While the role of division of labour is very important, in itself its scope for promoting economic growth is limited. This scope is tremendously expanded when division of labour is compounded with that of capital accumulation and technical progress and the interaction/reinforcing effects between these three important sources and their interaction with growth itself. The pioneering work of Xiaokai Yang’s contributions to the analysis of the division of labour and the evolution of economic organization and growth is also briefly outlined and some future research directions, especially regarding the problems of coordination/entrepreneurship and economic efficiency, is discussed.

Keywords: Division of labour; transaction costs; increasing returns; capital accumulation; technical progress.

The person most responsible for the establishment of this journal and the associated research is Xiaokai Yang. Unfortunately, he passed away on 7 July 2004 before the publication of the journal. Xiaokai was diagnosed with lung cancer in September 2001 and was then given a life expectancy of 3–6 months. Despite this (or was it partly because of this), he worked with me and others in the establishment of this journal. In honor and memory of Xiaokai, we hope to publish a special issue on “Division of Labour and Inframarginal Analysis” in this journal soon. A more detailed description of the live and contributions of Xiaokai Yang will be presented there. (Those reading Chinese may also be interested in Chen, 2004.) Here, the focus is more on those aspects related to the scope of this journal.

1. Division of Labour, Capital Accumulation and Technical Progress:
   Reinforcing Sources of Productivity Growth

The importance of division of labour is obvious. Without division of labour, each person has to produce everything she needs, including food, clothing, and shelter. Even a person who combines the physical strength of Mohamed Ali and the intelligence of Albert Einstein would barely manage to survive at a very primitive level, if at all. Even primitive men
and women relied on some division of labour, including marriage between the sexes and cooperation in hunting for animals.

The analysis of division of labour has a long history, dating back to Plato if not beyond. (See Sun, forthcoming.) However, Smith (1776) provided a celebrated analysis of division of labour and its implications for increasing the wealth of nations. As Loasby (1999, p. 131) puts it, “That productivity may be increased through the division of labour was hardly a new idea in 1776; but no-one had ever before assigned it the primary role in promoting economic growth”. Economists trained in the neoclassical analysis of production functions and economic growth naturally regard capital accumulation and technical progress as the main sources of growth. This may be depicted in Fig. 1 where the classical economists including Smith emphasized the arrow (direction of influence) labeled 1, with the division of labour affecting productivity. On the other hand, neoclassical economists emphasize arrows labeled 2 and 3.

The positive effects of the division of labour, capital accumulation, and technical progress on economic or productivity growth are clear. On the other hand, productivity growth in turn produces feedback effects on these three sources of growth. Obviously, higher production increases the ability of the economy to accumulate more capital and to devote resources to promote technical progress through research. It is less obvious that economic growth also increases the scope for further division of labour. This includes the effects of higher incomes in increasing the demand for more goods, more varieties, and higher quality, hence widening the scope of the division of labour. Thus, there are tripartite virtuous cycles, as illustrated in Fig. 2 between the three sources of growth and productivity that has led to the hundred-fold increases in productivities over the centuries. These are not the end of the story of virtuous cycles.

![Fig. 1. The effects of division of labour (DL), capital accumulation (K), and technical progress (T) on productivity (P).](image-url)
It is arguable that the division of labour is as, if not more, important than technical progress and capital at least in the following sense. Without division of labour, there may be no capital accumulation and technical progress. If each person (or even household and even allowing division of labour within the household but not between households) has to produce all she needs, she will be lucky if she can just manage to survive, leaving little if any scope for capital accumulation and time to think about how to improve the techniques of production. It is thus the division of labour that dramatically raises productivities and the scope for capital accumulation and technical progress. The higher productivity generated from the economies of specialization allows surplus production that could be saved for capital formation, facilitating more roundabout and more efficient ways of production. It also generates surplus time and experts to specialize in thinking on ways to raise productivities and other pursuits of curiosity which usually indirectly lead to the increase in knowledge and productivities.

On the other hand, without capital accumulation and technical progress, the division of labour alone cannot get us very far. (This is shown numerically for some specific examples in Appendix A.) Capital accumulation and technical progress in turn dramatically raise the scope for further division of labour. At the level of primitive production, there may be only a few or a few dozens of activities/goods and may require only very limited division of labour. A few hundred persons (or households) each specializing in one activity (not ruling out more than one persons specializing in some same activity) may be sufficient to exhaust the benefits of division of labour. An increase in population and/or the extent of the market that facilitates further division of labour may have no scope to play and no additional benefits to generate. However, with capital accumulation and technical progress, more and more sophisticated, roundabout, machine-using methods of production are used, with increasing numbers of intermediate inputs, processes, and goods, as well as the efficient size of the production units. This makes further division of labour more productivity-enhancing. The
higher productivity in turns increases the scope for further capital accumulation and technical progress.\(^a\)

In fact, the mutually re-enforcing relationships also apply between capital accumulation and technical progress in particular, and between the other two pairs in general. Without capital accumulation to provide the investment in new machines and infrastructures, the scope for technical progress is very limited. Similarly, without technical progress that calls for new machines and facilities, not much more capital accumulation will be needed. If we only know to use a spade in ploughing and a sickle in harvesting, there is not much need for capital. Also, technical progress increases the scope for further division of labour and the latter in turn raises technical progress. Similarly, higher degree of division of labour increases the scope for using more capital which in turns facilitates more division of labour. These three pairs of mutual influences are depicted in Fig. 3 by the 6 arrows labeled 7 to 12.

This is not the end of the story; at least six more arrows of influence may be added. The division of labour enhances the contribution of technical progress (arrow 13) and capital accumulation (arrow 14) to productivity. Similarly, capital accumulation enhances the contribution of division of labour (arrow 15) and technical progress (arrow 16) to productivity; technical progress enhances the contribution of capital accumulation (arrow 17) and the division of labour (arrow 18) to productivity. A list of these 18 arrows of effects is provided in Appendix B. While some of these 18 effects may be said to reflect different sides of a same coin, they are not yet exhaustive. For example, one may add the effects of further division of labour on how capital contributes to technical progress and the effects of technical progress on how higher productivity may affect the division of labour. Moreover, all these 18 indicated and other un-indicated effects operate within and are influenced by the cultural, geographical, and institutional environments, not to mention possible interaction with other factors like population growth. All these show the complicated and multi-factorial nature of the economy. Each school of thought typically focuses on one or a few factors or relationships and usually makes useful observations and analysis. However, to believe that it captures the whole picture is certainly mistaken if not self-deluding. Much more analysis and synthesis are needed to gain a more complete understanding.

2. Yang and His Contributions to the Analysis of Division of Labour

After completing his PhD at Princeton in 1987 (degree obtained in 1988), Xiaokai spent one year at Yale University in a post-doctoral capacity. Then he joined Monash University in 1988. At Monash, apart from publishing important papers in leading journals including *American Economic Review* and *Journal of Political Economy*, Xiaokai collaborated with me in rewriting his PhD dissertation into a monograph. This was published in 1993 as *Specialization and Economic Organization* in the “Contributions to Economic Analysis” Series by North-Holland. Though co-authored with me, the major contribution is certainly Yang’s.

\(^a\)The close relationship between technical progress and division of labour has long been discussed; see, e.g. Corsi (1991) and Reid (1989) on the discussion of classical economists and Rico (2003) on Marx’s views on this.
The most important contribution of Yang, at least from an academic point of view, is his formalization of classical economic thinking with many new results and extended analysis. After the neoclassical marginalism revolution, economists focus mainly on the problems of resource allocation, largely ignoring the classical insight on the importance of division of labour. This is partly due to the fact that specialization involves all-or-nothing choice not easily treated by marginal analysis. One chooses to be a full-time engineer or psychologist rather than choosing how many hours studying engineering and how many hours studying...
psychology. Yang developed a simple framework capable of analyzing such choice of different “corner” solutions and the network of such division of labour for the whole economy through trade, employment, emergence of firms, urbanization, industrialization, etc. Since an individual must consume many goods, specialization requires trade which involves transaction costs. Thus, the central trade-off is between the economies of specialization and the additional transaction costs. The lowering of transaction costs through technical advance and/or institutional improvements thus contributes to productivity through the economies of specialization facilitated by the division of labour. It may be noted that, while Adam Smith emphasized the limitation of division of labour by the extent of the market, Becker and Murphy (1992) emphasized the limitation by the costs of coordinating specialized workers to perform complementary tasks, and Yang emphasized the limitation by the transaction costs of trading goods. The difference in emphasis of the last two is partly due to the focus of Becker and Murphy on the industrial division of labour (division into different tasks in producing a single good) and the focus of Yang on the social division of labour (between the production of different final goods), though Yang and Ng (1993) also discuss the industrial division of labour in the form of roundabout production or the use intermediate goods.

The new framework can be used to analyze many economic problems. As Journal of Economic Literature reviewer Smythe (1994, pp. 691–92) of the 1993 book states: “This is an ambitious book. Although its authors claim their objective is merely to increase the variety of microeconomic frameworks, it ranges across topics in trade and growth, urban economics, comparative systems, industrial organization, and even macroeconomics. It argues for a complete reorientation of microeconomics away from problems of resource allocation toward problems of economic organization … This is an interesting and original book. Its motivation is sound, and its fundamental insights are compelling. … a refreshing new approach to microeconomics, one that has the potential to address many issues that have long resisted formal treatments.” (For a review of the literature using the new framework to address various issues, see Yang, 2003.)

Professor James Buchanan found the new framework of Yang so important that he obtained a National Science Foundation grant to run a workshop on “Economics Beyond the Neoclassical Limits” on 2–9 June 2002. Yang was invited to give lectures on the new framework to graduate students and economists in the U.S. Similar workshops were subsequently organised at Fudan University in Shanghai in July 2002, Monash University in February 2003, Hunan University in October 2003. Further workshops have been scheduled for 2004/5 at Renmin University, Beijing and at Academia Sinica in Taiwan. Also, referring to Yang’s work, both at a seminar in March 2003 at Monash University and the lunch before, Buchanan explicitly said that in his view “the most important research in economics in the world” was at Monash.

3. Some Issues and Future Research
I have already discussed some of the strengths (general-equilibrium analysis starting from the basic level of individual optimization, many results, flexibility) and weaknesses (specific functional forms, most models with only a few goods) of the new framework in Ng
The fact that the division of labour alone (without technical progress and capital accumulation) does not get us very far, as mentioned in Sec. 1 and illustrated for some simple models in Appendix A, and the many interrelationships illustrated in Fig. 3 also suggest that an important research within the new framework (which has so far mainly focused on the effect of higher transaction efficiency and the resulting higher degree of division of labour on productivity) is to incorporate the various routes of cumulative causation or virtuous cycles. In the following, I will also briefly mention some interesting welfare economic issues raised by the new framework.

Analyzing welfare economics with the new division-of-labour framework, it is natural to focus not only on the traditional concept of allocative efficiency but also on organizational efficiency. Organizational efficiency refers to the choices between different economic structures, including different numbers of goods produced, different degrees of the division of labour, different layers of intermediate inputs, and organization of firms. While allocative efficiency is important, organizational efficiency may be even more important in the long run. The analysis of organizational efficiency at the economy level could help answer such questions as: Why do governments encourage investment in infrastructure? While this may partly be explained by its public goods nature, the presence of indirect externalities due to economies of specialization may also be important.

The benefits of an improvement in transaction (including communication and transportation) efficiency arise not only from reducing the costs of transaction directly, but also from indirectly promoting the degree of specialization and the consequent tapping of the economies of specialization. Even assuming that the cost of exclusion is negligible and that there is no free-rider problem, a private producer of an improvement in infrastructure that reduces transaction costs may only be able to capture the direct benefits of lowering transaction costs, but not be able to capture the indirect benefits of promoting more specialization (even in the absence of individual differences giving rise to different consumer surpluses). People will just assess the benefits of lower transaction costs given the existing level of specialization of the economy. The benefits through a higher degree of specialization (through the appearance of new marketable goods) are taken not to be affected by the improvement in the transaction efficiency of an individual herself. Thus, there are two public-good problems. The improvement in infrastructure to raise transaction efficiency may itself be a public good. However, even if this public-good problem can be overcome through excludability, there is another public-good problem at the level of the increase in the level of specialization that the higher transaction efficiency contributes to. Even with perfect foresight, each individual does not take into account the benefits of a higher level of specialization because that level is determined by the general level of transaction efficiency prevailing in the whole economy, not appreciably affected by that of the individual. This second level of the publicness problem is quite impossible to solve through exclusion, as the producers of the new set of products are typically different from the producers of the infrastructure and might themselves not have emerged yet. Thus, the indirect externality of infrastructure may then make the public provision or encouragement desirable (Ng and Ng, 2001). Examining the organizational implications in the new framework is not confined to infrastructure. In fact, a big area of research awaits more study.
Another area worthy of much further study is that of the problem of coordination and the related problem of the role of entrepreneurship. I have repeatedly discussed this point over a number of years, including at the June 2002 Workshop in Virginia Tech organized by James Buchanan. (Gilles and Diamantaras also call the coordination problem the indeterminacy problem. See their paper in this issue for an excellent analysis and some suggested ways to tackle the problem.) As a simple example of the coordination problem, consider the simple case of 2 (or two million) identical individuals and 2 symmetrical goods $x$ and $y$. If transaction efficiency $k$ and the degree of economies of specialization $a$ are low enough, autarky is the general equilibrium and is Pareto optimal. If $k$ and $a$ are high enough, division of labour (with one individual specializes in one good and the other on the other good) is a general equilibrium and is Pareto optimal. Given $a$, as $k$ increases exogenously from a low to a high level, how does the economy moves from autarky to division of labour? In my view, some extra-price coordination is needed. Even with the right general equilibrium price of 1 (one) announced (by the fictional Walrasian auctioneer?), each individual is indifferent between producing $x$ or $y$ and may decide to produce either. There is a 50% chance that both will produce the same good and hence not optimal. Even if we assume that the fictional auctioneer does not allow this disequilibrium production plan to be carried out, he can only adjust the price, not dictate quantities. Any price other than one he announces will lead to disequilibrium with 100% certainly. A price of one will have only 50% of success in the case of 2 persons. In the case of two million individuals, the probability of exactly one million choosing to produce one good and exactly one million choosing to produce the other is vanishingly small. Some extra-price coordination is certainly needed. This need not imply the need for central planning. The needed extra-price coordination could just be one individual saying to the other, “Why don’t you produce $x$ and I produce $y$ and then we can exchange one to one?” This is extra-price coordination as who produces which good is specified. This could possibly be included under bargaining, but not under pure price coordination, especially in the Walrasian regime.

The fact that some extra-price coordination may be needed does not mean that it is best done by a central planning board. Consider the more general case of the introduction of a new good in a more realistic setting. When the transaction efficiency, population size, technology, etc. have increased to levels making the marketing of a new good efficient, its introduction into the market need not be an instant success, as people have to learn of the new good and perhaps make adjustments accordingly. For example, before the availability of take-away food, eating out was quite expensive and most people cooked their own dinners and packed their own lunches. Then, the introduction of readily available take-away food reduced significantly the costs of eating out. People gradually adjusted to this by reducing home cooking and having more leisure time and/or spending more time working on their specialized activities. However, most new goods need some time for consumers to learn and adjust to them before they become profitable. Thus, even the most successful entrepreneurs may have to sustain substantial initial losses. To be able to sustain such initial losses is one of the requirements of entrepreneurial success. This also suggests the importance of the existence of big firms and the role of financial institutions in transferring resources from savings into investment. If we compare a centrally planned economy and a free-enterprise
market economy in terms of the successful introduction of suitable new goods, the superiority of the latter is even more decisive than the allocation of resources between existing set of goods. Thus, the need for coordination is largely filled in a market economy by the function of entrepreneurial activities.

The need for entrepreneurial activities exists even in the traditional framework, as the use of a new lower-cost method of production and the introduction of new goods are by definition the function of entrepreneurship. However, the requirement of entrepreneurship is rather meager in the traditional framework of perfect competition with no increasing returns. When the technology/demand/transaction conditions have improved to a level such that the demand for and supply of a new good result in the intersection of the downward-sloping demand curve and upward-sloping supply curve at a positive quantity, the introduction of that new good will prove to be profitable. Moreover, whoever first introduces it will reap supernormal profits as the demand price is initially higher than the supply price. In contrast, in the framework of division of labour, someone shifting to the production of a newly marketed good may not even break even until a sufficient number of other individuals stop home-producing that good and buy from her instead. There is more need to sustain an initial period of losses. Thus, the new framework suggests that the role of entrepreneurship is much more important than that suggested by the traditional framework.\(^b\)

The outstanding issues, instead of reducing the degree of interest of the new framework, actually make it more challenging and point to further useful studies.

Appendix A. The Limited Contribution of Division of Labour without Technical Progress and Capital Accumulation

In the text, I mention that, without capital accumulation and technical progress, the level of division of labour alone cannot get us very far. This appendix shows this limitation numerically for some commonly used simple models analyzing the division of labour. Even taking the most favorable case for the division of labour, i.e., the case where there are no transaction costs, the maximum contribution of complete division of labour to productivity without capital accumulation and technical progress is shown to be in the order of several to several hundred percent rather than the several hundred times observed in the real world.

First, consider the simple case where the economies of specialization comes from the existence of a fixed cost (including learning costs) in the production of each good, with the production function \( x_i = l_i - A \) where \( l_i \) is the amount of labour used in the production of good \( i \) and \( A \) is the fixed cost, assumed the same across all goods for simplicity of calculation. If there are \( M \) goods to be produced/consumed, in the absence of the division of labour, an individual with a quasi-concave utility function symmetrical in all goods will allocate her available amount of labour \( L \) evenly to all these goods, with the amount of each good given as \( (L/M) - A \). On the other extreme, with full division of labour with no transaction costs, each individual use the full amount of labour \( L \) to produce one good and exchange the rest

\(^b\)Under what conditions will the coordination by entrepreneurial activities be efficient or otherwise are still poorly understood; cf. Tokumaru (2003).
of $M - 1$ goods with others at the price of one for all goods (due to symmetry), the amount of each of the $M$ goods consumed is given as $(L - A)/M$ which of course exceed the autarky level of $(L/M) - A$. The excess of the former over the latter, as a percentage of the latter, i.e., the percentage improvement of complete division of labour with no transaction costs over autarky, equals $(M - 1)/[(1/\alpha) - M]$, where $\alpha \equiv A/L$ is the proportion of the fixed cost to the total amount of labour. Obviously, the percentage gain increases with $\alpha$ and also increases with $M$, as these increase the degree of increasing returns in specialization and the scope for the division of labour respectively. The proportionate gain (in percentages) as a function of the various values of $\alpha$ and $M$ is given in Table 1. For example, for $\alpha = 0.01$, and $M = 10$, the maximum proportionate gain of complete division of labour is 10%. Some cells in Table 1 do not have figures as the fixed cost proportion is so high as to make the production of the corresponding number of goods infeasible.

Now consider another simple model where the economies of specialization do not come from the presence of a fixed-cost component but from increasing returns to scale in production as such, with the production function $x_i = l_i^a$ where $a > 1$ indicates the degree of increasing returns. In this case, the output under autarky of each symmetric good is $(L/M)^a$ and the output of each good under complete division of labour is $L^a / M$. The excess of the latter over the former as a proportion of the former is equal to $M^{a-1} - 1$ which clearly increases with $a$ and with $M$, for obvious reasons. This maximum proportionate gain (in %) under different plausible values of $a$ and $M$ is shown in Fig. 2.

In Table 2, the highest maximum proportionate gain is nearly 300% or 3 times. It may be thought that this proportionate can increase indefinitely if we increase the values of $a$ and $M$. However, the value of $a = 1.2$ is already a very high figure; it means that increasing

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Table 1. The maximum proportionate gain (in %) of division of labour. The case of $x_i = l_i - A$ (i.e., fixed cost).

<table>
<thead>
<tr>
<th>$a$</th>
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Table 2. The maximum proportionate gain (in %) of division of labour. The case of $x_i = l_i^a$. 
the amount of input by 100% will increase output by about 130%. Also, for our problem here on the limitation of the contribution of division of labour in the absence of capital accumulation and technical progress, the relevant value of $M$ should be the number of goods at the primitive stage of autarky where the required number of goods necessary for survival is relatively small. Thus, the figure in the last row and last column already indicates an unlikely high ceiling for the contribution of division of labour as such, i.e., in the absence of capital accumulation and technical progress.

Appendix B. Relationships between Division of Labour, Capital Accumulation, Technical Progress and Productivity: A Description of the 18 Arrows in Fig. 3

The numbers below correspond to the numbers in Fig. 3.

1. Division of labour (up to the optimal level) improves productivity. This is a well-known and much discussed effect, including but not confining to Smith’s three factors (dexterity, time saving, facilitating the use of machines). “The greatest improvement in the productive powers of labour, and the greater part of the skill, dexterity, and judgment with which it is any where directed, or applied, seem to have been the effect of the division of labour” (Smith, 1776, p. 13).

2. Capital accumulation increases production through the positive marginal productivity of capital. This is the basic source of growth in the neoclassical models.

3. Technical progress increases productivity by the very definition of technical progress here.

4. Higher productivity increases the scope for division of labour by increasing the demand for new goods, more varieties and higher quality.

5. Higher productivity increases the capacity to accumulate more capital.

6. Higher productivity increases the capacity to devote more resources to increase technical progress through research.

7. Technical progress increases the scope for more division of labour, including through the use more roundabout methods of production. (Becker and Murphy, 1992, p. 1146 show that “the growth in knowledge raise[s] specialization and division of labour”. It was recognized by Marshall that “the introduction of machines creates the demand for other types of specialized workers, from machine operators to workers with a high level of judgement” (Lavezzi, 2003, p. 91).c

8. Division of labour raises technical progress including (but not limited to) by providing more scope for learning by doing. In the words of Smith (1776, p. 20), “the invention of all those machines by which labour is so much facilitated and abridged, seems to have been originally owing to the division of labour”.

9. Division of labour increases the scope of using more capital, including by making certain tasks simple enough to be done by capital-using machines.

cOn the emphasis of Rae’s (1834) emphasis of the effect of invention on the division of labour rather than the reverse effect, see Ahmad (1996).
10. Capital accumulation facilitates more division of labour by allowing the use of more roundabout and more intermediate-input using methods of production. “As the accumulation of stock must, in the nature of things, be previous to the division of labour, so labour can be more and more subdivided in proportion only as stock is previously more and more accumulated” (Smith, 1776, p. 277).

11. Capital accumulation increases technical progress, at least when the accumulated capital includes human capital and research-related facilities.

12. Technical progress increases the scope for using more capital; more capital is needed to build newer and better machines, infrastructure, etc. Rae (1834, p. 172) also emphasised that technical progress raises expected returns and therefore increases “absolute capital” without any additional savings or investment. (On Rae’s contributions, see Brewer, 1991.)

13. Division of Labour enhances the contribution of technical progress to productivity as it allows the more high-tech methods of production to be more fully utilized. “Specialization … raises the benefits from investments in knowledge” (Becker and Murphy, 1992, p. 1157).

14. Division of labour increases the productivity of using more capital. As Young (1928, p. 530) noted, it would be “wasteful to make a hammer drive a single nail”; with division of labour, the hammer-using specialist will drive thousands of nails with a single hammer.

15. Capital accumulation enhances the contribution of division of labour to productivity. By allowing the production of machines and other intermediate inputs, capital increases the productivity-increasing effects of division of labour.

16. Capital accumulation enhances the contribution of technical progress to productivity by allowing the use of typically capital-intensive high-tech and more productive methods of production.

17. Technical progress enhances the contribution of capital to productivity; high-tech methods of production typically increase the marginal productivity of capital, shifting the curve of the marginal product of capital upward over most relevant ranges. In Marx’ (1867, p. 605) words, “science and technology give capital a power of expansion independent of the given magnitude of the capital actually functioning”.

18. Technical progress enhances the contribution of division of labour to productivity (Eq. (12) in Becker and Murphy, 1992, p. 1145) as more advanced techniques of production typically requires the use of more intermediate inputs and the cooperation of different tasks.

References