizing the number of transactions and other topological properties of economic organisms (the degree of interdependence between individuals and the degree of division of labor). Hence, equilibrium implications of the topological properties of economic organisms cannot be explored. It seems to us the specification of continuum of activities or individuals is inconsistent with the novelty of endogenization of individuals' levels of specialization for which inframarginal analysis and combinatorial mathematics are the best analytical instruments.

4. New Classical Economics and Inframarginal Analysis

Yang [1988] develops a general equilibrium version of Yang's model [1984] within the framework with consumer-producers, economies of specialization, and transaction costs. For brevity, we refer to the framework as the "new classical framework". The method of inframarginal analysis and the concept of general equilibrium based on this method shall be outlined in subsection 4.1. The other subsections shall survey applications of the inframarginal analysis in different fields.

4.1. Basic Approach

We use the Yang model [1991] to illustrate the concept of equilibrium based on inframarginal analysis. In order to endogenize each individual's level of specialization, each consumer-producer must be allowed to choose any range of production activities. Hence, each decision variable can take on zero and positive values. In order to capture Smith's concept of endogenous comparative advantage, all consumer-producers are assumed to be ex ante identical, equipped with the same production functions for each and every goods and the same quasi-concave utility function. An individual's labor share in producing a good is defined as his level of specialization in producing that good. A production function for a good is defined as displaying economies of specialization if labor or total factor productivity of the good increases with a person's level of specialization in producing the good. In addition to the specification of production functions for each individual, an individual-specific labor endowment constraint is specified to capture the fact that economies of specialization are individual-specific and increasing returns are localized. Hence, simply pooling labor together without an increase in individuals' levels of specialization cannot increase their productivities. Each individual's self-interested behavior is represented by a non-linear programming problem that maximizes a person's utility with respect to his quantities of goods consumed, produced, and traded, and level and pattern of specialization, subject to the production functions, endowment constraint, and the budget constraint.

For the decision problem, the first technical problem that must be tackled is a formidably large number of corner solutions. In each person's decision problem there are 3 decision variables for each good: quantity self-provided, quantity sold, and quantity purchased. Hence, for a model with m goods, there are 2^{3m} combinations of zero and positive values of 3m decision variables, and therefore 2^{3m}-1 possible corner solutions and one interior solution for each consumer-producer. In real world, individual decision makers can solve for the non-linear programming problem numerically for given parameters. But how can we economists solve the problem analytically to identify demand and supply functions? This problem has been solved by Yang who applies the Kuhn-Tucker theorem to narrow down the set of candidates for the optimum decision. According to Proposition 1 in Yang [1988] or in Yang [1991], 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 although he may produce several goods. For brevity, we refer to this proposition as the Wen theorem since Wen [1996] proves the proposition for the general specification of quasi-concave utility function and separable production functions with economies of specialization, and non-increasing transaction cost coefficient functions. The Wen theorem implies that the number of elements of the set of candidates for the optimum decision is much smaller than the number of elements of the set of all

corner and interior solutions. For instance, the number of elements of the set of candidates is 10, but the number of all possible corner and interior solutions is $2^9 = 512$ if there are 3 goods. The difference between the two numbers increases with the number of goods. Also, the Wen theorem implies that the interior solution can never be optimal, so that marginal analysis for interior solution does not work for the new classical framework.

A profile of zero and non-zero variables that is compatible with the Wen theorem is referred to as a configuration. The corner solution for each configuration can be solved using marginal analysis. Each corner solution determines the efficient allocation of resources for a given level and pattern of specialization. For instance, corner demand and supply functions for traded goods and corner consumption and production plans of non-traded goods are part of each corner solution. The optimum corner solution determines the optimum level and pattern of specialization. It can be identified by a total benefit-cost analysis across configurations. An important feature of the inframarginal analysis is that the demand and supply functions and the indirect utility function discontinuously jump, respectively, across corner demand, corner supply, and corner indirect utility functions when a decision maker shifts between configurations.

Despite the fact that the Wen theorem significantly narrows down the set of candidates for the optimum decision, each individual still needs inframarginal analysis for identifying the optimum one out of many corner solutions. Hence, the second problem arises when we try to define and solve for a general equilibrium based on one of many combinations of corner solutions using inframarginal analysis.

A combination of several configurations that is compatible with the market clearing conditions for traded goods is referred to by Yang as a market structure or simply a structure. For each structure, a market clearing condition can be established for each traded good by specifying the numbers of individuals selling different goods and by equalizing total corner market demand and supply. Also, utility equalization conditions can be established by competition for a higher income between specialties (configurations). Hence, for each structure, there may exist a set of relative prices of traded goods and a set of numbers of individuals selling different goods that satisfy the neoclassical market clearing condition. Yang refers to the set of relative prices and the set of numbers of individuals selling different goods in each structure as a corner equilibrium. Each corner equilibrium is associated with a certain network of the market. Different corner equilibria are associated with different numbers of traded goods for society, differing degrees of interdependence between different specialists, and different productivity levels. A Walrasian regime is assumed because the number of ex ante identical individuals is large and economies of specialization are individual specific.

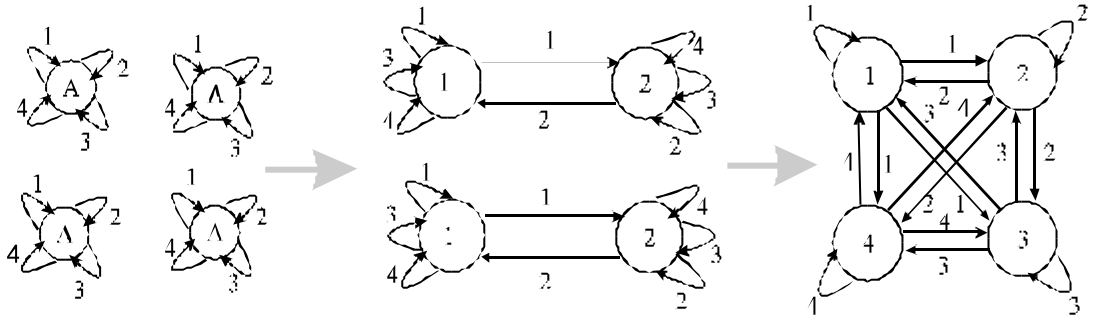
General equilibrium is defined as a fixed point that satisfies the following conditions. (i) Each individual uses inframarginal analysis to maximize his utility with respect to configurations and quantities of each good produced, consumed, and traded for a given set of relative prices of traded goods and a given set of the numbers of individuals selling different goods; (ii) The set of relative prices of traded goods and the set of numbers of individuals selling different goods clear the markets for traded goods and equalize utility for all individuals selling different goods. There are two steps in solving for general equilibrium. First, a corner equilibrium is solved for each structure. Then, the general equilibrium is identified as the corner equilibrium that generates the highest utility level since it satisfies the two conditions for the definition of general equilibrium. The other corner equilibria are not general equilibrium since they do not satisfy condition (i) for general equilibrium. A rigorous proof of the proposition that individuals have an incentive to deviate from these inefficient corner equilibria can be found from Yang and Y-K. Ng [1993, chap. 6].

There are two types of comparative statics of the general equilibrium. The first type of comparative statics implies that the general equilibrium, demand and supply functions, and indirect utility function will discontinuously shift between corner equilibria as transaction cost and production function parameters have reached some critical values. The discontinuous jump of the supply function is consistent with Stigler's conjecture [1951] that a change in the level of division of labor will discontinuously shift the cost function and it can be interpreted as endogenous technical progress. Another type of comparative statics of the general equilibrium imply that the equilibrium relative prices, quantities of goods, and number of individuals selling different goods will change continuously in response to continuous changes of the parameters within the ranges defined by the critical values given

by the first type of comparative statics. The second type of comparative statics are analogous to neoclassical comparative statics of equilibrium based on marginal analysis. It generates the implications for resource allocation for a given level and pattern of division of labor. But there is no neoclassical counterpart of the first type of comparative statics based on inframarginal analysis.

It is easy to see that the efficient extent of the market and efficient level of labor productivity, scarcity, and percapita real income are different aspects of the level of division of labor. The efficient level of division of labor is determined by the tradeoff between economies of division of labor and transaction costs. Different levels of division of labor are associated with different transformation curves, as shown in Fig 1. But a very high transformation curve may not be efficient because it may be associated with a very high level of transaction cost. Hence, the conventional coincidence between the production possibility frontier (PPF) and the utility frontier may not hold in this framework. But as the transaction cost coefficient falls, the utility frontier in general equilibrium will be closer to the PPF.

The first type of comparative statics substantially enhance the power of general equilibrium models in explaining changes in patterns of market network. The Yang model shows that the invisible hand can efficiently sort out the problem of network effects. Which network of the market and related division of labor is efficient depends on the transaction efficiency coefficient. If transaction efficiency is low, the positive network effect of the market is outweighed by transaction costs, so that autarky or a low level of division of labor, which is associated with a small size of the network of the market, is efficient and will be chosen by the invisible hand. If transaction efficiency is improved, the efficient and equilibrium level of division of labor and related efficient size of market network will increase. Hence, whether the positive network effects can be utilized all depends on where is the efficient tradeoff between the positive network effects and transaction costs.



(a) Autarky (b) Partial division of labor (c) Complete division of labor

Figure 2: Configurations, Structures, and Evolution of Division of Labor

Fig 2 gives an intuitive illustration of the first type of comparative statics of general equilibrium where the number of goods and the population are assumed to be 4 in an symmetric version of the Yang model [1991]. The lines in Fig 2 denote goods flows. The small arrows indicate direction of goods flows. The numbers beside the lines signify goods involved. A circle with number i denotes a person selling good i. Panel (a) denotes autarky where each person self-provides 4 goods, due to an extremely low transaction efficiency. Panel (b) denotes partial specialization where each person sells one good, buys one good, trades two goods, and self-provides three goods, as an improvement in transaction efficiency generates a partial division of labor. Panel (c) denotes extreme specialization where each person sells and self-provides one good, buys three goods, and trades four goods, due to a very high transaction efficiency.

It is interesting to note that marginal cost pricing rule no longer holds in the equilibrium involving specialization. In the Yang model [1991], for instance, the marginal opportunity cost of good x in terms of good y is infinite for a specialist of x, but is 0 for a specialist of y, but the equilibrium price of good x in terms of good y is a finite positive number in the general equilibrium with complete division of labor. This is a formal substantiation of Coase's argument [1946] against the marginal cost pricing rule. Coase shows that total benefit-cost analysis is necessary and marginal analysis is inappropriate for pricing of goods with increasing returns in production. Moreover, emergence of professional middlemen from the

division of labor between production and transacting activities is predicted by the Yang model [1991] where economies of specialization in transacting activities are assumed and the transaction cost coefficient is endogenized by individuals' decisions on their level of specialization in transacting activities.

Sun, Yang, and Yao (1999) have proved the existence theorem and the first welfare theorem for a general class of new classical models with a continuum of individuals and without explicit specification of functional forms. Zhou, Sun, and Yang (1999) extend the results to a general class of new classical models allowing ex ante different individuals. Also, they have proved that the set of equilibrium allocations is equivalent to the set of core allocations. Sachs, Yang, and Zhang (2000) and Cheng, Liu, and Yang (2000) apply the results to analyze evolution of dual structure and other interesting trade and development phenomena based on the coexistence of endogenous and exogenous comparative advantages.

These models simultaneously formalize many of the original ideas of Smith, Young, and Houthakker.[29] This model shows that demand and supply are two sides of the division of labor and that the extent of the market (absolute level of aggregate demand) can be endogenized as one aspect of the level of division of labor. The most important function of the market is to choose the efficient size of the market network based on the division of labor. The concept of endogenous comparative advantage is formalized. From Fig 2, it can be seen that the absolute level of aggregate demand of each person, which is one aspect of the extent of the market, is determined by each person's level of specialization.[30] As Smythe [1994] comments, Yang and Y-K. Ng's book [1993] reorients economics from problems of resource allocation to problems of economic organization. He and Ben-Ner [1995] have realized that the new classical framework and the concept of equilibrium based on inframarginal analysis provides a unifying core for trade and growth theory, the theory of the firm, the theory of transaction costs and property rights, and macroeconomics. Many works have been done to apply the new classical framework to these fields. The rest of the section shall survey the applications.

4.2. New Classical Trade Theory

Although general equilibrium models based on inframarginal analysis are not easy to manage, the symmetric version with identical tastes and identical conditions of production and transactions for all goods is quite easy to handle since each consumer-producer's choice among different configurations can be simplified as a choice of the number of traded goods. Yang and Shi [1992] introduce the CES utility function with the number of goods as a variable into such a symmetric version of the Yang model [1991] to endogenize the two aspects of the division of labor: individuals' levels of specialization and the number of all goods. A tradeoff between utility generated by consumption variety and each individual's management cost of the consumption variety is specified in addition to the tradeoff between economies of specialization and transaction costs.[31] If the transaction cost coefficient is large, then economies of specialization generated by a high level of division of labor are outweighed by transaction costs. Hence, each individual will choose autarky (self-sufficiency) where there is no demand and supply in the market place and the extent of the market is zero. Autarky implies a very narrow scope for trading off economies of specialization for consumption variety because of each person's limited time. Hence, a small number of goods are self-provided by each person. As the transaction cost coefficient

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29 Simple versions of the Yang model that are easy to duplicate and teach can be found from Yang [1994a] and Yang [1996].

30 Wen [1996] uses a new classical model to show that a crisis caused by population growth (labor surplus) or by a shortage of resources, such as the energy crisis caused by the shortage of wood in the 18th century, may increase the equilibrium level of specialization and thereby promote progress of productivity.

31 The tradeoff between economies of specialization and economies of complementarity was noted by Smith. He considered the division of labor as a source of increasing skill and of inspiring inventive faculties as well as a source of making workers "as stupid and ignorant as it is possible for a human creature to become" [1776, pp. 781-5]. Schiller [1793], Hegel [1821], and Ruskin [1851-3] further emphasized the disadvantage of the division of labor. On the other hand, West [1964], Marshall [1890, p. 265], and others emphasized the positive effect of division of labor in stimulating intelligence and in creating mental resources.

falls, each person will choose a higher level of specialization, so that greater scope for trading off one against others among economies of specialization, economies of complementarity between different goods in raising utility level, transaction costs, and management costs of consumption variety emerges from the higher level of division of labor between different specialists. The equilibrium level of specialization, which determines the number of traded goods, and the equilibrium number of all goods increase side by side as transaction efficiency is improved. The extent of the market, absolute levels of aggregate demand and supply, productivity, trade dependence, consumption variety, the degree of market integration, the degree of production concentration, diversity of economic structure, variety of professions, each person's level of specialization, and the extent of endogenous comparative advantage which is defined by Yang and Borland [1991] as the difference in productivity between sellers and buyers of a traded good, all increase concurrently as division of labor develops.[32]

The new classical trade model is similar to the new trade models of Dixit-Stiglitz and Krugman because both of them endogenize the number of all consumption goods, productivity, and trade dependence (ratio of trade volume to income). However, the differences between the two types of models are important. Smythe [1994] draws the distinction by inferring to the new classical trade model as "endogenous trade theory" in the sense that the degree of involvement of a country in international trade is endogenized by the new classical trade model, but not by the new trade models of Dixit-Stiglitz and Krugman.

Because of the feature of the D-S model and its variants, each consumer must buy goods from each of the monopolist producers. This, combined with the productivity implication of the size of an economy, implies that the integrated world market is always better than any other patterns of organization and that separate local markets cannot occur in equilibrium. In other words, the degree of market integration is not endogenized in the D-S model. But from Fig 2, it is clear that the degree of market integration is endogenized if we assume that individuals trade first with those closest in the new classical models. Suppose the transaction cost coefficient is slightly larger for international trade than that for domestic trade, then international trade can be endogenized. If transaction efficiency is extremely low in a symmetric new classical trade model, autarky is the general equilibrium where no domestic and international trade exists and the economy is divided as M (population size) separate "local communities". As transaction efficiency is improved, the number of traded goods for each person as well as for the economy, n, increases and the number of separate local business communities, M/n, decreases. 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 story is explicitly spelt out by S. Ng [1995], using a two country model. Here, the rationale for domestic and international trade is the same: the tradeoff between economies of specialization and transaction costs.

4.3. New Classical Theory of the Firm

It is easy to see that the new classical framework has very important implications for the theory of the firm since firms are not ex ante actors and they may emerge as ex post actors endogenously from the division of labor if trade in goods is replaced with trade in labor. Yang and Y-K. Ng [1995] introduce intermediate goods and a differential in the transaction cost coefficients between trade in goods and trade in labor into the Yang model to develop a new classical theory of the firm.

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[32] The Herfindahl index of specialization cannot reflect the level of division of labor and thereby may be misleading because it does not reflect another side of the division of labor: diversity of various professions. According to the index, the level of specialization of Los Angeles, Chicago, San Francisco, and New York City are lower than Albany, Gary, and Norfolk (see Diamond and Simon [1990, pp. 180-183]). But from casual observation, we can perceive that the four large cities have certainly a much higher level of division of labor than the three small cities because of a higher degree of diversity of professions in the four large cities than in the three small cities. Chandler [1990] has documented that full exploitation of economies of scale and scope was a condition for rapid economic growth in the US in the end of the 19th century and early 20th century. In essence, scale and scope relate to two sides of division of labor, that is, specialization and diversification, respectively. Economies of division of labor can be fully exploited only if transaction efficiency is sufficiently great.

Yang and Y-K. Ng's story of the firm runs as follows. Each individual as a consumer must consume a final good, called cloth, the production of which requires an intermediate good, called management service, as an input. There is a tradeoff between economies of specialization and transaction costs. If transaction efficiency is high, then division of labor will occur in equilibrium. Otherwise autarky will be chosen as the equilibrium. There are three different structures of residual rights which can be used to organize transactions required by the division of labor. Structure 1 is comprised of markets for cloth and management services. Specialist producers of cloth exchange cloth for the management consultant service with specialist producers of management services. For this market structure, residual rights to returns and control are symmetrically distributed between trade partners and no firms and labor market exist. Structure 2 is comprised of the market for cloth and the market for labor hired to produce the management service within a firm. The producer of cloth is the owner of the firm and specialist producers of management services are employees. Control rights over employees' labor and rights to the firm's residual returns are asymmetrically distributed between the employer and his employees. The employer claims the difference between revenue and wage bill, has residual control rights over his employees' labor, and sells goods that are produced from employees' labor. Structure 3 is comprised of the market for cloth and the market for labor hired to produce cloth within a firm. The professional manager is the owner of the firm and specialist producers of cloth are employees. For the final two structures of residual rights, the firm emerges from the division of labor. Compared with structure 1, these two structures involve a labor market but not a market for management services. As Cheung [1983] argues, the firm replaces the market for intermediate goods with the market for labor hired to produce the intermediate goods. Although both structures 2 and 3 involve a firm and an asymmetric structure of residual rights, they have different firm ownership structures.

Assuming that transaction efficiency is much lower for the management service than for labor, the institution of the firm can be used to organize the division of labor more efficiently because it avoids trade in management services. Suppose further that transaction efficiency for labor hired to produce management services is much lower than for labor hired to produce cloth because it is prohibitively expensive to measure efforts exerted producing intangible management (a sort of intellectual property) and to measure the output level (quality and quantity) of management services. Then the division of labor can be more efficiently organized in structure 3 than in structure 2 because structure 3 involves trade in cloth and in labor hired to produce cloth but not trade in management services nor in labor hired to produce management services, while structure 2 involves trade in cloth and in labor hired to produce management services. Hence, structure 3 will occur in equilibrium if the transaction efficiencies for labor hired to produce cloth and for cloth are sufficiently high. The claim to the residual return of the firm by the manager is the indirect price of management services. Therefore, the function of the asymmetric structure of residual rights is to get the activity with the lowest transaction efficiency involved in the division of labor while avoiding direct pricing and marketing of the output and input of that activity, such that the division of labor and productivity are promoted. In a sense, the function of the asymmetric structure of residual rights is similar to that of a patent law which enforces rights to intangible intellectual property, thereby promoting the division of labor in research and development. However, the asymmetric structure of residual rights to returns and control can indirectly price those intangible intellectual properties which are prohibitively expensive to price even through a patent law.

The Yang-Ng model, which formalizes the Coase-Cheung theory of the firm (Coase [1937] and Cheung [1983]), can explain the emergence of the firm from the division of labor and other endogenously complicated stories in the absence of uncertainty, exogenous comparative advantage, incomplete contracts, and other exogenous complications.[33] The model does not endogenize transaction costs if endogenous transaction cost is defined as a departure from the Pareto optimum. However, if endogenous transaction cost is defined as the transaction cost whose value is endogenously determined

[33] In contrast to the Grossman-Hart-Moore theory of specific asset, Yang and Ng and Holmstrong and Milgrom [1995] emphasize the labor contract as a distinctive feature of the firm. If the entitlement of the name of a firm is considered as a specific asset that can be used to protect exclusive rights to intangible intellectual properties through the legal system, then Yang and Ng's theory is complementary to Grossman-Hart-Moore's theory.

by individuals' decisions and the equilibrium process, then the Yang-Ng model has endogenized transaction costs. This is because the number of transactions for individuals and for the economy as a whole is endogenized in this model due to the tradeoff between economies of specialization and transaction costs. Yang and Yeh [1996] introduce moral hazard into the Yang-Ng model to simultaneously endogenize transaction costs and emergence of the firm from the division of labor. Borland and Yang [1995] have developed a dynamic version with the CES production function of the Yang-Ng model.

This theory has an interesting empirical implication. It 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 increasingly more intangible intellectual properties need to be protected by different types of firms as they are involved in the division of labor. Liu and Yang [1994] have tested the hypothesis against Hong Kong's data set.

4.4. New Classical Urban Economics and New Classical Theories of Industrialization and Hierarchy

Yang and Rice [1994] introduce a differential in the transaction cost coefficient between the manufacturing and agricultural sectors into the Yang model to show how and why the dual structure between urban and rural sectors emerges from the evolution of division of labor. A dual structure in terms of a differential in the level of specialisation and productivity between the two sectors may also emerge in a transitional period from a low level to a high level of division of labor. Shi and Yang [1995] have extended the Yang-Shi model [1992] to incorporate producer goods and the CES production function. The Shi-Yang model is a synthesis between the Yang model [1991] and Ethier model.[34] It endogenizes the three aspects of the division of labor described by Smith [1776] and Young [1928]: the level of specialisation of individuals, the length of a roundabout production chain, and the number of producer goods in each link of the chain. Shi and Yang's story runs as follows.

Where there are economies of specialization, economies of complementarity between producer goods in producing the final good, economies of roundaboutness, and transaction costs, several tradeoffs exist. A greater degree of horizontal division of labor in producing upstream producer goods may generate more opportunities for the vertical division of labor in producing upstream and downstream goods, which is associated with a larger number of layers of the hierarchy of goods. This implies higher productivity, generated by a greater variety of sophisticated professional equipment and machines, but, at the same time, greater transaction costs.

If transaction efficiency is extremely low, then the gains to introducing more layers of the hierarchy and further horizontal and vertical division of labor are outweighed by transaction costs. In this case, each individual will choose autarky, that is, he will self-provide all producer goods and consumer goods. A tradeoff still exists in autarky 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. Thus, in autarky the foregone economies of specialization due to the production of many producer goods at many layers of the hierarchy of goods outweigh the gains to a variety of producer goods. Therefore, in autarky, each individual will choose a hierarchy of goods with a small number of layers and a small number of producer goods at each layer, so that he can capture more economies of specialization by concentrating his limited labor in a few activities directly related to final consumption.

If transaction efficiency is extremely high, then people may choose a greater degree of horizontal as well as vertical division of labor and in the meantime maintain each individual's level of specialization at a high level through the division of labor between many different specialists. Therefore, a high transaction efficiency may bring out some new layers in the hierarchy of goods and new producer goods at each layer in the hierarchy. The emergence of the new layers and new producer goods implies new technology and new industries that are associated with an industrialization process. Hence, the general equilibrium model predicts concurrent increases in the number of producer goods at each layer, in the level of specialization, and in the number of layers of the hierarchy of goods. Shi and Yang draw the distinction between ex ante and ex post production functions. Since the supply functions will discontinuously jump across structures and new ex post production functions emerge as

[34] Sun and Lio [1996] extend the Shi-Yang model to the case with the number of intermediate goods as a variable at a link of the roundabout production chain.

improvements in transaction efficiency drive division of labor to evolve, productivity progress and emergence of new producer goods and new layer of roundabout production generate endogenous technical progress.[35]

Yang and Y-K. Ng [1993, chap. 14] explore the intrinsic relationship between the level of division of labor and the number of layers in the efficient hierarchy of transactions. Yang [1994c] develops a general equilibrium model of hierarchy.[36] This model shows that improvements in transaction efficiency for transaction services will generate simultaneous evolution of division of labor in producing various goods and different kinds of transaction services and a decentralized hierarchical structure of wholesale and retail network. Professional wholesale and specialist retail middlemen will emerge from this evolution.[37] Also, Shi and Yang [1996] combine their 1995 model with the Yang and Y-K. Ng model of the firm to endogenize the dividing line between hierarchical structure within each firm and hierarchical structure in the market.

4.5. New Classical Growth Models

All the new classical models of specialization so far reviewed are static models. Although the comparative statics of the general equilibrium based on inframarginal analysis can generate shifts in the level of division of labor and productivity, the evolution of division of labor and productivity is an exogenous process driven by exogenous improvements in transaction efficiency. Hence, Young's conjecture that dynamic equilibrium (the original phrase used by Young was "moving equilibrium") may generate spontaneous (endogenous) evolution of division of labor and extent of the market had not been formalized until Yang and Borland's dynamic general equilibrium model of specialization [1991].[38]

The Yang and Borland model with consumer-producers, economies of specialized learning by doing, and transaction costs begins from the premise that the distinguishing feature of learning by doing in an economic system is specialized learning by doing through the division of labor. In their model, a mechanism of spontaneous evolution of the division of labor can generate endogenous growth. The evolution increases all individuals' productivity and at the same time decreases the ability of a single individual to survive independently of society. The feature distinguishes the learning by doing and knowledge accumulation that is associated with the evolution of the division of labor from the learning by doing that does not depend on the division of labor. Learning by doing in Arrow's [1962] and Alwyn Young's [1991] models is independent of the evolution of division of labor.

There are three patterns of learning by doing in the Yang-Borland (Y-B) model. The first is learning by doing in autarky in the absence of the division of labor and its evolution. The growth rate of percapita real income generated by this kind of learning by doing declines over time. The second pattern is learning by doing based on the evolution of division of labor. The compounded effect of individuals' specialized learning by doing and an increase in division of labor accelerates the learning speed of society and increases the accumulation rate of human capital for society as a whole. As shown in the Y-B model, this pattern of learning by doing based on evolution of division of labor can generate takeoff (accelerated growth or increasing growth rate). This pattern of takeoff can be interpreted as economic miracle referred to by Lucas [1993]. Intuitively, a person's experience in an activity built up through the learning over a long period of time when he disperses his time among many activities at each point in time is equivalent to his experience in this activity through specialized learning by doing in this activity over a short period of time. If learning by doing occurs in the absence of division of labor, learning speed declines. If learning over time and specialized learning through increasing division of

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35 The concurrent phenomena predicted by the new classical models here coincide with Krugman's [1994] definition of so called complexity theory which involves emergence of new phenomenon, evolution of economic structure, and self-organization.

36 Chu and Tsai [1995] have explored the implication of the population size for the equilibrium level of division of labor by endogenizing the transaction cost coefficient within the new classical framework.

37 This model formalizes Marshall's idea (p. 256, p. 264) that the division of labor in production creates more scope for the division of labor in management.

38 Nelson's survey paper [1995] about evolutionary economics does not cover the literature of dynamic equilibrium models that explain economic growth by spontaneous evolution in division of labor.

labor take place simultaneously, then the speed of learning for society as a whole increases. The third pattern of learning by doing is based on a high level of division of labor in the absence of the evolution of division of labor. The growth rate of percapita real income generated by this kind of learning by doing declines over time although it is always positive.

The intuition behind the model is quite straightforward despite the technical sophistication of the control theory and dynamic general equilibrium based on corner solutions. Suppose there are productivity gains from specialized learning by doing, transaction costs, and consumer-producers who prefer diverse consumption. At t=0 each person does not have much experience in producing each and every goods, so that his productivity is low and he cannot afford the transaction costs caused by specialization and division of labor. Autarky is thus chosen. As time goes by, each person builds up some experience (or so called human capital) in producing each and every goods, so that his productivity goes up slightly and he can afford a slightly higher transaction cost and therefore will choose a slightly higher level of specialization. The specialized learning by doing will speed up the accumulation of professional experience, so that each person's productivity in his professional activity increases further and therefore he can afford an even higher transaction cost and will choose an even higher level of specialization, and so on, until the potential for further evolution of division of labor has been exhausted. In the process, the growth rate of percapita real income declines in autarky, then increases (takeoff) as the division of labor evolves, and finally 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 (percapita effective demand times population size), production concentration of each traded good, the diversity of different professions, the extent of endogenous comparative advantage, the degree of market integration, each person's level of specialization, an income share of transaction cost, each person's productivity in his profession, and so on. Fig. 2 provides an illustration of the spontaneous evolution of division of labor if the comparative statics are interpreted as dynamics in the Yang-Borland model. The calculus of variations does not work and the control theory is essential for managing the model.

This model not only formalizes Young's insights into the relationship between the level of division of labor and the extent of the market and his point that demand and supply are two sides of the division of labor, but also can accommodate convergence and divergence phenomena of growth rates between developed and less developed economies. In the Y-B model, if the transaction cost coefficient falls, the evolution of division of labor will be speeded up although the change in the parameter is not necessary for the spontaneous evolution of division of labor. Suppose an economy started the evolution process earlier than other economies because of a lower transaction cost parameter (due to geographical position, say, this economy is in an island with a lower transaction cost coefficient for shipment) and it entered the takeoff stage when other economies were still in autarky (or at a low level of division of labor), then the growth rates between the two kinds of economies will diverge. But as the developed economy has finally exhausted the potential for further evolution of division of labor, and other economies have eventually entered the takeoff stage, then the growth rates between the two types of economies will converge. The model is consistent with Barro and Sala-i-Martin [1991, 1992] and Tamura's [1991] argument and evidence for convergence phenomenon, on the one hand, and is consistent with Romer [1986, 1990] and Lucas' [1988] argument and evidence for divergence phenomenon, on the other.[39]

In the Yang-Borland model, as division of labor evolves to a very high level, a few specialists in producing each traded good will gain bargaining power from accumulated specialized learning by doing. Hence, long term contracts are essential for eliminating endogenous transaction costs caused by economies of specialized learning by doing even if uncertainty is absent. However, casual observation indicates that a high level of division of labor may intensify competition between a few specialists through magnification effects of specialization. A high level of specialization implies that a small differential in performance will generate a large difference in the market share. This may more than

[39] Jones [1995] shows that within Romer's neoclassical framework if scale effects that are incompatible with empirical observations are avoided, growth will be exogenous. Within the new classical framework, there is no such incompatibility between endogenous growth and empirical observation.

offset the bargaining power resulting from specialized learning by doing. This idea needs another dynamic general equilibrium model to formalize.[40] J. Wang [1994] and J. Wang and Yang [1996] touch on this problem. They use a new classical general equilibrium model with individuals' preference for relative position to show that division of labor may be promoted where individuals pursue relative position.[41]

Since the Yang-Borland model [1991] is a dynamic version of the Yang model [1991] and the Borland-Yang model [1995] is a dynamic version of the Shi-Yang model [1995], on the one hand, and Judd, Romer and Grossman and Helpman's new growth models are dynamic versions of new trade model of Dixit-Stiglitz and Ethier, on the other hand, the differences and similarities between the new classical growth models of Borland and Yang and the new growth models of Judd, Romer, Grossman, and Helpman are analogous to those between the new classical trade models (Yang and Shi-Yang) and new trade models (Dixit-Stiglitz and Ethier).[42]

Ng and Yang [1997] incorporate Kreps and Wilson's concept of sequential equilibrium into the Yang model [1991] to investigate the function of the market in experimenting with various patterns of division of labor. They specify a tradeoff between information gains from experimentation with various patterns of division of labor and pricing costs incurred in the information acquisition process. If there is a fixed bargaining cost or a fixed cost of the communication between the Walrasian auctioneer and individuals, then individuals must trade off the pricing cost against expected information gains before they acquire all information about economic organization. Suppose individuals can experiment with one pattern of division of labor in each period. Each individual applies dynamic programming to maximize expected total discounted utility according to updated information in each period. The sequential Walrasian 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 faster is the evolution of division of labor and productivity, the more social experiments will be undertaken, and the more information will be acquired through the price system.[43] This model with adaptive behavior, limited decision horizon, and uncertainties generates concurrent evolution in division of labor and information of organization acquired by society.[44] It is not only more realistic than deterministic endogenous growth models with infinite decision horizon, but also much easier to manage.[45]

4.6. New Classical Theory of Contract and Property Rights

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40 Rosen's statement [1983, p. 48] that "greater division of labor is itself a manifestation of increasing competition in the labor market" is consistent with our conjecture.

41 Lio [1996] specifies the tradeoff between consumption and leisure in a new classical model to show that productivity, the level of division of labor, and leisure time increase concurrently as transaction efficiency is improved. A surprising result of his model is that the level of division of labor and productivity may be increased by an increase in desire for more leisure if the elasticity of substitution between goods is small (that is, if positive effects of consumption variety on utility are significant), although the opposite is true if the elasticity is large.

42 Zhang [1995] and Wen [1996] have introduced monetary and fiscal policies into the Yang-Borland model to show that new classical models that endogenize evolution of division of labor can generate much richer stories for endogenizing aggregate demand than new trade and growth models that endogenize the number of goods instead of individuals' levels of specialization.

43 The evolution of division of labor generated by this model happens to satisfy Nelson's [1995] definition of evolutionary economics which involves uncertainties and a certain trend for the direction of evolution of an economy.

44 Arrow [1979, pp. 161-64] describes the tradeoff between economies and diseconomies of information asymmetry. He argues that the divergence between dictionaries of different professions enhances society's ability to accumulate knowledge, on the one hand, and increases communication costs between different professions, on the other.

45 Zhao [1996] has applied the concept of sequential Walrasian equilibrium to dynamize new classical trade theory and new classical theory of the firm.

Since the size of the market network is endogenized in the Yang model [1991], if uncertainty is introduced into the new classical framework, a tradeoff between economies of specialization and coordination reliability of the market network can be formulated to tell interesting stories about contracts, transaction costs, and property rights. The first of this kind of models was developed by Yang and Wills [1990]. This general equilibrium model explains the equilibrium level of division of labor and equilibrium degrees of competition, reliability, and vagueness of contractual terms by the tradeoffs among economies of specialization, coordination reliability, a risk of losing property rights, and transaction costs in specifying and enforcing property rights. The story runs as follows. A risk is specified for each transaction in the Yang-Wills model with m goods. This risk is caused by anticipated opportunistic behavior or uncertainty in transactions. As the level of division of labor increases, the chain of many different specialties connected in series becomes longer, so that the compounded risk for the coordination failure in the complicated network of division of labor increases more than proportionally, or compounded reliability decreases more rapidly. There are two ways to reduce the risk of the coordination failure.

One is that each buyer keeps in touch with many potential specialist suppliers connected in parallel to put pressure on the incumbent supplier. A large number of incumbent and potential partners connected in parallel will raise total reliability for a given risk for each purchasing contract. But a larger number of the same type of specialists implies a smaller number of different types of specialties and thereby a lower level of division of labor for a given population size. Also, an increase in the number of each person's incumbent and potential partners for each good bought will increase exogenous transaction costs in keeping many potential relations (see Yang and Y-K. Ng [1993, chap. 11]). The other way is to increase resources allocated for the specification and enforcement of each incumbent contract, so that the risk of coordination failure for each contract can be reduced. This will reduce welfare loss caused by the compounded risk of coordination failure. The welfare loss can be interpreted as an endogenous transaction cost. However, the decrease in the endogenous transaction cost is associated with an increase in the exogenous transaction costs for specification and enforcement of contracts. Hence, there are tradeoffs among economies of specialization, exogenous transaction costs in widening potential relations (investment in public relations), exogenous specification and enforcement costs of incumbent contracts, and endogenous transaction costs.

The comparative statics of equilibrium suggests that as the transaction cost coefficient in specifying and enforcing property rights falls, the equilibrium level of division of labor, equilibrium size of the market network, and productivity increase and the equilibrium risk of coordination failure which relates to vagueness of contract terms may either increase or decrease, depending upon relative values of the parameters representing the degree of economies of specialization, transportation efficiency, and conditions for specifying and enforcing property rights which relate to technical and institutional environment. Yang and Y-K. Ng [1993, chap. 11] specify two cost coefficients to characterize the transaction costs, respectively, for deepening a relation and for widening potential relations. For a large value of the cost coefficient for deepening the incumbent relation relative to the cost coefficient for widening potential relations, "classical contracts" with many potential trading partners (similar to perfect competition) may turn up in equilibrium. For a small value of the deepening cost coefficient, "relational contracts" without potentially alternative trading partners may turn up in equilibrium (Williamson [1975]).

This model formalizes Cheung's [1970, 1983] insights into the problem of "externality."[46] According to this model, as transaction efficiency is improved, the equilibrium level of division of labor and equilibrium level of the risk of coordination failure may increase side by side. The equilibrium degree of unreliability and related endogenous transaction costs can be considered as the equilibrium extent of externalities. Eliminating all the "externalities" is certainly not efficient. Another interpretation of the equilibrium degree of unreliability of each contract (specified as an endogenously determined

[46] Cheung [1970, 1983] argues that the essence behind the concept of externality is a tradeoff between two kinds of transaction costs. Ex post transaction costs caused by the distortions can be reduced by an increase in ex ante transaction costs for specifying and enforcing property rights. If the tradeoff is taken into account, according to Cheung, many seemingly inefficient contractual arrangements are the outcomes of an efficient balance of this tradeoff.

probability) is the degree of the softness of budget constraint. With this interpretation, the model implies that a perfectly binding budget constraint is not efficient if all the complicated tradeoffs are taken into account. The theory is tested against data for China by Yang, J. Wang, and Wills [1992]. The equilibrium degree of risk of coordination failure is a risk for mass unemployment since individuals will be forced to choose autarky and the corresponding low productivity when the coordination of complicated network of division of labor breaks down. However, this equilibrium and efficient degree of the risk for mass unemployment will increase as the transaction cost coefficient falls provided the economies of division of labor outweigh the expected welfare loss caused by the risk.

Lio [1996] introduce uncertainties, insurance, and moral hazard into the new classical framework to show that insurance can promote division of labor and productivity and that incomplete insurance can alleviate problems of moral hazard despite the fact that it increases endogenous transaction cost when it increases division of labor and related number of transactions. If Lio's approach is applied to Y-K. Ng and Yang model [1997], the function of the stock market in providing insurance for entrepreneurs organizing experiments with various patterns of division of labor will be explored.

Avner Ben-Ner [1995] regards new classical economics as part of the New Institutional Economics. But he indicates "These authors' emphasis on specialization gives their framework a unique flavor which distinguishes them from Coase, Williamson and others. The endogenization of the choice of specialization sets Yang and Ng apart from much of the industrial organization and organizational economics literature, from which the authors draw many of their modeling techniques."

4.7. New Classical Theory of Money

Since aggregate demand is endogenized in the new classical equilibrium models and discontinuous jumps of the general equilibrium across many corner equilibria enhance predictive power, explaining many so-called macroeconomic phenomena is the most interesting application of new classical economics. Subsections 4.7, 4.8, and 4.9 review three new classical equilibrium models which explain the emergence of money, unemployment, and business cycles from the division of labor and explore the intrinsic relationship between capital and the evolution of division of labor. This intellectual adventure will show that the dichotomy between microeconomics and macroeconomics is an unfortunate consequence of the fatal flaw of neoclassical microeconomics which was called economics and was supposed to be able to explain all micro and macro economic phenomena.

As Ostroy and Starr [1990, p. 29] have noted `... a general formal treatment of the Smithean view of the interaction of money and specialization is still absent'. Although Smith's suggestion [1776, chapter 4] that the driving force behind the use of money is specialization is generally accepted, Borland and Yang [1991] have shown that specialization is in fact a necessary but not sufficient condition for the emergence of money. They introduce a sufficiently long chain of roundabout production activities into the new classical framework and assume that transactions take time to complete. Hence, simultaneous implementation of all transactions essential for a high level of division of labor in a sufficiently long chain of roundabout production activities is infeasible. As transaction efficiency is sufficiently improved, the division of labor will involve a long chain of roundabout production activities, so that double coincidence of demand and supply between each pair of specialist trade partners is not satisfied. Hence, commodity money or fiat money becomes essential for achieving a high level of division of labor in roundabout production. Their model with one final consumer goods and two intermediate goods connected in a series of roundabout production chain shows that the equilibrium will jump from autarky first to the partial division of labor, and then to the complete division of labor as the transaction cost coefficient falls. Money is not needed in autarky or in the partial division of labor where double coincidence of demand and supply is satisfied in trade. For the complete division of labor with three links in a roundabout production chain, double coincidence of demand and supply is not satisfied for some links. If an enforceable credit system exists, the equilibrium will involve trade which occurs through that credit system. In the absence of an enforceable credit system, the medium of exchange will be commodity money which is associated with the lowest transaction cost coefficient.[47] An advantage of

[47] Cheng [1996] has shown that a sufficiently high level of division of labor is more essential than a long chain of roundabout production for the emergence of money.

the endogenization of both the division of labor and emergence of money is that it allows the productivity implications of the emergence of money to be investigated.[48]

4.8. New Classical Theory of Capital

Most classical economists from Smith, John Mill, Marx, to Marshall emphasized the connection between capital and the division of labor. Smith [1776] and Young [1928] explicitly spelled out the relationship between capital and the division of labor. According to them, capital and investment is a matter of the development of division of labor in roundabout productive activities (Smith [1776, p. 371]). If there is the division of labor between production of final consumption goods (say food) and production of producer goods (say tractor) and if the production of a tractor takes time to complete due to, for instance, a significant fixed learning cost, then the specialist producers of tractors cannot survive in the absence of investment which is used to provide the specialists with food before tractors can be sold. Hence, capital is a vehicle for society to increase the level of division of labor in roundabout productive activities. The high level of division of labor can speed up the accumulation of knowledge through specialized learning by doing, thereby generating productivity progress. Mill's wage fund argument [1848, chap. 2, sec. 2, chap. 5, sec. 3] is somehow against the modern dichotomy between investment and consumption. He stated "capital, although the result of saving, is nevertheless consumed". This proposition implies that a theory of capital should explain why a transfer of consumption goods from their producers to the producers of intermediate goods can improve productivity through an increase in the division of labor in producing different goods. Marshall attributed the invention of the steam engine by Boulton and Watt to a deep division of labor in invention activities [1920, p. 256]. Edison's experience is further evidence for the implication of the division of labor for successful inventions. Not only Edison himself specialized in inventing electrical machines for most time of his whole life, but also, he organized the first professional research institution with more than one hundred employees who specialized in different invention activities (Josephson [1959]).

These observations suggest that investment in physical capital goods, in education, or in research would not automatically increase productivity in the future if the investment were not used to develop the right level and pattern of division of labor. Hence, the essential question regarding the notion of capital is not so much as to how much we invest and save, but rather what level and pattern of division of labor are used to invest in machines, education, and research.

The Yang model [1994b] has formalized the classical theory of capital. The story of capital runs as follows. There are many ex ante identical consumer-producers in an economy where food can be produced out of labor alone or out of labor and tractors. In producing each good, there are economies of specialized learning by doing. A fixed cost is incurred in the period when an individual engages in a job for the first time or when job shifting takes place. Each individual can choose between specialization and self-sufficiency. The advantage of specialization is to exploit economies of specialized learning by doing and to avoid the job shifting cost. However, it increases productivity in the future at the expense of current consumption because of an increase in transaction cost.

Moreover, in producing a tractor, there is a significant fixed learning cost. The production of a tractor cannot be completed until the learning cost has reached a threshold level. Hence, there are tradeoffs among economies of specialized learning by doing, economies of roundaboutness, transaction costs, and fixed learning costs. If the transaction cost coefficient is sufficiently great, the economy is in autarky in all periods. If the transaction cost coefficient is sufficiently small and economies of specialized learning by doing and of roundaboutness are significant, the dynamic equilibrium involves division of labor. For the division of labor there are two patterns of investment and saving. If the fixed learning cost in producing tractor is not large, each individual will sacrifice consumption in period 1 to pay transaction costs in order to increase the level of division of labor, so that productivity in period 2

[48] In other studies of the transaction role of money (for example, Kiyotaki and Wright [1989]) money is not necessary if all individuals are ex ante identical and the transition of an economy without money to an economy with money cannot be predicted. Kiyotaki and Wright [1993] claim, by interpreting a parameter of acceptability of commodity money as the reciprocal of level of specialization, that their model has endogenized the level of specialization. According to Yang and Ng's definition of an individual's level of specialization, the Kiyotaki and Wright model [1993] has not endogenized individuals' levels of specialization.

can be increased. This is a self-saving mechanism which does not involve the transfer of saving funds from an individual to another. This story of saving and investment for increasing division of labor is the same as in the Yang-Borland model [1991]. If the fixed learning cost in producing tractors is so large that the production of a tractor cannot be completed until time for specialized learning by producing tractor is longer than a certain period, then an explicit saving arrangement which involves a loan from a specialist producer of food to a specialist producer of tractor in period 1 is necessary for the specialization in producing tractors.

Under the assumptions of a large fixed learning cost in producing tractors, a small transaction cost coefficient, and significant economies of specialized learning by doing and roundaboutness, the dynamic general equilibrium yields the following story. A specialist producer of food produces food using his labor only and makes a loan in terms of food to a specialist producer of tractors in period 1 when the production of a tractor is yet to be completed. In period 2, a specialist producer of tractors sells tractors to a specialist farmer in excess of the value of his purchase of food in period 2. The difference is equivalent to the amount of the loan received in period 1. Percapita consumption of food in period 1 is lower than in an alternative autarkic pattern of organization. But in period 2, tractors are employed to improve productivity of food. The discounted gains will exceed the reduction in the level of percapita consumption in period 1 if the transaction efficiency coefficient and economies of specialized learning by doing and roundaboutness are sufficiently large. Economic growth takes place not only in the sense of an increase in per capita real income between periods, but also in the sense that total discounted real income is higher than in alternative autarkic patterns of organization.

The dynamic general equilibrium model based on corner solutions shows that investment does not necessarily increase future productivity. Productivity in the future can be increased by an investment that is used to create a higher level of division of labor which speeds up accumulation of professional experience (human capital) through specialized learning by producing roundabout productive equipment or services. If the transaction cost coefficient is large due to a deficient legal system or to a protectionist tariff, such opportunities for lucrative investment for increasing division of labor does not exist, so that investment may not increase real income. A decrease in the degree of economies of specialization and roundaboutness, an increase in the transaction cost coefficient, and/or exhaustion of the potential for further evolution of division of labor will reduce real rates of return on investment and reduce opportunities for lucrative investment. This new classical theory of capital and interest rates is substantially different from Keynes' theory of capital [1936], which explains a sudden decline of interest rates by pure consumers' preferences for liquidity. The new classical theory of capital is supported by the success of Hong Kong and Taiwan governments' liberalization and internalization policies towards investment and capital flow, and is consistent with Sachs [1993] and Srinivasan's [1990] arguments about the implications of liberalization policies for economic growth.

4.9. New Classical Theory of Business Cycles and Unemployment

The intimate relationship between the division of labor in producing durable goods, unemployment, business cycles, and economic growth is explored by Yang and Y-K. Ng [1993, chap. 18] using a new classical dynamic equilibrium model. The story of efficient endogenous business cycles with unemployment runs as follows.

Suppose each individual can produce a non-durable consumer good called food and a durable producer good called a tractor. A tractor is indivisible and can be used for 2 years. Each individual can drive one and only one tractor to produce food at any point in time. There are economies of specialized learning by producing any good and two kinds of costs will be incurred if an individual shifts between productive activities. An individual will forget his experience built up in an activity if he shifts to another activity from this activity. Also there is an entry cost, such as a threshold learning cost, into any activity. Each consumer derives utility from food and maximizes his total discounted utility. For this simple economy, there are at least three possible organizational structures of production and consumption. The first is autarky where each person self-provides each good himself. He spends some time producing a tractor and the rest of time driving the tractor to produce food in the first year and produces only food using the tractor in the second year. Therefore, no business cycle and no unemployment exists for this structure. The second structure is the complete division of labor where the population is divided between the production of tractors and the production of food. Professional farmers drive tractors to produce food in two years. Professional producers of tractors produce tractors

in the first year and are unemployed in the second year. In this structure, the aggregate output level is higher in the first year than in the second year. Hence, there is a business cycle of two years with unemployment in the second year. The second cycle occurs over the third and fourth years, and so forth. The third structure is the partial division of labor which is the same as the second except that the producers of tractors shift to the production of food in the second year. The final two structures involve the division of labor and specialization, but the second structure generates business cycles and unemployment and the third does not. However, autarky and the partial division of labor without business cycles and unemployment involves costs to the producers of tractors from shifting between activities. The complete division of labor with business cycles and unemployment does not involve this shifting cost. If shifting costs and economies of specialized learning by doing are sufficiently great, the complete division of labor with business cycles and unemployment is Pareto superior to autarky and the partial division of labor without business cycles and unemployment. The market mechanism (the invisible hand) will choose the efficient structure with business cycles and unemployment.[49] This model can generate long term endogenous growth and long term regular, endogenous, and efficient business cycles. In contrast, most macroeconomic models cannot generate both at the same time.

5. Where Are We Going from Here

A principles textbook of new classical economics that is substantially different from Samuelson's principles textbook is badly needed. From several readers of Yang and Y-K. Ng's book [1993], we received requests for new classical economics teaching materials. Yang [forthcoming] and Sachs, Warner, and Yang [forthcoming] fill in this gap. A series of textbooks of new classical economics will resurrect the spirit of classical economics in the modern body of new classical framework. A broad range of research can be further pursued. For instance, the existence theorem and the first welfare theorem may be proved for a more general class of new classical models with producer goods and firms. Yang and Yeh [1993] use the new classical framework to explore the economic implications of topological properties of economic organisms. They show that the essential difference between neoclassical microeconomics and new classical economics is that the former is mainly concerned with non-topological properties of an economic system (such as quantities consumed and produced), while the latter is mainly concerned with the implications of topological properties of an economic system (such as level of division of labor and the number of transactions). Further application of topology and graph theory in the analysis of economic organisms may generate some ground-breaking results, analogous to those which emerged from the application of topology and graph theory in the analysis of bio-chemical organisms.

If uncertainties are introduced into Yang's general equilibrium model of hierarchy [1994c], the implications of the distribution of degree of competition across different layers of the hierarchy might be explored. The conjecture is that in the equilibrium of such a model, competition at the higher layer of the hierarchy of division of labor should be more intense than at the lower layers since the reliability of a few elements at the higher layer is more important than that of many elements at the bottom. This, combined with Rosen's model of hierarchy [1982], may explore the implications of skewed distribution of income and intensity of competition across different layers of an equilibrium hierarchy. A synthesis between Yang' model of equilibrium hierarchy [1994c] and Yang and Y-K. Ng's theory of the firm [1994] may be used to tell a story about emergence of professional wholesale and retail firms from a decentralized network hierarchy of division of labor. Yang and Y-K. Ng [1993, chaps. 5, 6, 8] touch on the question: why the concentrated geographical location of exchanges can improve transaction efficiency to an increasingly greater degree as the level of division of labor increases. More models can be developed to explain how the geographical location structure of transactions, the level of division of labor, the number of layers of the network hierarchy of transactions, transaction efficiency, and the

[49] Weitzman's micro-equilibrium model [1982] and the models of monopolistic competition and sticky prices (see, for example, Mankiw [1985] and Ball, Mankiw, and Romer [1988]) explain business cycles by economies of scale and market failure. However, they cannot generate persistent efficient business cycles.

skewed distribution of land price between the business center and peripheries are simultaneously determined in a decentralized market.[50]

A blend of Borland and Yang's model of money [1991] and Yang and Y-K. Ng's model of the firm [1995] may yield a new classical theory of professional banking firms. A combination of Y-K. Ng and Yang's model of organization experimentation [1997], Lio's approach to endogenizing emergence of insurance and the level of division of labor, and Yang and Y-K. Ng's model of the firm may yield a new classical theory of the stock market as a powerful vehicle for society to share risk in experimenting with various patterns of division of labor. If an information asymmetry is introduced into Y-K. Ng and Yang's sequential Walrasian equilibrium model [1997], the role of entrepreneurship in experimenting with various patterns of division of labor may be explored. If the concept of sequential Walrasian equilibrium is introduced into all static new classical models, the comparative statics in the models will become dynamics that can explain the spontaneous evolution or emergence of relevant phenomena by the experimentation costs of many patterns of organization and institution. The blend between the Yang and Wills model of property rights [1990] and Borland and Yang's dynamic model of the firm [1995] may be used to predict a spontaneous evolution of a sophisticated structure of property rights and contractual arrangements. If the distinction is drawn between learning from others' experiences (learning by learning as Sah and Stiglitz [1986] call it), learning by teaching, learning by thinking, learning by experimentation (research), and learning by producing, then emergence and evolution of professional education and research may be explained by a new classical model. Of course, it is quite easy to propose the ideas, but much more difficult to substantiate them by striking an efficient tradeoff between generality, tractability, realism, and predictive power of models.

[50] Krugman's economics of geography [1991] based on economies of scale relates to and differs from the implications of specialization and division of labor for economics of geography.

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