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INSTITUTIONAL DESIGN FOR EMERGING ECONOMIES

by
CHUEN-MEI FAN* and LIANG-SHING FAN**

1. *Introduction*

The last two decades have seen drastic institutional changes in both Eastern European and Asian countries. On one hand, there is the amazing rapid growth of the Chinese economy since 1980 under Deng Xiao-Ping's economic reform schema. On the other hand, the poor performance of the Russian economy since the collapse of the communist regime is also puzzling. The Chinese economic growth has been accomplished under strict authoritarian control by the Chinese Communist Party (CCP). But, in the former Soviet Union, there was a complete dismantling of the authoritarian communist regime when it was replaced by a supposed "democratically" elected political institutions. In between these two extremes, there have been many different degrees of successes and failures among the formerly command economies trying to make a transition, both economically and politically.

As socio-politico-economic situations change, new institutions evolve to meet the need of the people and the regime. However, as rapid changes occur, policy "designers" have to devise suitable institutions, including institutional entities, institutional arrangements, and especially economic mechanisms. In this paper, we present a synthesis of a basic theoretical framework in the field of institutional design mechanisms.[1] Then, a comparative institutional analysis is introduced. This is followed by a study

* Department of Economics, Colorado State University, Fort Collins, CO (U.S.A.). E-mail: cmfan@lamar.colostate.edu

[1] For example, see Hurwicz (1973, 1994).

of the changing pattern of institutions in a group of Asian economies, emerging from the classical to a neoclassical environment, in contrast to the experiences in China and in Russia. The former would be characterized by an increasing government involvement while the Chinese and the Russian experiences would be characterized by a decentralization, both politically and economically. The last section of the paper provides a summary and conclusions.

2. *Background*

In the capitalist world, whether under a democracy or another political system, the market has prevailed for the last couple of centuries. The competitive price system has been considered an efficient mechanism in directing production and consumption decisions. In a market economy, the market coordinates demand and supply, with changes in price signaling producers and consumers to recalculate their demand and supplies. This system keeps any individual market participant's informational requirement to a minimum, in that each individual consumer only needs to know about her/his own preferences and each producer only needs to know about her/his own firm's technical capacity.

However, a competitive market equilibrium prevails only in the classical environment with divisibility, non-increasing returns to scale, absence of externality, and free disposal. If any of these conditions is violated, the competitive equilibrium is not Pareto optimal and the resource allocation is not efficient. In capitalistic market economies in the real world, many non-competitive behaviors do exist and may have contributed to a non-optimal allocation of resources. Increasing returns to scale and indivisibility in production technology tend to result in natural monopolies. Furthermore, the existence of externalities (positive or negative) and public goods (Samuelson, 1954) renders a private market inoperable, or with its outcome not conforming to the truly socially-optimal solution at the least.

As social interactions become more complex, informational asymmetry is likely to become pervasive with consequent adverse selection and moral hazard. To protect the more atomistic market participants, a set of soundly regulated financial institutions and markets must be established. Many of these regulations and government interventions, designed for the protection of basic property rights, have been evolving over many decades. That is to say, these social institutions are normally the product of a natural social evolution process over decades (and centuries). However, in extraordinary

situations, such as the Great Depression when people lost their lifetime savings, the government designed and executed many extraordinary institutional arrangements such as Social Security, Federal Deposit Insurance, etc. As time passes, these arrangements are continuously modified and revised. In recent years, the collapse of the Soviet Union and other communist regimes in the Eastern European countries were equally dramatic, making designs of many new institutions urgent in these countries.

In the Soviet Union, with the Communist revolution and adoption of the socialist system at the turn of the twentieth century, a central planning (i.e., a command allocation) mechanism replaced the functions of the traditional system. In a centrally planned command economy, it is necessary for the planner to be knowledgeable about every individual consumer's preferences and every producing unit's production technology. This informational requirement is so stringent that it is beyond any one agent's/organization's handling capability.[2] In the 1930s, Lange, Lerner and others attempted to solve this problem by suggesting the adaptation of a market price system in a socialistic economy, i.e., by creating the so-called "market socialism" (Hurwicz, 1973, pp. 2-3).

In more recent history, attempts by Eastern European and other socialist economies to use markets as a solution to their inefficiency problems are also well known. In particular, after the collapse of many communist regimes all over the world, "marketization" has gained tremendous popularity. As an example, without relaxing communist rule, China's CCP has been using competitive mechanisms in various sectors of the economy. However, many transition economies have also rushed to marketize the economy in order to take advantage of the supposedly efficient outcome of a competitive system, but have neglected many legal, judicial, and economic institutions completely or have designed them very poorly.

3. *Institutions and the Role of the Government*

Perfect competition in a classical environment produces an outcome which is Pareto optimal and individually rational (i.e., in line with the utility maximization and profit maximization objective). Furthermore, since it is as

[2] The most important rationale behind this criticism is the belief that social institutions are the result of a natural evolution process, involving interaction of cultural, economic and human resources, and technological changes, and these elements and the institutions are often recursive in nature. Thus, it is doubtful for a government to be able to obtain quick and satisfactory results from conscious and deliberate human designs of institutions. E.g., see Hayek (1983) and Ruttan (1998).

efficient as any mechanism from the standpoint of the informational requirement, the government is left with little role to play besides enforcing property rights and conducting lump-sum transfers for distributional purposes. This situation is the world in which the two fundamental theorems of welfare economics would prevail: i.e., a competitive equilibrium is Pareto efficient, and with government lump-sum transfers, any Pareto efficient allocation can be sustained by a competitive price system.

However, the attraction of the so-called "free market" system tends to obscure non-optimal outcomes in market economies when market failures are present. This is a world with the role of the government necessarily extended beyond the enforcement of basic law, property rights, and income distribution. The extensive involvement of the government in its resource allocation function is an effort to correct the market failures existing in the private sector. For example, a government would most likely regulate natural monopoly industries in the economy. Secondly, even though there could be Pareto efficient processes/ mechanisms to generate an equilibrium outcome in the private provision of public goods (e.g., the Lindahl solution and the Grove-Ledyard mechanism, see Grove and Ledyard, 1977), they are generally not compatible with the incentive of individual utility maximization and/or profit maximization. The difficulty in truthful preference revelation and in overcoming the free rider problem is still insurmountable because of the lack of information regarding the characteristics of individuals. Furthermore, this information problem would also renders the Coasian bargaining solution to many externality problems inappropriate (Coase, 1960, 1992). Lastly, in a neo-classical world with market failures, lump-sum transfers are only second best in nature in that any income redistribution scheme is likely to create new kinds of distortions. In summary, it is difficult to design an allocation mechanism which has the Pareto optimal and individually rational outcomes in the presence of market failures. Even if a mechanism is successfully designed, the consequence of prohibitively high informational costs is unavoidable.

One important aspect of an institution is that its success depends on the compliance of all participants playing by the rules. Thus, unless the institution is designed as a game which produces a Nash equilibrium outcome, there has to be an enforcement agency to see that the rules are obeyed. The difficulty in institutional designs in the last decade since the collapse of command economies is mainly due to the fact that there has not been enough time to allow the institutions to evolve naturally. The government must design various laws (e.g., corporate and bankruptcy laws) quickly to facilitate the fast changing economic activities, but typically

without a well functioning enforcement agency. Quite often the government would try to learn from the experiences of some successful emerging economies of earlier years. But, to blankly copy the processes used in other economies may not guarantee instant success for these new transition economies.

Since a classical perfectly competitive environment is characterized by allocational efficiency as well as informational efficiency, it can afford the highest degree of decentralization economically and politically. On the contrary, a command system is typified by quantity control, and is more likely to be allocationally and informationally inefficient; thus, it is more centralized, economically and politically. However, neither of these two extremes is in the realm of the world today. Thus, one can see the need, theoretically and practically, for an evolution toward a new set of institutions encompassing a more moderate degree of government intervention, from both the perspectives of the laissez-faire type of the classical market system and the strictly quantity control of a command system. This new set of institutions is to reflect the existence of and to correct the problems of externalities, non-convexity in production technology, public goods, and informational asymmetry. On one hand, there is increased government interventions of various degrees when we start from a classical environment moving toward a more realistic neo-classical environment with market failures. On the other hand, government interventions are relaxed to various degrees as we start from a command system moving toward marketization, by softening the informational requirement and other deficiencies associated with a command economy. The convergence of the two extremes toward the center is illustrated by Table 1.

4. *Comparative Analysis of Institutions – the Asian Experiences*

The experiences of some Asian countries can illustrate the convergence toward greater government involvement from the original state of laissez-faire in a capitalistic market economy. In their post-WWII economic growth and development, some East Asian countries sustained amazing successes up to the time of the 1997 "Asian Crisis". A watershed research report, *The East Asian Miracle* (EAM) – *Economic Growth and Public Policy* (World Bank, 1993), attempts to analyze the High-Performing Asian Economies (HPAEs), including, Japan, the Four Tigers (Hong Kong, Singapore, South Korea, and Taiwan), and the newly industrializing economies (NIEs: Indonesia, Malaysia, and Thailand).

Table 1. The Theoretical Framework

Environment	Classical	Non-classical environment: Existence of non-convexity, externality, public goods, and information asymmetry	Quantity Control
Mechanism and institution	Market mechanism	Various evolved or designed mechanisms and institutions	Command systems
	---------->	<----------	
	More government interventions	Marketization	
Allocational efficiency	Pareto optimal, individual rationality	Pareto optimal but not individual rationality, or may not be Pareto optimal	Most likely inefficient
Informational efficiency	Most decentralized (efficient)	Various degrees of informational (de)centralization	Most centralized (inefficient)
Economic/political decentralization	Most decentralized	Various degree of (de)centralization	Most centralized
		<----------	
		Fiscal federalism	

The successes of HPAEs are due partly to the policies adopted by the government and due partly to institutional mechanisms developed to facilitate the implementation of these policies (EAM, pp. 352-3). First, incentives through high salaries were used to attract competent civil service and economic managers who would administer a wide range of policy instruments. This step is followed by institutionalizing the civil service employment procedures and rules, insulating them from political interventions. Last but not least, public employment has long been accorded high social status in these societies. These factors provided high quality bureaucracy and minimized the temptation for corruption. However, not every Asian country succeeded in this regard. For example, the glaring corruption and crony-politics of Indonesian bureaucracy under the Suharto regime was exposed by the 1997 Asian crisis (Fan and Fan, 1999).

Government interventions, by granting subsidies to special industries for the sake of promoting growth, often did not work in these Asian countries. The low interest rate strategy and direct credit policies worked only occasionally. But, the export-push strategy has proven to be the most successful of all of these policies. The export-push strategy, including the establishment of a free trade zone to foster a favorable environment and incentives to export, provided an invaluable mechanism through which

export industries quickly became strong enough to be internationally competitive. The incentive structure, which is based on the outcome of competition as reflected in the performance in global markets, was institutionalized. However, the export-push, by way of attracting direct foreign investment to the export sector, was done excessively among the NIEs which subsequently contributed to the NIEs' crisis in 1997.

As illustrated earlier, the starting point of decentralization mechanism analysis is to highlight the contrast between the efficiency of the market on one hand and the inefficiency of the centralized command economy on the other. However, strictly classical environments are often not present in the real world, meaning that market failures do create various non-optimal allocations and rent-seeking behaviors within the market economies. The legitimacy of a general economic role for the government in a market economy is thus in general established. Within this general principle, however, the World Bank study suggests that there are two approaches to the role of government in Asian countries' development processes. On one hand, there is the "pro-market approach" (the market-friendly view), as adopted in Hong Kong and Singapore, which expects the market to achieve economic coordination and it will only approve a very limited scope of government activities such as providing the infrastructure to facilitate market transactions and providing/producing goods that are subject to extreme market failure. On the other hand, there is the "developmental-state approach" as adopted in South Korea and Taiwan, which takes the position that market failures are much more pervasive and will seek not only government action in dealing with market failures but will advocate a very active role, and designate a major responsibility to the government, in solving resource allocation problems. Nevertheless, the commonality of both approaches is that the market and the government are treated as dichotomized entities and therefore as substitutes for each other.

Aoki et al. (1997) presents a third view of the role of the government in Asian economic development, namely, the "market-enhancing approach". According to this market-enhancing approach, the government is not a substitute for the market; rather, it is to be a complement to the market, by promoting coordination in the private-sector. The government facilitates the development of private-sector institutions, through which the private sector remains as the major actor responsible for and capable of resolving the coordination problems in the private sector. To substantiate this market-enhancing view of government for the East Asian countries, Aoki et al. cites as evidence the fact that the public sector's economic activities remain a small share of the total economic activities in these countries when measured

against the practices of the Western world (Aoki et al., 1997, p.19).

As an illustrative example of the market-enhancing view of the government, one can see that in the process of economic development, informational asymmetry between lenders and borrowers is a particularly prevalent form of market failure. The facilitating role of the government can be seen in the establishment of sound institutions and regulations in the financial intermediary sector to protect depositors. The incentive structure of this process can be seen in setting the level of rent (the difference between the loan rate and the deposit rate) that banks are allowed to enjoy, with the level of rent being established and modified by diligently monitoring the loan risk. This rather mild government intervention can actually be conducive to a competitive environment in the credit market by minimizing the potential losses caused by adverse selection and moral hazard in the presence of informational asymmetry.

Lau (1997) has suggested that even within the market-enhancing framework, the role of the government can be more rule-based or more discretion-based. Hong Kong, Taiwan, and China are used as illustrative examples to highlight the different roles played by the government regarding the development in human and physical capital, and in R&D and management methods. These three economies have strong economic ties with one another and all have had tremendous success in raising GDP in their respective pursuits of economic development. However, China is a much larger economy by size, and China's development process started much later.

In general, the culturally, historically and environmentally determined institutions define the validity of different policies for different economies. From historical, geographical, demographic, and environmental perspectives, these three economies share some commonalities such as a high saving-investment rate and a great emphasis placed on human development. However, the differences among these three economies are also significant. Hong Kong has been influenced by Western capitalism for the longest period of time and has become a fundamentally rule-based free market economy. The government in Taiwan has been taking a more interventionist role, obviously to try to maintain political and economic stability after the Nationalist government fled from mainland China after the end of WWII. Therefore, the economy has been more discretion-based over the past 40 years, and only in recent years, has become more open and has been moving toward a more rule-based system through political democratization. Taiwan has a very efficient export sector compared to its domestic non-trade sector.

In China, marketization occurred much later than in Hong Kong and Taiwan. The coexistence of a strong Communist Party-dominated

government and profit/rent-seeking entrepreneurs has created a heavily discretion-based system in which kinship, friendship, and any other personal relationship are still the determining factors for contracting and economic success. The Chinese government, in its effort to model its path of economic development based on the experiences of the Four Tigers through trade promotion with other nations, has recognized the necessity of establishing a set of institutional arrangements and organizations to facilitate economic transactions. In its early stage of development, the central government played a role similar to that of the governments of some other Asian countries. The success of China's Township and Village Enterprises (TVEs), which are the local production units, in taking the lead in the country's rural economic development is astonishing. This success was mainly attributable to the power of autonomy and profit incentives granted by the central government.[3]

In summary, from the comparative study of the economic development experiences of various Asian countries, it is important to realize that there is a wide range of efficiency roles for the government to play regarding economic development and growth, from the more passive type as implied by the pro-market approach to the more aggressive type as necessitated by the developmental-state approach. Even within the context of the market-enhancing approach, there is still a wide range of government involvement. Furthermore, comparative institutions analysis may be more fruitful in shedding new light on the causes of success or failure of economic developments in various countries, if it takes a step further to "endogenize" the government in the analytical framework (Aoki et al., 1997, p. 30), i.e., to treat the government as more than merely a neutral facilitator of private sector economic transactions because the government does often have independent incentives of its own. The difference in performance between the Township-Village-Enterprises (TVEs) and the State-Owned-Enterprises (SOEs) in China could be explained in terms of different government incentives at different levels within a fiscal federalism framework which will be elaborated in the following section.

5. *Road to Fiscal Decentralization – The Chinese and the Russian Experiences*

The central government's commitment to preserving market incentives

[3] The Chinese experience is an illustration of the movement toward decentralization from a centralized command economy, in contrast to a movement toward a greater involvement by the government from a classical market economy.

through decentralization of information and authority through fiscal federalism has been an important aspect of the economic development experience for most emerging economies, with its success or failure being particularly important for the economies transforming from a command regime. Fiscal decentralization involves the devolution of government revenue sources and the delegation of expenditure responsibilities from the central government to the sub-national level governments, identified as local governments from this point forward (De Mello, 2000). In other words, it is the decentralization of fiscal policy-making, a tailoring of fiscal decisions to specific local characteristics in culture, environment, and resource endowment, and other economic and social institutions. The benefits of fiscal decentralization are the expected improvement in overall resource allocation efficiency and responsiveness of the public sector to the needs of citizens. This situation results from an informational perspective in that, local government officials are much better equipped to access information concerning the preferences and specific production constraints of their constituents. Given the right incentive,[4] local officials also tend to be more accountable.

However, there are also shortfalls in fiscal federalism in that it may entail greater complexity of intergovernmental fiscal relations and coordination. It also decreases the flexibility of the central government in carrying out its responsibility to maintain the nation's macroeconomic stability and income distribution objectives. The necessary dilution of financial resources might result in economic and political instability. Thus, the success of decentralization depends on its careful design (World Bank, *World Development Report* 1999-2000, Chapter 5) with appropriate political institutions to align the incentives of political officials with the welfare of the citizens.

The financing sources of the local government in a fiscally decentralized structure consist of locally raised taxes and the transfer receipts from the central government, with the relative sizes of the two reflecting the local government's degree of fiscal autonomy. The more prominent the local taxes are, the greater the tendency for success in decentralized allocation decision-

[4] Oates (1999) suggests that fiscal federalism can serve as a means of policy experimentation for the advanced industrial countries as well as the new emerging economies. For example, in the United States, the general dissatisfaction with the effectiveness of federal welfare programs led to the growth in federal block grants to local governments to determine the most efficient way of administering the country's welfare program. The popularity of the "state-specific environmental policy" follows the same vein of reasoning. Deng's economic reform structure also had the intent of using sub-national production units as laboratories to discover which reform procedure would work better.

making, due to the reduced opportunity of central government control through conditional revenue-sharing. However, this two-parts financing arrangement may also have the shortcoming of creating disincentives for the local government to rely on its own tax base and instead compete for transfer receipts from the central government. Revenue sharing has the characteristic of being a two-edged-sword.

Fiscal decentralization itself does not guarantee success. The *World Development Report* 1999-2000 suggests that the following proper sequencing of political decentralization is a key to its success: (i) establishing expenditure and revenue rules, (ii) decentralizing the functions and corresponding revenues simultaneously, and, (iii) decentralizing the necessary management control.

Weingast (1995) suggests that in order for a political decentralization system to be successful it must have the capability to sustain a productive and growing market economy. That is to say, fiscal federalism must be "market-preserving" in such a way that the autonomy of each government is institutionalized, with the local government possessing the primary regulatory responsibility over the economy. Furthermore, there should be a common market among horizontally equal political units with no barriers to trade among them, and each of the local governments must face a hard budget constraint which precludes the power to print money, bailouts by the central government, or chronic deficit financing.

In China, the emphasis has been on the introduction of the market and an adherence to a price mechanism. First, by introducing the "responsibility" system in the agricultural sector with "nearly" complete property ownership allowing the transfer of a long-term lease, the peasants' property rights to additional output above the preassigned responsibility quota (tax) were established and protected. With a transferrable long term lease, the incentive to produce efficiently prompted an amazing expansion in the agricultural sector. Then, the growth in the agricultural sector provided a major source of national saving. This result is particularly important since more than 80 percent of the Chinese population belonged to the rural sector in the 1980s. In addition, small scale enterprises were allowed for private ownership. The rapid growth of the local government owned Township-Village-Enterprises (TVEs) exemplified the central government's willingness and sustained commitment to relinquishing its rights to local officials. By allowing the local units to retain excess revenues, the central government provided incentives for efficiency and competition and triggered an enormous expansion of commercial economic activities at the local level.

Qian and Weingast (1997) point out that, in addition to creating positive

market incentives, the Chinese fiscal decentralization scheme also created a mechanism (the so-called negative market incentives) for punishing economic failures by the local government. This outcome was accomplished by institutionalizing the no-trade barrier rule among local jurisdictions to foster inter-jurisdictional competition and to prevent the predatory behaviors of local officials. According to the "voting with their feet" property of fiscal federalism asserted in the Tiebout thesis, it is natural for a local government to want to adhere to a more responsible, harder budget when there is a need to compete with other jurisdictions in order to attract mobile resources into its own locality.[5]

Since property rights at the local level are obtained by the decree of the central government, they can be perceived as only orders without real substance (Bowen, 1999). However, one can argue that the durability of political reform in China had passed the test when the failed effort of the Chinese central government to reverse the direction of reform after the 1989 Tiananmen Square incident did not create long lasting turmoil (Weingast, 1995). A message was sent to the central government that it was in its best interest that the reform be continued on its original course. There is an important lesson to be learned by the government in all transition economies: to consistently honor the property rights of local production units, especially when the property rights are granted by the central government decree in contrast to the western industrial countries where property rights are usually earned naturally with a secure protection of enduring social and economic laws.

In contrast to the TVEs, the performance of the State-Owned-Enterprises (SOEs) in China has been very discouraging, besieged with chronic losses and constantly requiring financial subsidies from the central government. The central government in turn often had to resort to an inflationary measure, printing money. From an institutional perspective, a logical explanation is that SOEs are a kind of impure public goods because they are treated as common properties, owned by all concerned (Jefferson, 1998). Common properties invite opportunistic behaviors and there is a lack of incentives, on the part of workers and managers alike. This is another example of the importance of well-institutionalized property rights and responsibilities.

The most important contrast between the economic reform in China on one side and the former Soviet Union (and Eastern European countries) on the

[5] Oates (1999) also points out the down side of inter-jurisdictional competitions when each locality tries to attract industries into the locality by lowering the environmental standard. The competitive environmental degradation can happen in the industrialized countries as well as in the emerging economies such as China and Eastern European countries.

other is that the Chinese economic reform is relatively more decentralized. Measured in terms of the shares of total revenues and expenditure responsibilities, the central government still has a larger share than the local governments in both Russia and China. But, the local share of the total public sector expenditures has grown considerably, reaching about one-third in Russia and almost 50 percent in China by early 1990s. However, local governments in both countries still rely heavily on central government revenue-sharing as their major financing source, especially in Russia (Zhuravskaya, 2000). In Russia, instead of being formally institutionalized, the revenue sharing scheme was mostly done through political negotiations between the central government and the particular local government in question. It is discouraging to the local government because any effort by the local government to enhance its own local tax base would most likely be met by a corresponding reduction in the transfer receipt coming down from the central government. This is in stark contrast to the Chinese decentralization scheme in which local governments were allowed to keep whatever revenue was leftover beyond the pre-agreed tax responsibilities to the central government. Thus, a shift in expenditure responsibility toward the local government, without a corresponding shift in fiscal autonomy, offers an explanation for the relatively discouraging results of economic reform in Russia.

Moreover, the Chinese economic reform and political decentralization took place simultaneously, while the former Soviet Union started out its drastic shock therapy of economic reform without a comparable political decentralization. The administration of the economic reform process continued to be in the hand of the old Soviet bureaucrats. In the post-communist Russia, the failure of the central government to achieve macro economic stabilization and control of inflation is well documented. The privatization of industries failed miserably because corruption and mafia-type takeovers of industries have created a non-competitive environment in which billions of dollars of precious foreign exchange were siphoned abroad. It is ironic that the original rationale for choosing a rapid privatization strategy in Russia was to prevent asset stripping by the old managers of the state-owned enterprises. But, the same type of behaviors are now being observed among the new owner-managers because Russia has yet to establish a system of enterprise property rights which will ensure the accountability and the protection of all investment parties.

The stifled Russian economy also presents a strong contrast to the relatively strong economic performances in countries like Poland and the Czech Republic, which actually started their economic reform by following

the same drastic reform strategy as Russia.[6] In other words, in Russia political transition did not occur, so the entire economic transition effort was not consistent with the 'market-enhancing' criterion. The political control over the people's economic lives continued and the predatory behavior at various level governments persisted in Russia.

The relative maturity of the political transition in Poland can be attributed to Poland's richer endowment of social capital. The leadership of the Solidarity labor union and the Catholic church has been credited with forming an important part of social capital which was lacking in Russia (Shleifer, 1997). Social capital reflects the "density of trust"; it helps to promote the ease with which people work together and it also helps to reduce transaction costs (Paldam and Svendsen, 2000). The difference is reflected in Poland's having had more new political leadership since transition took place. Thus, it seems essential that social capital be included as an important explanatory factor in determining the productivity of human and physical capital resources in the comparative studies of transition economies.

Russian fiscal institutions are under-developed, and tax rights (i.e., the property rights over a given tax base) have not been properly defined and are often simultaneously claimed by multiple levels of governments, and even by the non-governmental agencies such as the mafia. Berkowitz and Li (2000) have estimated that an average business firm has to face up to an average of 5.4 government agencies in dealing with its tax and regulatory affairs. Thus, the tax base has become a common property resource, with the nonexcludable yet rival characteristic of an impure public good. This feature invites over-exploitation by various governments, corruptions by administrative officials, and rent-seeking and bribing activities by business enterprises. This is parallel to the common property resource argument offered above in explaining the poor performance of the Chinese State Owned Enterprises in contrast to the local Townships-Village-Enterprises.

6. *Summary and Conclusions*

In the aftermath of the collapse of communist regimes, most transition economies have rushed to the market to seek remedies for the inefficiency in resource allocation left over from the former central-planning regime. The

[6] Both Russia and Poland went through the shock-therapy of economic reform between 1992 and 1995. However, the Polish private sector had been already well established by 1990. The Russian economy failed to grow in the 1990s, but Poland enjoyed a 5% growth rate annually.

frenzy in privatizing national enterprises and in using market prices as a mechanism to direct resource allocation without having proper judicial, financial, and political institutions in place has created a rather chaotic and/stagnating economic and political situation in these economies. The design of mechanisms and institutions should be a high priority in these transition economies.

At the same time, many of the traditional market economies in the world also encountered various market failures due to indivisibility, externalities, public goods, and most importantly, information asymmetries. The governments in these economies also have a strong desire to achieve a more efficient resource allocation to improve their records of economic growth. Various institutions have evolved naturally, or have been intentionally designed, to correct these market failures.

Some desiderata have to be considered in the design of allocation mechanisms and institutions. From a theoretical perspective, the basic desired properties, such as Pareto-efficiency, individual incentive-compatibility, and information efficiency (cost) of the designed mechanism, are the major features to be considered. The desirability of these properties is not difficult to comprehend theoretically, but the difficulty of attaining them is insurmountable in reality. There could be short-cuts, as well as pitfalls, in trying to design new institutions by a blank imitation of the procedures which have been undertaken by earlier successful emerging economies.

In this paper, the successes of some of the Asian economies are analyzed from a comparative institutions perspective. There is definitely an increased degree of government involvement in these countries' economic development efforts. However, it is more palatable to see the government playing a complementary role to the market (i.e., market-enhancing) in contrast to the World Bank's view that the government plays a role of substitute for the market (World Bank, EAM).

The routes to marketization in China and Russia are both characterized by fiscal decentralization from a complete quantity control of a former command regime. China has enjoyed tremendous success while Russia's economic performance has been discouraging. The main conclusion drawn from this comparative institutions analysis is that China has started its economic decentralization along with political decentralization while Russia has plunged into its drastic economic decentralization without the support of a simultaneous decentralization of its political system. The Chinese fiscal federalism has been market-preserving while the foundation of the Russian fiscal federalism is still very shaky and the reform effort has not been incentive compatible.

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ABSTRACT

Among the emerging economies, on one hand, most former command economies have abandoned central planning and moved toward the market system with reduced role for the central government in resource allocation decisions; on the other hand, many traditionally market oriented developing economies have redefined and strengthened the role of the government and restructured the institution to deal with market failures. A theoretical synthesis of the design of mechanism and institutions is presented to highlight the evolution of the role of the government from the extremes toward the center. This framework serves as the foundation for comparative institutions analysis of some Asian economies. Furthermore, the relative effectiveness of embarking on fiscal decentralization as means of economic reform in China and Russia is analyzed.

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COMPETITION OR HARMONIZATION AMONG THE RULES IN THE EUROPEAN UNION: TWO DISTINCT APPROACHES

by
GABRIELE ORCALLI*

1. *Introduction*

Trade policy, particularly the effects on trade caused by the adoption of custom duties, quotas and, more recently, non-tariff barriers have for long been of interest to researchers in the field of international trade. The fact that other formally internal policies can have an impact on international trade and on the competitive capacities of a country, has only just started to be taken into consideration, mainly because of pressure by businessmen, politicians and jurists.

Trade policy is primarily aimed at managing border exchange obstacles (barriers created in order to restrain goods and service mobility at the border) and at export subsidies, but also at managing indirect obstacles, such as the differences among internal regulations. Harmonization supporters believe differences among internal regulations can give rise to "negative" forms of subsidy and should therefore be considered as a source of distortion of international trade.

Internationally, there have been many requests for "harmonization" of the internal rules that can influence foreign trade, such as the regulation of the labour market, the environment, competition, taxation and investments. In

* Department of Economics, University of Padua, Padua (Italy). E-mail: gabriele.orcalli@unipd.it

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contrast, many argue that the difference among national regulations legitimises the competitive (as well as the rational, from an economic point of view) advantage of a country.

Similar and more detailed requests can be found in the area of regional integration. In this case, the debate between competition and harmonization of national rules is set within a pre-federal structure of the economic system, where determining the correct governmental level for the creation of such rules becomes all important as does the issue of compatibility among national regulatory differences and access to the market.

This paper will analyse two distinct methodological approaches to competition or harmonization:

(a) the approach of neoclassical economics which involves the application of criteria of efficiency and a constructivist view of the market role: the market is seen as a means of obtaining specific results in an optimal way, provided that relevant "data" is available. We will show that, when applied to EU integration, efficiency criteria presuppose knowledge of the nature of trade rules which is *a priori* unavailable; (b) the approach of institutional economics, where the focus is on the economic and institutional evolution of the different jurisdictions through a knowledge-creating process of competition. We will call this approach "*evolutionary*" based on the evolutionary metaphors from biological science introduced first by Veblen (1899) and then by Alchian (1950), Boulding (1981) and Hayek (1988)[1].

We will then argue that the nature of competition coincides with a *discovery procedure* aimed at the creation of new knowledge.

2. *Neoclassical Approach: Towards Criteria of Efficiency*

Harmonization supporters point out that we already have national policies aimed at increasing national welfare when adopted within a closed system, such as regulatory policies for the employment market or policies aimed at defending competition. Such policies can even increase worldwide welfare, if adopted at the same time by all countries. The question is whether worldwide welfare would decrease if these policies were adopted unilaterally.

With the theory of public goods, traditional economic science can help us understand the problem of regulations and the request for harmonization. By rationalistically measuring the outcome of a competitive process among

[1] The term "evolutionary economics" was introduced into current economic literature mainly by Nelson and Winter (1982)

jurisdictions in terms of efficiency of the final equilibrium, the theory states that the essential goal of a regulation is to facilitate exchanges and relationships bound by a contract. Such a regulation must, therefore, be a public good or convention which may take various juridical forms, ranging from law provisions to private agreements, and through which a social group can reach a goal shared by everybody.

Regulations for products and services can guarantee:

a) a standard which makes their exchange and compatibility possible;
b) quality standards;
c) the ability to generate the expected effects;
d) that the use of such products and services does not damage other public goods, such as the environment;
e) that the process of production respects public goods such as workers' rights.

The theory of public goods states that, as such, public goods cannot be privately acquired or have their consumption separated. This has important consequences for their connection to international trade. Because public goods are normally shared by a community at national level, in so far as they enable common objectives to be achieved, they are also clearly linked to the preferences, habits, technological skills, quality of life and cultural traditions of the community itself (Casella, 1996). As a consequence, since these communities can be very different from one another, we cannot claim that regulations should be the same everywhere. Moreover, these regulations are, by their very nature, endogenous and can change only when the essential characteristics of the communities which expressed them change.

Casella argues that international trade plays a fundamental role: opening up to trade can radically change the characteristics of a community by modifying its expenditure capacity, its production models or the distribution of income. It can therefore indirectly contribute to changes in the requested regulations. Similarly, when a country opens its doors to international trade, it can benefit from new and previously unavailable information, such as innovative technological solutions. It can therefore also resolve the asymmetry of information which can sometimes be the source of different regulations.

At this stage, we need to make a clear distinction between the *existence* of different regulations, which in the light of the theory of public goods is absolutely rational, and the *strategic use* of such regulations which can lead to distortions in the allocation of resources and hence to an inadequate economic outcome. From a logical point of view, these are two distinct issues: if the different modalities of market regulations within the different

communities also reflect a difference in the characteristics and preferences of citizens, this difference is *neither* the source of distortions in the international system, *nor* does it become a suitable way of preventing them. However, imposing a similar regulation in substantially different countries may give rise to a distorted use of resources.

In other words, heterogeneity in regulations causes very different consequences for international trade depending on the reasons which determined it. According to the definition given by Sykes (1996), *good* heterogeneity ensues from the difference in preferences, tastes and incomes of citizens. We can therefore explain the reasons for which the demand for banking or insurance regulations is higher in a community that has had to bear the cost of serious failures caused by financial institutions. Similarly, a community with a low income level is going to be less willing than other communities to bear the costs deriving from very strict regulations on the quality or safety of products. Moreover, income distribution in a community can also give rise to heterogeneity: if preferences about regulations are expressed by average voters, a community characterized by egalitarian income distribution will tend to show its preferences for regulations which favour health or safety. A community with strongly concentrated income distribution will not have the same preferences.

However, the situation changes when the source of heterogeneity is simply motivated by accidental factors or factors linked to misinformation. For instance, a new rule may only have been approved because of the community's traditions rather than its preferences or income levels, or because national government was misinformed about the need for some new technology to further the community' interests. In this case, the need for differences among national rules is difficult to sustain, especially when these differences produce additional costs for international trade.

Just as doubtful is *bad* heterogeneity caused by groups with shared interests who capture regulations, such as groups which form in strictly regulated sectors and are able to use these regulations as a protectionist device. This type of situation can give rise both to rules with an explicitly discriminatory content which is detrimental to foreign competitors, as well as to formally non-discriminatory rules, which can however generate distinctions which harm competitors themselves. According to international trade theory, rules decrease social welfare in the same way as traditional means for trade protection do, whether characterized explicitly by discriminatory aims or not.

Therefore a *good* heterogeneity is strongly justified and represents the origin of differences among countries which determine the existence of trade

advantages. On the contrary, differences which arise from accidental factors, misinformation or capture, may not be advantageous and thus, in an ideal world, should be eliminated.

It is clear that demanding international harmonization of internal rules cannot only take into account the reasons for heterogeneity, but must also define the domestic consequences of adopting a regulation. In fact, even when encountering the second type of motivations, if the regulatory difference does not imply any costs for international trade, but only for the countries which use it, there are no rational reasons for linking trade liberalization to harmonization. These aspects need to be considered in order to avoid a distorted use of the requests for harmonization.

If any rule or policy of public intervention can trigger disputes relating to fair trade, the most detrimental consequence would be not reaching global agreement about a rule-oriented international trade system, a failure which, in turn, could lead to the establishment of a trade system managed by national bureaucracies in favour of the interests of the most influential internal lobbies.

The counter-motivation of the theory on international trade claims that stricter social or environmental regulations simply reflect the highest position obtained by the quality of industrial relations or the environment in ranking the collective preferences of the country which adopted them. If such preferences, along with the provision of resources, vary from one country to the other, similarly, productive specialization varies as well. Moreover, these differences determine the advantages of international trade.

Radically eliminating national differences by obtaining a general commitment from all countries to comply with the same basic rules in order to eliminate their effects on trade is an extreme solution. So much so, that many economists adopting a classical approach believe such a solution to be both unachievable and inadequate.

International trade suffers no distortion when the adoption of an efficient mechanism, for instance by the WTO, to control national decisions can guarantee that the origin of national differences is due to the existence of legitimate differences among consumers' preferences or income levels, rather than to bureaucratic incompetence, lack of correct information, an over or under-assessment of the necessary level of intervention, or the capture of regulatory policies by interest groups. Therefore, considering its implications for worldwide welfare, harmonization could be seen as a secondary solution in comparison to the ones which allow regulatory differences to be maintained.

Finally, if international trade causes a convergence of income levels, then

rules will also automatically tend towards convergence. This can clarify how harmonization itself is a consequence, and not a prerequisite, of trade liberalization. Furthermore, from a political point of view, international regulations tend to be stricter than national ones: this may be because the already difficult process of reaching a consensus for their creation may not be achieved again when they need to be changed, especially when these changes are required by technological innovations that not every country has at its disposal.

3. *Applying Efficiency Principles to Integration in the European Union*

So far we have referred to situations which can arise in the international trade system in which trade liberalization *between* national markets is an important issue and where, consequently, the only political means to achieve liberalization is intergovernmental cooperation.

The situation becomes very different in regional areas which are undergoing either a process of economic integration for the creation of a single market, or a process of political integration aimed at a more efficient use of public economic intervention policies.

Therefore, the expression *deep integration*, introduced by Lawrence (1997), indicates a series of governmental policies for reducing the effects of market segmentation caused by differences among national regulatory policies through coordination and cooperation. Non-tariff barriers, dealt with in programs for regional integration, often belong to the type of policies which add supplementary costs or costs of a frictional character to the international trade of goods and services, or restrain the access of new economic operators in national markets. Their elimination requires a more advanced level of cooperation, which, in turn, can often lead to giving up national sovereignty. Multilateral agreements, by contrast, are normally based on unilateral decisions taken by a national Government (such as the adoption of an agreed policy or the acknowledgment of other countries' policies).

The European Union (EU) is a case in point as far as technical needs to reach formal governmental agreements are concerned. In the EU, the objective of contestability is radically dealt with – as indicated in art. 3 of the Treaty of Rome – through the establishment of an internal market and its appropriate functioning. The creation of an internal market is dealt with by eliminating obstacles to trade, whereas the appropriate functioning of the market is dealt with by adopting policies which can eliminate market failures, in other words regulatory policies (Pelkmans, 1997).

A substantial difference between the situation described above and the EU is that the creation of a single market by an integrative process is now more of an issue than commercial relationships between national markets. The achievement of effective contestability of national markets in the EU Member Countries, by creating a single market, is an appropriate example of the difficult task of reaching the optimal level in economic regulation, as well as of choosing the procedures and means for harmonization.

The theory of regulation applied to an international context argues that cooperative solutions are to be preferred to non-cooperative ones when international regulations are inter-dependent, as one can have an impact on the other. If we apply the same argument on a community level, regulatory harmonization becomes a European problem when market failures occur at a European level and when the costs for managing European regulation do not exceed the costs of market failure.

In European integration, this kind of approach is called the subsidiarity principle. This principle states that only those regulations which can be efficiently managed at a European level should be transferred from national or local Governments.

The regulatory strategy of the Community – finalized after a long and demanding process of learning by doing – follows three distinct processes which interact with each other (Pelkmans, 1997):

1) the political process referred to previously is based on the decision taken by the Single Act (art.100b) of introducing the procedure of qualified majority voting in all those fields related to the creation of the single market. This decision has unanimously been acknowledged as a fundamental one, since it has opened the way to fully creating the internal market and it has almost completely eliminated the incentive, for national Governments, to impose vetoes against common decisions in order to safeguard the interests of one party.

2) the legal process is based on some important interpretative sentences of the Court of Justice that have later opened the way to the practice of a mutual recognition of national regulations. Two of the most well known sentences ("Dassonville", 11th July 1974 and "Cassis de Dijon", 20th February 1979) allowed for a better understanding of important procedural aspects in the application of the Treaty of Rome. In particular, the second sentence enabled the principle of mutual recognition to be applied even when the derogations in art. 36 could have been applied instead. The Court decided that mutual recognition is valid when the objectives of national regulations are equivalent. According to the Commission's interpretation of the sentence, a Member State cannot prevent imported products from entering its national

market when such goods are produced in conformity with the provisions or technical specifications of another Member State and when they correspond "adequately and satisfactorily" to the legitimate objective established by the country's regulation.

It is clear that the principle of mutual recognition can only be based on mutual trust between Member States. Mutual trust, according to Mattera Ricigliano (1990, p. 294), is the link between States which "have common cultural and scientific sources and live together in a Community characterized by ever stronger constraints, defended by a common law, by common institutions and by an over-national jurisdiction whose decisions are imposed on all States"[2].

The ban for Member States, in conformity with art.30, to adopt rules that can be an obstacle to free trade in the Community as well as the strong limitations on the use of the derogations in art. 36 (when the equivalence among national regulatory objectives has been acknowledged), guarantees free circulation and allows for procedures provided in art. 100 and 100B for the approximation of national rules to be applied when strictly necessary. According to Pelkmans, the practice of mutual recognition has allowed us to reduce the number of cases that may require assessment through the second step of the subsidiarity test. Assigning a regulatory competence at community level is not necessary when national objectives are equivalent. Similarly, the guarantee which mutual recognition gives to free circulation refrains from employing an excessive regulation with indirect protectionist functions. Moreover, it has also allowed Community regulation to be limited, when necessary, to only providing *essential requirements* for products or productive processes, by leaving the task of defining technical requirements to Member States or to private bodies for standardization.

3) the regulatory process becomes easier to manage thanks to the transparency in both the political and legal processes. Its pillars, which are listed in the Treaty, are meant to provide a trustworthy guarantee for the contestability of national markets for both goods and services.

4. *Evolutionary Approach: Towards a Cognitive Understanding*

The structure of the approach described so far is clearly neoclassic and because of this, information about citizens' preferences is presupposed: on the basis of such information, a competitive process takes place which should then lead to optimal Paretian conditions. The inadequacy of the approach

[2] My translation.

does not arise from the principles of the neoclassic theory of competition – whose supporters themselves admit to be not very consistent with reality – but rather from the methodological postulate that knowledge about the mechanisms of social interaction is already known. Therefore, in the neoclassic model there is no room for cognitive processes driven by competition, neither can there be an analysis of the role of institutions in the creation of a social order (Vanberg and Kerber, 1994).

A substantially different approach can be found in an institutional analysis, based on a different interpretation of the concept of competition, considered as an evolutionary knowledge-creating process. If, on the one hand, a classical approach focuses on the issue of the final equilibrium obtained in a competitive process, with final efficiency therefore being the key parameter, on the other, an evolutionary approach tends to focus on the modalities that characterize the competitive process and, in particular, on the changes that over time affect the distribution of *population* characteristics, a perspective which is called *population thinking* (Mayr, 1982; Vanberg and Kerber, 1994).

The evolutionary approach analyses the evolution of a population which has changed because of competition by addressing two different yet complementary issues:

- how competition among rules provokes evolution through a cognitive process;
- what procedures (institutional constraints) make the evolutionary process possible.

Before proceeding with the analysis, we need definitions relating to competition among rules or, better still, among jurisdictions. Jurisdictions are groups of populations which consider a system of interacting rules as a basis for regulating their own social action and their relationships (Vanberg and Kerber, 1994). Such rules (or institutions) determine not only the general behaviour of a population – which Hayek calls "spontaneous order" – but also an organized order, defined by formal rules.

Therefore, general behaviour rules are spontaneous institutions, such as property or contracts, whilst organizational rules are institutions which define organized orders, such as businesses or jurisdictions. The main characteristic of an organized institution is its territorial nature. By this we mean that being resident in a given territory is essential for including individuals in the domain of common rules.

Thus, the competitive process among jurisdictions is aimed at acquiring resources. To use Hayek's terms, it is a cognitive process or a *discovery procedure*, as in the case of normal market competition.

The application of this evolutionary perspective to normal market

competition can clarify which cognitive process economic agents are dealing with. The process starts from the conjectures producers are able to make about consumers' preferences. Producers are encouraged to take a risk which is proportional to the chances they have – if their conjectures are correct – of gaining a competitive advantage which, in turn, allows them to benefit from a temporary position of monopoly. At the same time, the competitors who lost their market share change their behaviour either by imitating winning competitors or by creating innovations themselves. In any case, the cognitive process tends to continuously reproduce the conditions according to which competitive advantages are first created and later denied, thus eliminating previously gained profit margins and market powers.

Heterogeneity among competitors is therefore especially important: the greater heterogeneity is, the wider the knowledge generated. Consumers' welfare increases since there are many possibilities to choose from and the chances of finding better solutions increase. Eventually innovation, favoured by competitors' heterogeneity, will play the role envisaged by Schumpeter, who argues that innovative and imitative processes are the leading force of economic development, and by Hayek, who defined competition as a process of gradual discovery.

Can an evolutionary concept of competition be applied to a comparison among jurisdictions? In this case, it can be argued that jurisdictions – which exist in virtue of the rules and institutions they themselves created – are in competition with their ability to solve the problems. We can further add that the differences among institutional systems affect the competitive process.

We can now deal with the issue by asking the following question: how can competition determine the distribution of institutional characteristics among different jurisdictions? Tiebout (1956) and others have addressed this in terms of general equilibrium by asking how citizens' preferences can match political choices. An evolutionary approach, as opposed to a neoclassical analysis, focuses on the role played by competition in creating new knowledge through the *discovery procedure*.

Vanberg and Kerber believe that the cognitive problem, which relates to normal market competition, can also be the essence of competition among jurisdictions. In the evolutionary approach, knowledge about the best solutions cannot be taken for granted – as happens instead in classic economic analysis – nor is it possible to know in advance what will be a future problem. The *political entrepreneur* works as a normal entrepreneur, making conjectures about what is likely to be considered right or wrong, and takes part in the competitive process by trying to explore the best institutional solutions to compare with the existent ones.

The dimension of competitive success can, once more, be compared to situations typical of a normal market: profits in this case can be identified in the ability to attract production factors. Competition thus becomes instrumental in the evolution of institutions. As with market competition, jurisdictions which introduce new, more efficient rules gain a competitive advantage over losing jurisdictions.

Consequently, an outflow of production factors is generated which in turn provides losing jurisdictions with an incentive to renew their institutional system, particularly by reproducing the institutional innovations implemented by leading jurisdictions. In other words, competition becomes a means of assessing the properties of alternative rules, of examining how such rules are enforced in different jurisdictions and which channels are available for citizens to pass judgment on the results which these rules produce. The final outcome of such overall confrontation is what we call institutional evolution.

This conceptual approach has been criticized because of the increased chances of destructive competition it could trigger: a kind of race to the bottom caused by the desire of political entrepreneurs to attract production factors by offering institutional structures not suitable for facing a series of well-known problems, such as environmental protection or social regulation.

We can respond to such a negative forecast in several ways:

- first of all, competition among jurisdictions is far less flexible than normal competition among firms, as the choice to move from one jurisdiction to another in order to exploit, for instance, the advantages of a different social regulation, implies a remarkably higher cost than the one needed for moving from one supplier to another. These costs include having to entirely give up an institutional structure which has developed the ability to adapt to residents' needs thanks to its increased knowledge and experience.
- secondly, incentives for political entrepreneurs are different to those for private entrepreneurs. Jurisdictions, for example, differ from firms in that their decisions are collective. Therefore, while private entrepreneurs make decisions on their own and benefit entirely from the resulting advantages, in a jurisdictional framework the interest for incentives, as well as for their distribution among citizens, can vary. In the case of social regulation, for instance, this means that some citizens may be very attracted by incentives such as obtaining more capital through liberal rules, whereas others may not be. Vanberg and Kerber also point out that even if the political market is less flexible than the normal market, it is possible to have effective competition which, in this case too, is favoured by heterogeneity and the number of jurisdictions.

– thirdly, competition among jurisdictions needs to be bound by constitutional constraints.

Vanberg (1993) and the Freiburg's School introduce the concept of competition *constrained* by constitutional rules, rules that give rise to a regime which can force the strategies of both firms and jurisdictions towards goals which are also shared by citizens. Therefore, they allow for incentives which are favourable to some strategies yet unfavourable to others. The Freiburg's School has introduced the basic concept of *Ordo-liberalism* for market competition, where the latter is a process which should occur within the framework of rules which can guarantee "that the only road to business success is through the narrow gate of better performance in service of the consumer" (Ropke, 1960, p.31). The competitive order, i.e. the appropriate rules chosen by a community, must channel the entrepreneurs' efforts for innovating market competition towards a better understanding of consumer preferences. In this case too, the same concept of competitive order can be applied to competition among jurisdictions. The constraints for this type of competition are clearly aimed at limiting the entrepreneurs' political choices within a reference structure similar to the one considered for normal market competition. Here, instead of consumer's sovereignty, supporters of evolutionism take into consideration citizens' sovereignty, a criterion which sees citizens' preferences in a jurisdiction as a fundamental parameter according to which regulatory choices must be measured.

Vanberg and Kerber introduce a set of rules – or a competitive order – which can regulate competition among jurisdictions in order to generate innovations which can satisfy the citizens' interests. Rules on competition determine whether the behaviour and strategies adopted by jurisdictions are acceptable or not. In the light of the Freiburg's School arguments, this means identifying which rules are more likely to make the Governments' competitive efforts meet the citizens' interests. An appropriate competitive order should be the main instrument to achieve a better political order.

This concept should then be applied to actual situations such as competition among jurisdictions within the same State, or within a Federation or a pseudo-federation (such as the EU), or even worldwide (e.g. the competitive order based on the GATT/WTO). The nature of this competitive order can vary considerably according to each situation and some of its main aspects have been described following research in the field of new institutional economics.

One such aspect is the existence of rules which ensure the efficiency of institutional competition by guaranteeing the inter-jurisdictional mobility of people and capitals, as well as of goods and services. A second aspect, linked

to the idea of achieving effective competition, is the regulation of protectionist policies by a series of rules which restrain the attempt of eluding competition by effectively demanding intervention against presumed externalities. A third aspect connected to the second, is creating rules that allow Governments to avoid the capture of their own regulation by groups organized according to shared interests. This may happen, for example, when – in order to handle competition with other jurisdictions – the Government itself is strongly urged to relieve the burden of environmental or social regulations.

To conclude, an evolutionary analysis of the study of the relationship between harmonization and competition among rules within the EU claims that:

- competition among jurisdictions is a process of knowledge creation;
- achieving positive results depends on compliance with appropriate rules in order to serve the citizens' interests.

5. *Applying the Evolutionary Approach to Integration in the European Union*

How and to what extent can these two key concepts of the evolutionary approach be identified in the EU institutional structure and in the European process of integration?

Given that European integration comes as the result of two processes, integration *from above*, led by Governments, and integration *from below*, which ensues from private operators (Pelkmans, 1997), we are dealing with two different forms of integration: one achieved by means of public intervention, the other by means of *framework activities*, in which results depend on autonomous choices made by private operators on goods and services, as well as on localizations and institutional systems (Streit and Mussler, 1994).

The first process is inspired by key aspects of the economic analysis of the classic theory of public goods, which considers public intervention as necessary when there are distortions or imperfections in the market. As we have seen, this implies that the system would be informed beforehand of both the failure and the best solution for it.

The second process seems to be closer to evolutionary analysis: competition, typical of integration *from below*, is strengthened by the fact that market expansion offers private operators more choice, and its cognitive function is proportional to the extent in which operators are given permission to pursue their own interests, even when it comes to choosing the most

appropriate institutional system for their needs.

The issue, now, is whether the mechanism of mutual recognition of national rules within the European internal market can promote real, effective competition among regulations, forced to comply with constitutional rules which can confine competition within the framework of the general choices made by citizens.

Streit and Mussler have aptly shown the different consequences produced by the two approaches on legislative choices: integration from below, in an evolutionary perspective, implies accepting both *lack of knowledge* as a basic characteristic of the system, and competition among rules as the means to improve the institutional structure, even if this cannot be predicted. On the contrary, the choice of integration from above is based on lack of trust as far as *discovery capacity* is concerned, and emphasizes the need for a *purpose oriented* legislation, which therefore considers results based on a priori knowledge of the causality chains within the system to be possible.

In fact, the analysis of the Treaties of the European Community, and their evolution, allows for both processes to be acknowledged. The evolutionary approach requires that constitutive rules are able to guarantee fundamental economic freedoms to operators and to define the framework of constraints within which competition among jurisdictions may be performed whilst respecting collective choices. From this perspective, the Treaty guarantees freedom of choice to citizens, as shown in art. 3, in terms of both their free circulation within Member States and of restrictions which may arise from private behaviour and States' behaviour.

Moreover, solutions adopted in terms of constraints to States' regulatory intervention come from an accumulation of knowledge which in turn comes from the historical evolution of relationships among Member States.

The new approach for the elimination of non-tariff barriers, briefly described above, is based on two principles of the evolutionary process: mutual recognition of national rules – whose respect guarantees competition among national jurisdictions – and adoption of a series of rules meant to guarantee the quality of competition, such as:

- compliance, when necessary, with some essential requirements set by Community directives,
- the proportionality principle in the adoption of national rules,
- presupposition of mutual trust when national objectives are equivalent,
- acceptance of conformity controls on products and services by the country of origin.

This approach is the result of a process of learning which comes from the comparison/competition among national legislations relating to technical

rules and standards. The German legislative technique was based on the acceptance of a principle of conformity with the *Deutsche Industrie Normen* (DIN). According to such a principle, in order to guarantee compliance with regulatory standards, firms and certification institutes indicated that, from a technical point of view, their products were made in conformity with legal requirements.

Later, the principle of conformity to technical requirements, defined by specialized bodies, was adopted in 1973 by the EC for the *Low Voltage Directive*, which required a certain level of conformity without imposing pre-defined technical specifications.

France, unlike Germany, opted for a system of rules that already included technical specifications that companies were obliged to comply with. The remarkable difference among the two systems posed a serious problem for the Community as it tried to guarantee access to national markets, since foreign suppliers had to comply with both the German DIN standards and specific French technical rules. The dispute between the two countries became very intense and was settled thanks to Germany's decision to acknowledge not only that French rules were equivalent to its internal rules from a technical point of view, but also that conformity tests made by French institutes were equivalent.

Comparison between these two legislative techniques resulted in the EC adopting the German model based on the principle of conformity. This choice was later strengthened by the famous Cassis de Dijon sentence, by which the Court of Justice officially recognized the principle of mutual recognition and also accepted its active responsibility in the process of economic integration thanks to its powers for acknowledging equivalence among national standards. This was also an incentive for the Commission and the Council to intervene, when necessary, with their own regulatory directives (Woolcock, 1996).

Pelkmans (1997) also notes that the Community's regulatory strategy is, to date, the non-definitive result of a complex process of learning by doing and of many years of experimenting within the framework of a project to create a community's internal market for goods and services. A number of solutions have been assessed thanks to this kind of experiment and a new approach has finally been adopted which, compared to the approach used until 1985, increases the chances of having different regulatory solutions in competition.

This also shows that the cognitive nature of competition among jurisdictions is often better at improving the quality of proposed solutions only when the rules that determine such quality are clearly stated. Specifically, we are referring to the need for rules that limit or prevent the

possibility of 'capturing' national regulation by interest groups.

In this case too, the unsuccessful creation of the internal market before the EC-92 program, was caused by the option national firms were given to influence their own Governments to create non-tariff barriers. After 1992, the combination of the above-mentioned general rules (guarantee of market access, subsidiarity, proportionality) reduced the number of incentives for capturing national technical rules to internal protection aims, while new incentives aimed at capturing community rules were created with a view to improving European competitiveness in worldwide markets. Therefore, even if the goal has changed, the incentive to strengthen the interaction between Governments and firms still exists and it is precisely the nature of such interactions which should be limited.

Sun and Pelkmans (1995) provide a useful framework and analysis of two case studies, which highlight the fact that, due to the unpredictability of the outcome of Government-business enterprise interaction, knowing what the outcome of competition among rules is can be difficult. Again, this highlights the importance of setting constitutional constraints on competition. Moreover, the authors' argument that after the Community's new approach harmonization of rules is today less costly and therefore a valid alternative to competition, is based on the outcomes of the discovery procedure, which we find in an evolutionary approach. In fact, the lower cost of harmonization can be said to ensue from a cognitive process resulting from the comparison of different regulatory structures. This process has favoured a convergence towards homogenous regulatory structures which make common rules easier to achieve.

However, today the problem seems to be quite different. The rules which limit competition among jurisdictions (i.e. horizontal competition) presuppose the existence of a trustworthy arbitrator able to enforce such rules, whereas the current role of Community institutions is put into question: their position together with their inherent impartiality in terms of vertical competition decision-making has come under close scrutiny.

A second form of competition has appeared in the Community, besides the horizontal form among jurisdictions of the same level: it is a form of vertical competition among different governmental levels in the pre-federal structure of the Community itself. The previously mentioned article by Vanberg and Kerber (1994) highlighted that the highest Government levels, when deciding which strategies lower jurisdictions can adopt in their horizontal competition, also decide what the vertical distribution of competencies among the various Government levels should be. Vaubel (1999) argues that the highest Government levels do not necessarily coincide with impartial arbitrators able

to judge vertical or horizontal forms of competition because they are directly involved in these forms of competition. The decisions taken by the EC's highest institutions have often shown this to be the case. On the other hand, while the decisions taken by the Court of Justice, for instance, on how to interpret the Treaty of Rome with regard to the issue of guaranteeing market access, opened the way to competition among jurisdictions which were able to exploit the markets' innovative opportunities, the Maastricht revision of institutive Treaties and the recurrent behaviour of Community authorities generate ambiguities which ultimately limit the cognitive function of competition.

A case in point is the pursuit of "competitiveness of the Community's industry" introduced by the Treaty of Maastricht (art. 130). Streit and Mussler note that this measure gives rise to ambiguities between the functional interpretation of competition (art. 130, 3° comma: "This title shall not provide a basis for the introduction by the Community of any measure which could lead to a distortion of competition") and the fact that no form of industrial policy can work without making a choice among firms, industries or economic activities. An evolutionary approach can show that such ambiguity and the ensuing operative procedure, is inconsistent with Hayek's conception of competition as a discovery procedure. The fact of considering competition as a process based on the endemic lack of information – which, from an evolutionary perspective, characterizes the economic system and is due to the system's complex, internal relationships – implies institutional choices which are substantially different from the ones we have described.

6. *Inconsistencies in Community Practice*

The Community's institutions actually see competition as a means of achieving already set objectives on the basis of available information. When it comes to analysing the role of the European market, there is a striking difference between the evolutionary and constructivist approaches. According to the Community "... the main issue is which conditions need to be present in order to strengthen the optimal allocation of resources by market forces, towards accelerating structural adjustment and towards improving industrial competitiveness and the industrial and particularly technological long term framework" (COM (90) 556 final, 1; quoted by Streit and Mussler, 1994). Therefore, the Community's policy is mainly focused on the Community's interests, and not on private objectives: "... Those policies which favour firms' initiatives and guide them in the direction of a long term

perspective funded on the Community's interests are to be preferred" (ibidem); this is clearly inconsistent with a concept of a market which operates by leaving the task of identifying the most suitable processes of development for citizens to private agents and competition.

Moreover, what is meant by *Community's interests*? Surely, Treaties indicate generally accepted common objectives, whereas the struggle of Community institutions against national protectionism, non-tariff barriers and governmental subsidies has been a way of achieving such objectives. It is also the case that a greater inter-dependence of the markets causes requests for Community interventions in favour of firms or other economic activities to increase, which could be anti-competitive. These requests can be supported by interest groups which feel they are better protected by the Community rather than by their country, because European institutions are better at representing the Community's interests worldwide and in multilateral organizations and because the level of democratic control on the opportunities for rent seeking is inferior.

Yet, there is an even more complex and dangerous chance that the same national Governments may be supporting forms of collusion. Such Governments may address intergovernmental cartels on taxation or regulation, supported by Community Institutions, to find a way of managing interventions. In a situation of effective competition among jurisdictions, this would give rise to the outcomes predicted by Tiebout, i.e. that activity would move among jurisdictions pursuing the incentives offered by different regulations.

According to Vaubel (1999), the explicit trend in Treaty reforms to increase the centralization of intervention policies at a Community level can be interpreted as a way to strengthen, rather than prevent, collusion among firms, among firms and governments, and among jurisdictions. Examples of this are: the trend to favor Community regulations even when this was unnecessary (for instance, recent common rules for chocolate or traditional food products, such as types of salami or cheese, were, according to some observers, clearly inspired by the interests of large corporations)[3], but also to favour agreements among Governments on taxation or regulation, in particular utilities.

Thus, the Community's competence to control horizontal competition

[3] Vaubel (1999) notes that regulations on products are often the result of a lobbying activity led by big firms, which expect to use such rules in order to exploit greater economies of scale on the domestic market and to receive protection against external competitors. Moreover, Olson (1965) claims that the incentive to bear the costs of such lobbying activity is greater for firms which have greater market quotas.

among jurisdictions – which has been performed with great commitment (e.g. controlling State aids to firms) – may be overcome by the need to meet the consensus of Member States in order to strengthen centralized powers, by offering the support of Community Institutions to intergovernmental cartels in exchange.

7. *Conclusion*

Debate on competition among rules in the European Union has been traditionally centered on a neoclassic approach, based primarily on trying to measure the outcome of a competitive process between jurisdictions according to final efficiency.

The principle of subsidiarity (Art. 3B of the Maastricht Treaty), which is the result of such an approach, indicates that harmonization only applies to those interventions and rules that can be managed more efficiently at the Community level, whereas the rest remain in the domain of local or national regulations and are the object of competition among jurisdictions.

Our discussion has shown that such a deterministic approach is subject to methodological inconsistencies which supporters of the theory also recognize: by following a neoclassic approach, information about citizens' preferences is presupposed. This leads to a competitive process which should, in turn, lead to optimal Paretian conditions. We have therefore argued for a different methodological postulate in order to redress the issue, that is to say a cognitive process which is driven by competition and an analysis of the role of institutions in the creation of a social order to take away the emphasis from a priori knowledge of mechanisms of social interaction. Such methodological failings have in fact given rise to problems which are well known to European observers: the capturing of community regulations by the strongest interest groups has been seen to depend on the lack of knowledge held by common Institutions.

When we no longer focus on the final equilibrium obtained in a competitive process, we can adopt an evolutionary approach which concentrates on the modalities of the competitive process. This is possible when we look at:

a) how competition among rules provokes evolution through a cognitive process;
b) which procedures (institutional constraints) the evolutionary process must go through.

Consequently, two essential aspects of the evolutionary analysis involve:

1) approaching competition among jurisdictions as a process of creating such knowledge;
2) seeing the possibility of achieving positive results as dependent on compliance with appropriate rules in order to serve the citizens' interests.

Moreover, since the Community's institutions use competition to achieve set objectives on the basis of available information, we are faced with a further inconsistency: private agents and competition are prevented from identifying the most suitable processes of development for citizens. This attitude is heightened by the need to find and maintain political equilibrium through compromise in the relationship between national Governments and common institutions. Such equilibrium leads to common Institutions loosing their fundamental role as impartial arbitrators for competition among jurisdictions in the European market.

Finally, for competition among jurisdictions to play the cognitive role indicated by new institutional economics, a series of constitutional constraints is required (although these are still weak in current European Treaties) as well as control that the Community's institutions are not able to enforce at present, mainly because they lack democratic legitimisation and are linked to forms of vertical competition which encourage collusive agreements with lower levels of Government. An important issue for the future evolution of European integration will, therefore, probably be that of finding solutions to this problem.

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ABSTRACT

The aim of this paper is to highlight the differences between the following approaches to the problem of harmonizing national rules in the European Union: (a) the approach of neoclassical economics, whose analysis involves the application of criteria of efficiency and a constructivist view of the market role, (b) the approach of evolutionary economics, where the focus is more on the cognitive nature of the competitive process among the different jurisdictions within a pre-federal system.

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competitive process among the different jurisdictions within a pre

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R&D IN TRANSPORT AND COMMUNICATION IN A COURNOT DUOPOLY

by
LUCA LAMBERTINI *, ANDREA MANTOVANI*, and GIANPAOLO ROSSINI*

1. *Introduction*

By and large, R&D expenditure can be devoted either to process or to product innovation. Product innovation decreases the degree of substitutability between rival goods in oligopolies, as it is argued in Singh and Vives (1984) and Lambertini and Rossini (1998), due to the fact that innovation takes each product far away from similar goods sold by rival firms belonging to the same industrial sector. Product innovation is therefore undertaken with the aim of making own's products less close to those of other firms (Tirole, 1988).

No matter which firm engages in product innovation there is a beneficial effect also on competitors that find products less close among themselves. Literature has emphasized the different degree of efficiency of process innovating R&D in a Cournot market setting *vis à vis* a Bertrand setting (Brander and Spencer, 1983; Dixon, 1985). Recently Lambertini and Rossini (1998, 1999) and Lambertini et al. (1998) have shown that R&D in product innovation may give rise to the choice of no heterogeneity as a result of a prisoner's dilemma, no matter whether Bertrand or Cournot competition is assumed. This appears to be quite consistent with the externality brought about by product innovation through its effect on substitutability.

*Department of Economics, University of Bologna, Bologna (Italy). E-mail: lamberti@spbo.unibo.it, mantovan@spbo.unibo.it, rossini@spbo.unibo.it

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A more comprehensive analysis reveals that other kinds of R&D activities may be considered. Casual observation suggests that firms invest in R&D that is neither devoted to product innovation nor to process innovation, yet it is a kind of R&D that allows firms to reach markets in a more efficient way and be more competitive just in serving their customers. The activities involved concern mainly transport and communication needed to let the product reach the final buyer. The related R&D may be figured out as an expenditure that is going to improve the technology of the last stage of the production process. To this category belongs the investment in the Internet, in advanced logistics, or in faster transport technology. We define this sort of activity transport and communication R&D (TCRD). Most of the times transport and communication services are modeled as if a portion of the output is used up to produce them, while only a fraction of the final product is finalised to the consumer. In such a framework, the purpose of investing in TCRD is just to reduce this chunk of product lost while approaching the final buyer.

We borrow from trade theory (see, e.g., Helpman and Krugman, 1985) the modeling of transport and communication costs, assuming that they are of the iceberg type: a quantity q_i of product i is produced, yet only a fraction $t \in]0,1]$ of the product reaches the consumer. This fraction depends on the investment policy of the firm, since, by committing to TCRD a firm may increase it, indirectly reducing production costs while making rival products virtually come closer, even though they remain homogeneous. Investing in TCRD is then somehow similar to investing in product innovation R&D, but with an opposite effect, as far as substitutability is concerned. Moreover, TCRD has a further effect similar to that of process innovation R&D since it reduces marginal costs. Investing in TCRD is then a sort of combination of process and, reversed, product innovating R&D.

Our aim is to analyse, in a Cournot setting, various scenarios in which firms behave symmetrically or asymmetrically as to TCRD.

First we consider a binary model of choice of TCRD and the reduced form game that can be derived. At the subgame perfect Nash equilibrium, firms invest in TCRD if the resulting increase in efficiency is large enough. As the efficiency of the TCRD decreases, firms keep on investing without being able to maximize their aggregate profits. For a

further decrease of efficiency of TCRD only one firm invests, as a result of a chicken game. Finally, near the lower bound of efficiency neither firm invests. From a policy standpoint, there seems to be room either to subsidize or to avoid excessive TCRD depending on its efficiency.

We then go through a parallel model of TCRD with continuous strategies and find the correspondent subgame perfect equilibrium of the two stage game.

The paper is organized as follows. In the next section we analyse the choice between investing in TCRD and not investing. In Section 3 we go through the reduced form of the game played by firms. In Section 4 we provide the welfare evaluation of the market solutions. In Section 5 we go through the continuous strategies case. Final remarks are in Section 6.

2. *The Model*

We analyse a duopoly where firms i and j compete in a two stage framework in a Cournot setting. In the first stage they decide whether to invest either in TCRD or not to invest. The second stage is the market stage. We resort to backward induction to solve the game and get subgame perfection. The R&D strategy space is given by the binary choice between undertaking TCRD or doing nothing $\{0, k\}$, with capital expenditure in TCRD represented by $k > 0$. We assume, for the sake of simplicity, that, if the firm invests in TCRD it will be able to ship the entire product to its customers and no portion will be lost in the way ($t = 1$). Otherwise, if it doesn't invest in TCRD, it will be able to ship only a fraction $t \in]0, 1[$ of the product. Marginal production cost is assumed constant and equal to c. We consider three cases.

Only one firm invests in TCRD (case a). - Firm i invests in TCRD while firm j does not. Firm i is able to deliver the entire product to its customers, while firm j affords only a portion $t \in]0, 1[$ of the product to reach the consumer after its production, since $1 - t$ is used up in transport and communication due to an inferior technology. We assume a linear market demand for the two homogeneous products and unit

reservation price:

$$p = 1 - q_i - tq_j \tag{1}$$

Operative profits are respectively:

$$_a\pi_i = q_i(1 - q_i - q_j t) - cq_i \tag{2}$$

$$_a\pi_j = tq_j(1 - q_i - q_j t) - cq_j \tag{3}$$

From market stage first order conditions (FOCs),[1] we get the following quantities:

$$_aq_i^* = \frac{c + t - 2ct}{3t}$$

$$_aq_j^* = \frac{-2c + t + ct}{3t^2}$$

Equilibrium total profits are:

$$_a\pi_i^* = \frac{(c + t - 2ct)^2}{9t^2} - k \tag{4}$$

$$_a\pi_j^* = \frac{(ct - 2c + t)^2}{9t^2} \tag{5}$$

Both firms invest in TCRD (case b). - Assume firms i and j invest in TCRD. Operative profits are

$$_b\pi_i = q_i(1 - q_i - q_j) - cq_i \tag{6}$$

$$_b\pi_j = q_j(1 - q_i - q_j) - cq_j \tag{7}$$

Equilibrium quantities are:

$$_bq_i^* = {}_b q_j^* = \frac{1 - c}{3}$$

and equilibrium profits are:

$$_b\pi_i^* = {}_b \pi_j^* = \frac{(1 - c)^2}{9} - k \tag{8}$$

[1] Second order conditions are always satisfied, as it may be easily checked in this and subsequent cases.

Neither firm invests in TCRD (case c). - Assume that neither firm i nor firm j invest in TCRD. Operative profits become:

$$(9) \qquad {}_c\pi_i = tq_i(1 - tq_i - tq_j) - cq_i$$

$$(10) \qquad {}_c\pi_j = tq_j(1 - tq_i - tq_j) - cq_j$$

Equilibrium quantities are:

$$(11) \qquad {}_cq_i^* = {}_c\, q_j^* = \frac{t - c}{3t^2}$$

while equilibrium total profits are

$$(12) \qquad {}_c\pi_i^* = {}_c\pi_j^* = \frac{(t - c)^2}{9t^2}$$

In case d, firm i does not invest in TCRD, while firm j does. Therefore we just obtain the reversed payoffs of case a, i.e: ${}_a\pi_i^* = {}_d\,\pi_j^*$ and ${}_d\pi_i^* = {}_a\,\pi_j^*$.

3. *The Reduced Form of the Game*

The reduced form of the game is represented in normal form in matrix 1.

		firm j	
		0	k
firm i	0	${}_c\pi_i^* = {}_c\,\pi_j^*$	${}_d\pi_i^*;\ {}_d\pi_j^*$
	k	${}_a\pi_i^*;\ {}_a\pi_j^*$	${}_b\pi_i^* = {}_b\,\pi_j^*$

Matrix 1.

The above game shows different solutions according to the productivity of TCRD.

By partitioning the admissible set of k into four regions, as it can be seen in Table 1 below, we can derive the following:

Proposition 1. a) *When TCRD is very efficient, the game has a unique Nash equilibrium in dominant strategies where both firms invest in TCRD and maximize their aggregate payoff reaching Pareto optimality. This happens for all* $k \in \left[0, \dfrac{c(t-1)(c-2t+ct)}{9t^2} = k_1\right]$.

b) *As TCRD becomes less efficient, i.e., for* $k \in \left[k_1, \frac{4c(c-t)(t-1)}{9t^2} = k_2\right]$, *the game has a unique Nash equilibrium in dominant strategies in which both firms invest in TCRD failing to maximize their aggregate payoff as a result of a Prisoner's Dilemma.*

c) *For* $k \in \left[k_2, \frac{4c(c-1)(t-1)}{9t} = k_3\right]$ *we get a a chicken game and there exist two asymmetric equilibria in which only one firm invests in TCRD.*

d) *For all* $k \in [k_3, \infty)$, *the game has an equilibrium in dominant strategies where the aggregate payoff of the firms is maximized by not investing in TCRD. Such an equilibrium is Pareto-efficient from the firms' standpoint.*

Table 1. Taxonomy of equilibria in the TCRD game

	a	*b*	*c*	*d*
Equilibria	Nash in dom. strat.	Nash in dom. strat.	Chicken game	Nash in dom. strat.
Action	All invest	All invest Prisoner's Dil.	Only one invests	None invests
Efficiency	Pareto effic.	Pareto ineffic.		Pareto effic.
Intervals of k	$k \in]0, k_1]$	$k \in [k_1, k_2]$	$k \in [k_2, k_3]$	$k \in [k_3, \infty)$

Proof: First consider non-negativity constraints on quantities. We distinguish between two cases according to whether either $c < 1/2$ or $c > 1/2$. Consider now $c < 1/2$.

In case *a*) we have that ${}_aq_i^* \geq 0$ if $t \geq \frac{c}{2c-1} = t_4$ and ${}_aq_j^* \geq 0$ if $t \geq \frac{2c}{1+c} = t_3$. If we compare the two threshold levels of t we find that, $t_4 < t_3$. Therefore, in order to have ${}_aq_{i,j} \geq 0$, it must be $t \in [t_3, 1]$ which represents our feasible set.

In case *b*) the same requirement boils down simply to $c \leq 1$, while in case *c*) it becomes $t \geq c$.

Taking into account the above constraints on the parameters, we compare the payoffs appearing in matrix 1.

First, we can see that ${}_c\pi^*_{i,j} \geq_b \pi^*_{i,j}$, if

$$\frac{(t-c)^2}{9t^2} \geq \frac{(1-c)^2}{9} - k$$

which holds if

$$k \geq k_1 = \frac{c(t-1)(c-2t+ct)}{9t^2}$$

Then compare ${}_c\pi^*_{i,j}$ with ${}_a\pi^*_i$. We see that

$${}_a\pi^*_i \geq_c \pi^*_{i,j}$$

if

$$k \leq \frac{4c(t-1)(c-1)}{9t} = k_3 \tag{13}$$

Third, compare ${}_b\pi^*_{i,j}$ with ${}_a\pi^*_j$. It appears that ${}_b\pi^*_{i,j} \geq {}_a\pi^*_j$ if

$$k \leq \frac{4c(c-t)(t-1)}{9t^2} = k_2 \tag{14}$$

Moreover, the comparison between ${}_a\pi^*_j$ and ${}_c\pi^*_{i,j}$ reveals that, for all t belonging to the feasible set, ${}_a\pi^*_j \leq {}_c\pi^*_{i,j}$. By the same token we find that ${}_a\pi^*_i \leq {}_b\pi^*_{i,j}$ regardless of the value of the investment in TCRD.

Then, we have to compare k_1, k_2, k_3. It appears that in the feasible set of t:

$$k_3 \geq k_2 \geq k_1$$

Therefore:

i) If $0 < k \leq k_1$ the sequence of payoffs becomes

$${}_a\pi^*_i \geq \quad {}_b\pi^*_{i,j} \geq \quad {}_c\pi^*_{i,j} \geq \quad {}_a\pi^*_j$$

and the game has a unique Nash equilibrium in dominant strategies where both firms invest in TCRD giving rise to a Pareto efficient outcome.

ii) If $k_1 \leq k \leq k_2$ the sequence of payoffs is

$${}_a\pi^*_i \geq \quad {}_c\pi^*_{i,j} \geq \quad {}_b\pi^*_{i,j} \geq \quad {}_a\pi^*_{,j}$$

and the game is a Prisoner's Dilemma with a unique equilibrium with both firms investing in TCRD.

iii) if $k_2 \leq k \leq k_3$ the sequence of payoffs becomes

$$_a\pi_i^* \geq \quad _c\pi_{i,j}^* \geq \quad _a\pi_j^* \geq \quad _b\pi_{i,j}^*$$

and we face a chicken game with two Nash equilibria off the main diagonal, with only one firm investing in TCRD.

iv) if $k \geq k_3$ the sequence of payoffs becomes

$$_c\pi_{i,j}^* \geq \quad _a\pi_i^* \geq \quad _a\pi_j^* \geq \quad _b\pi_{i,j}^*$$

and the game has a unique Nash equilibrium in dominant strategies where none invests in TCRD. This turns out to be Pareto efficient from the standpoint of firms.

It can be easily checked that the sequence of payoffs presented is invariant as we consider $c > 1/2$. In that case the feasible set becomes $t \in [t_3, t_4]$ while leaving untouched the above conclusions. Q.E.D.

4. *Welfare Analysis*

If we now go to the welfare assessment, we can state the following:

Proposition 2. *The solution of the TCRD game is also the outcome preferred by the social planner when the efficiency of TCRD is high and both firms invest, i.e., case b. For lower levels of TCRD efficiency, i.e., for larger k, the social planner would like only one firm to invest, while both firms invest as a result of a Prisoner's Dilemma. As TCRD becomes less efficient the social planner's preference coincides with the market outcome, since only one firm invests in a chicken game. If we consider even less efficient TCRD we find that firms stop investing while the planner still would like one firm to invest. The coincidence between the views of the planner and that of firms resurfaces at the lower bound of the efficiency of TCRD.(The entire proposition is summarized in Table 2).*

Proof: We start by calculating the social welfare in the three cases *a*, *b*, *c*.

Table 2. Welfare comparisons in the TCRD Game

	I	II	III	IV
Planner's preferred equilibria	Both firms inv. TCRD	Only one firm inv. TCRD	Only one firm inv. TCRD	No firm investing
Intervals of k	$k \in]0, k_4]$	$k \in [k_4, k_6]$	$k \in [k_6, k_5]$	$k \in [k_5, \infty)$

In case a) the consumer surplus is:

$$cs_a = \frac{(c - 2t + ct)^2}{18t^2}$$

while social welfare, defined as the sum of consumer surplus and profits, is:

$$sw_a = \frac{c^2(11 - 14t + 11t^2) - 8t(c - t + ct)}{18t^2} - k$$

In case b) both firms invest in TCRD and then we get:

$$cs_b = 2\left(\frac{1-c}{3}\right)^2$$

while social welfare is

$$sw_b = \frac{4(1-c)^2}{9} - 2k$$

In case c) we have:

$$cs_c = 2\left(\frac{c-t}{3t}\right)^2$$

while social welfare is

$$sw_c = \frac{4(c-t)^2}{9t^2}$$

Compare first sw_b with sw_a. It appears that $sw_a \geq sw_b$ if

$$k \geq k_4 = \frac{c(1-t)(8t + 3ct - 11c)}{18t^2}$$

Then we can see that $sw_a \geq sw_c$ if

$$k \leq k_5 = \frac{c(1-t)(8t+3c-11ct)}{18t^2}$$

Now compare sw_b with sw_c. It appears that $sw_b \geq sw_c$ if

$$k \leq k_6 = \frac{2c(1-t)(2t-c-ct)}{9t^2}$$

A straight comparison reveals that

$$k_4 \leq k_6 \leq k_5$$

Then for $k \leq k_4$ the social planner would like to have both firms investing in TCRD.

For $k_4 \leq k \leq k_5$ the social planner prefers only one firm investing, while for $k \geq k_5$ the preference goes to no firm investing.

We now compare social planner's preferences with those of firms. To this purpose we put together all k's obtaining the following ranking:

$$k_1 \leq k_4 \leq k_2 \leq k_6 \leq k_3 \leq k_5 \tag{15}$$

for $t \geq t_5 = \frac{9c}{4+5c}$; while for $t \leq t_5$ the ranking becomes:

$$k_4 \leq k_1 \leq k_2 \leq k_6 \leq k_3 \leq k_5$$

Confining the analysis to the first ranking (15), we see that, up to k_1, there is a coincidence between the social planner and firms since they both want to invest in TCRD and firms do so in a Pareto efficient manner. Between k_1 and k_4 the coincidence remains, even though firms do not maximise their aggregate payoff. Between k_4 and k_2 the coincidence disappears since both firms invest while the planner would like only one firm to invest. Between k_2 and k_3 the coincidence of views is recovered with only one firm investing. A disagreement between firms and the planner reappears for $k \in [\, k_3, k_5]$. Finally, for high levels of $k \geq k_5$ the planner and the firms shun investment. The above results replicate for $t \leq t_5$. Q.E.D.

We have seen that for intermediate levels of TCRD commitment the social planner would like one firm to invest. Therefore, there is a case

for a public subsidy to TCRD whenever the cost of TCRD is not too high. On the contrary, there is a case for taxing TCRD when both firms invest while the planner would like only one firm to do so.

5. *The Continuous Case*

We finally consider the case of a continuous choice of the level of TCRD, instead of the binary one, seen above.

The framework is one of a two stage game that is solved backward to get a subgame perfect equilibrium. The market setting is the same as above. The only difference concerns the opportunity for the firms to tune the amount of TCRD expenditure and get an optimal reduction of the transport cost.

Then the market demand is:

$$p = 1 - t_i q_i - t_j q_j \tag{16}$$

We assume, for the sake of simplicity, that TCRD gives rise to a linear reduction of transport costs according to the following technological specification:

$$t_{i,j} = \bar{t} + k_{i,j} \tag{17}$$

where $\bar{t}$ is the minimum fraction of the quantity that reaches the market and we assume that it is equal to zero.

Profits are:

$$\pi_i = p t_i q_i - c q_i - k_i \tag{18}$$

$$\pi_j = p t_j q_j - c q_j - k_j \tag{19}$$

First we go through the solution of the second stage of the game (market stage) according to Cournot strategic interactions, taking TCRD investment as given. We therefore get first order conditions (FOC) by deriving profits with respect to quantities and equalizing them to zero. We then obtain:

$$q_i^* = \frac{c t_i - 2 c t_j + t_i t_j}{3 t_i^2 t_j} \tag{20}$$

$$q_j^* = \frac{ct_j - 2ct_i + t_i t_j}{3t_j^2 t_i} \tag{21}$$

The above quantities are non negative in all symmetric cases, provided $t_{i,j} \geq c$. Second order conditions are satisfied in the feasible region of parameters. After substituting optimal quantities in the profit functions we get the FOC's with respect to TCRD expenditure from which first stage optimal $k_{i,j}$ result.

These solutions are not amenable to analytical scrutiny even for the simple technology adopted. Therefore we are obliged to resort to numerical analysis. We just provide a simple example for a particular scenario of marginal costs. Assuming $c = 0.001$, we have an equilibrium which is subgame perfect. The coordinates of the equilibrium are:

$k_i = k_j = 0.0205$;
$\pi_i = \pi_j = 0.0800$;
$q_i = q_j = 15.4221$;
$p = 0.3658$.

From the numerical analysis, it appears that an equilibrium obtains only if the c is low vis à vis the market size and TCRD costs.

Few conclusions can be drawn from the continuous case, whose importance lies mostly in a sort of consistency proof of the binary case. As we have suggested above, the game allows for a solution only if the level of marginal cost is quite small. Moreover, TCRD is undertaken only if the transport cost looms quite large in relative terms.

Welfare evaluations parallel those of the binary case.

6. *Concluding Remarks*

We have analysed, in a simple Cournot duopoly setting, the choice of firms to undertake a particular kind of R&D, that has not been considered so far in the literature and that is devoted to improve the transport and communication (TC) technology that firms adopt to reach final buyers in the market.

Firms competing in quantities and producing homogeneous goods have an incentive to undertake TCRD if the advantage they get is fairly high, that is, if the efficiency boost, associated with the resulting TC technology, is large enough. This outcome is the result of a perfect Nash

equilibrium in dominant strategies whereby firms maximise their aggregate payoffs. Firms are willing to invest also for lower levels of efficiency of TCRD, even though they fail to reach aggregate maximum profits. Going further down the scale of TCRD efficiency, a chicken game appears where only one firm invests. Finally, near to the lower bound of TCRD efficiency, neither firm undertakes it.

The continuous case analysis of the technology choice in a two stage game provides consistency and adds further insights since a solution exists only when marginal costs are quite low vis à vis TC costs and market size. Only in that case subgame perfect equilibria solutions exist for non negative levels of TCRD expenditure.

Second best social welfare is maximised in the two extreme cases, i.e.: when firms invest in TCRD and when neither firm invests.

Coincidence between the social planner and the firms partially disappears in the intermediate cases. When both firms invest, failing to maximize aggregate profits, there is an interval of the efficiency scale where the planner would prefer only one firm to invest. The introduction of a tax on TCRD may increase second best welfare.

The planner and the firms share the same stance in the chicken game. However, going down in the efficiency ladder, there is an interval where both firms shun TCRD, while the social planner would like at least one of them to invest. In such a case, it appears that a subsidy to TCRD could be introduced to obtain a second best result.

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ABSTRACT

We analyse R&D in transport and communication technology (TCRD), in a Cournot duopoly. Transport and communication costs are of the iceberg type, i.e., using up some portion of the product along its path to the buyer. Firms invest in TCRD to increase the amount of the product that reaches consumers. A variety of equilibria arise. If TCRD's productivity is high, the game has a unique Nash equilibrium in dominant strategies with both firms investing. As the efficiency of TCRD fades, we come across first a prisoner's dilemma and then a chicken game. At the lower bound of efficiency, neither firm invests. Social welfare reveals coincident strategies by the planner and the firms at high and low levels of efficiency, while at intermediate levels such a coincidence partially disappears. In a continuous choice space equilibria exist only if production costs are low vis à vis market size and transport costs.

JEL classification: *D43,L13, O31*
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A NOTE ON QUADRATIC GENERALISATIONS OF LEWBEL DEMAND SYSTEMS

by

DANIELE MORO*

1. *Introduction*

In empirical demand analysis, a crucial issue is demand specification. Normally, we assume that, at market level, prices are predetermined, and quantities adjust: therefore, we specify a direct demand system. However, this assumption may be unrealistic, at least in some cases; thus, it may be more appropriate to have quantities exogenous, and prices that adjust to clear the market. In these situations, the empirical approach to model the consumer response to market changes is to specify an inverse demand system, where prices are endogenous and quantities are predetermined, as opposed to direct demand systems (Anderson, 1980; Weymark, 1980). Barten and Bettendorf (1989) discussed the rationale of resorting to inverse demand systems as a device for modelling price formation in certain markets, where the causality can be seen as going from quantities to prices.

A related issue is the choice of the functional form; although it is common practice to resort to functional forms that are flexible, results (elasticities) may largely depend upon the chosen functional specification. It is therefore important to discriminate among functional forms.

The Almost Ideal (AIDS) model of Deaton and Muellbauer (1980b) and the Translog (TL) model of Christensen et al. (1975) are two (direct) demand systems largely used in empirical analysis; they have similar properties. In

* Institute of Agro-alimentary Economics, Catholic University, Piacenza (Italy). E-mail: dmoro@pc.unicatt.it

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fact, they both can be derived from a PIGLOG (Price-Independent-Generalized Logarithmic; Muellbauer, 1976) representation of preferences, thus sharing exact aggregation properties. Lewbel (1989) nested the two models in a larger one (GAITL: Generalised Almost Ideal Translog). In the case of inverse demand, a parallel situation is given by the inverse AIDS (IAIDS) of Moschini and Vissa (1992) and Eales and Unnevehr (1994), and by the (direct) inverse Translog (ITL) of Christensen et al. (1975): both models are nested in the Lewbel inverse demand system (Eales, 1994).

Recently, it has been questioned that a parsimonious representation of preferences may provide a good fit to actual data. In direct demand systems, for some goods further terms in income are required to give a better picture of reality. In the case of inverse demand systems, the analogous situation is to augment commonly used demand systems to account for further non-linearities. It is an important remark, especially if the estimated model is used for simulation and/or forecasting: the quadratic specification allows for more flexibility, and the more we move from in-sample values, the more the gain in flexibility may reduce the bias.

Banks et al. (1996 and 1997) proposed a Quadratic Almost Ideal Demand System (QUAIDS): it has been derived as a generalisation of the PIGLOG preferences, starting from a (general) representation of the indirect utility function. They claim that they could have equally worked with the Translog model. Moro and Sckokai (2002) derived a quadratic inverse (almost ideal) demand system (IQUAIDS); with a different specification of the distance function, a Translog quadratic inverse demand system (IQUTL) could be derived (see also Beach and Holt, 2001).

In this note, we derive, for either direct or inverse demand systems, a larger model that, with a parsimonious representation, nests both quadratic models, following the suggestion in Lewbel (1989). We term them as the generalised quadratic almost ideal-translog (Q-GAITL) demand system and as the inverse generalised quadratic almost ideal-translog (Q-IGAITL).

2. *Generalised Quadratic Lewbel Demand Systems*

A convenient way to derive a direct demand system is to start either from the indirect utility function or from the cost function; on the other hand, an inverse demand system can be obtained either starting from the direct utility function or from the distance function. The parallel between the cost function and the distance function is well known (Blackorby et al., 1978; Deaton and Muellbauer, 1980a); with the exception of the direction of monotonicity, the

cost function and the distance function, although defined over different arguments, share the same properties.[1] Thus standard functional forms employed for the cost function can be extended to the distance function.

Therefore, take a cost-distance function $F(u, \mathbf{z})$ of the form:

$$(1) \qquad \ln F(u,z) = \frac{1}{c(z)}\left[\ln a(z) \pm \left(\frac{ub(z)}{1-u\lambda(z)}\right)\right]$$

where u indicates utility, z may represent either prices (i.e. a cost function) or quantities (i.e. a distance function), and $a(z)$, $b(z)$, $c(z)$ and $\lambda(z)$ are functions appropriately chosen in order to satisfy the homogeneity property of the cost-distance function; finally the sign $\pm$ account for the different direction of monotonicity.

A direct demand system (i.e. $z = p$) can be retrieved by applying the Shephard's lemma to the cost function in (1). This cost function is a further generalisation of the PIGLOG specification proposed by Banks et al. (1996 and 1997): their cost function lead to a rank three demand system[2], as defined in Lewbel (1991), thus allowing for exact aggregation across consumers.

To derive an inverse demand system, (i.e. $z = p$) we can exploit the Shephard-Hannoch lemma on the distance function in (1). The distance (or transformation) function $D(u, q)$ is implicitly defined from the direct utility function $U(q)$ as $U\left(\frac{q}{D(u,q)}\right) = u$, where u is the reference utility level: thus, it is the amount by which a bundle q must be divided (scaled) to bring it on the indifference curve u (see Deaton and Muellbauer, 1980a).

By applying the derivative property to the cost-distance function in (1), we obtain a demand system in budget shares $w_i \equiv (p_i q_i / m)$, where m indicates income, of the general form:

$$(2) \qquad w_i = \frac{1}{c(\mathbf{z})}\left[\frac{\partial \ln a(\mathbf{z})}{\partial \ln z_i} + \frac{\ln a(\mathbf{z})}{c(\mathbf{z})}\frac{\partial c(\mathbf{z})}{\partial \ln z_i} + \frac{u}{1-\lambda(\mathbf{z})u}\frac{\partial b(\mathbf{z})}{\partial \ln z_i} + \right.$$

[1] The cost-distance function is monotonic, continuous in (z, u), and non decreasing, homogeneous of degree one and concave in z; while the cost function is increasing in u, the distance function is decreasing in u.

[2] The rank of a demand system equals the rank of the matrix of Engel curves coefficients: Gorman (1981) showed that the maximum possible rank for any exactly aggregable demand system is three.

$$\pm \frac{u^2 b(\mathbf{z})}{(1-\lambda(\mathbf{z})\cdot u)^2} \frac{\partial \lambda(\mathbf{z})}{\partial \ln z_i} \pm \frac{1}{c(\mathbf{z})} \frac{ub(\mathbf{z})}{(1-\lambda(\mathbf{z})u)} \frac{\partial c(\mathbf{z})}{\partial \ln z_i} \Bigg]$$

To get a parametric specification for either the direct or the inverse demand system, we set $\ln a(z)$ as a translog aggregator function:

$$\ln a(z) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln z_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln z_i \ln z_j \tag{3}$$

$b(z)$ as a Cobb-Douglas aggregator function:

$$b(z) = \prod_{i=1}^{n} z_i^{\beta_i} \tag{4}$$

$c(z)$ as a linear aggregator function:

$$c(z) = \sum_{i=1}^{n} \alpha_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln z_j \tag{5}$$

and $\lambda(z)$ as a linear aggregator function:

$$\lambda(z) = \sum_{i=1}^{n} \lambda_i \ln z_i \tag{6}$$

This demand system is subject to a set of parametric restrictions, implied by the theory, that pertain to the properties of the cost-distance function; such restrictions are:

$$(7) \quad \sum_i \alpha_i = 1 \qquad \sum_i \beta_i = 0 \qquad \sum_i \sum_j \gamma_{ij} = 0 \qquad \sum_i \lambda_i = 0 \qquad \gamma_{ij} = \gamma_{ji}$$

Further, flexibility is ensured by the fact that the proposed generalisation nests common flexible functional forms; however (see Ryan and Wales, 1999), it is not only flexible in the Diewert sense, since the quadratic specification allows for further flexibility in the income/scale term (see also Moro and Sckokai, 2002).

2.1. *Direct demand systems.* - By considering the cost function, therefore setting $z = p$, and substituting for u, we obtain the parametric specification of the Q-GAITL:

$$(8)\ w_i = \frac{1}{c(\boldsymbol{p})}\left[\alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln p_j - \sum_{j=1}^{n}\gamma_{ij}\ln m + \beta_i\left(c(\boldsymbol{p})\ln m - \ln a(\boldsymbol{p})\right) + \right.$$
$$\left. + \frac{\lambda_i}{b(\boldsymbol{p})}\left(c(\boldsymbol{p})\ln m - \ln a(\boldsymbol{p})\right)^2\right]$$

Note that the Q-GAITL system has only $(n-1)$ additional parameters with respect to the GAITL; this latter model can be easily derived by setting $\lambda_i = 0$ $\forall i$ in the Q-GAITL:

$$(9)\quad w_i = \frac{1}{c(\boldsymbol{p})}\left[\alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln p_j - \sum_{j=1}^{n}\gamma_{ij}\ln m + \beta_i\left(c(\boldsymbol{p})\ln m - \ln a(\boldsymbol{p})\right)\right]$$

The QUAIDS and the quadratic Translog can be obtained by imposing restrictions on the Q-GAITL. In order to retrieve the QUAIDS we set $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$, to get:

$$(10)\quad w_i = \alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln p_j + \beta_i \ln\left(\frac{m}{a(\mathbf{p})}\right) + \frac{\lambda_i}{b(\mathbf{p})}\left[\ln\left(\frac{m}{a(\mathbf{p})}\right)\right]^2$$

while the quadratic Translog (QUTL) requires to set $\beta_i = 0$ $\forall i$:

$$(11)\ w_i = \frac{1}{c(\boldsymbol{p})}\left[\alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln p_j - \sum_{j=1}^{n}\gamma_{ij}\ln m + \lambda_i\left(c(\boldsymbol{p})\ln m - \ln a(\boldsymbol{p})\right)^2\right]$$

Finally, the common AIDS and Translog are nested within the general specification; the AIDS can be retrieved from the Q-GAITL by setting $\lambda_i = 0$ $\forall i$ and $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$; the Translog by setting $\lambda_i = 0$ $\forall i$ and $\beta_i = 0$ $\forall i$.

The relationships among different specifications are showed in Figure 1;

different specifications can be tested using straightforward nesting procedures.

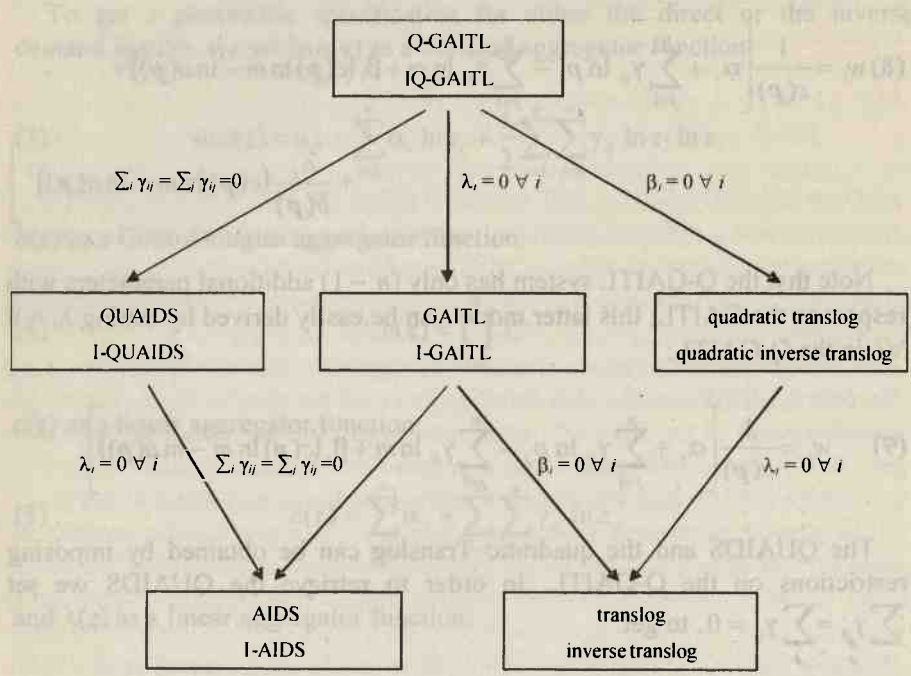

Figure 1. Relationships among different demand systems and testing procedure

2.2. *Inverse demand systems.* - By considering the distance function, therefore setting $z = q$ and substituting for u, given the fact that at $D = 1$ the distance function is an implicit representation of the direct utility function, that is $U(\boldsymbol{q}) := \dfrac{\ln a(\boldsymbol{q})}{\lambda(\boldsymbol{q}) \ln a(\boldsymbol{q}) + b(\boldsymbol{q})}$, we obtain uncompensated inverse demand functions:

$$(12) \qquad w_i = \frac{1}{c(\boldsymbol{q})}\left[\alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln q_j - \beta_i \ln a(\boldsymbol{q}) - \lambda_i \frac{1}{b(\boldsymbol{q})}\left[\ln a(\boldsymbol{q})\right]^2\right]$$

We term this model as the IQ-GAITL, which is a quadratic generalisation of the inverse Lewbel demand system (I-GAITL) derived by Eales (1994). This will allow us to derive a demand system with the same quantity flexibility of the I-GAITL, but a more flexible specification of the scale term[3].

Again, the IQ-GAITL system has only $(n - 1)$ additional parameters with respect to the I-GAITL; this latter model can be easily derived by setting $\lambda_i = 0 \ \forall i$ in the IQ-GAITL:

$$w_i = \frac{1}{c(\boldsymbol{q})}\left[\alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln q_j - \beta_i \ln a(\boldsymbol{q})\right] \tag{13}$$

The IQ-GAITL also generalises the IQUAIDS system derived by Moro and Sckokai (1999)[4] and a quadratic generalisation of the basic (inverse) translog. The IQUAIDS can be derived by imposing the restrictions $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$ on the IQ-GAITL:

$$w_i = \alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln q_j - \beta_i \ln a(\boldsymbol{q}) - \lambda_i \frac{1}{b(\boldsymbol{q})}\left[\ln a(\boldsymbol{q})\right]^2 \tag{14}$$

while the quadratic inverse translog (IQUTL) can be obtained from the IQ-GAITL by setting $\beta_i = 0 \ \forall i$:

$$w_i = \frac{1}{c(\mathbf{q})}\left[\alpha_i + \sum_{j=1}^{n}\gamma_{ij}\ln q_j - \lambda_i\left[\ln a(\mathbf{q})\right]^2\right] \tag{15}$$

Finally, the IAIDS and the direct (inverse) Translog are nested within the

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[3] Engel curves and Scale curves have a different interpretation; thus, the same functional form does not provide the same implication on the structure of preferences. For a discussion on the link between inverse and direct demands, in terms of scale and income elasticities, see also Park and Thurman (1999).

[4] Although this distance function has the same parametric structure of the PIGLOG cost function, they are not dual; thus Moschini and Vissa (1992) correctly stressed the fact that the term "Almost Ideal" used by Barten and Battendorf (1989) and Eales and Unnevehr (1994) is not correct, since the IQUAIDS and the IAIDS do not share the same aggregation property as the (direct) AIDS. However, we maintain the use of the attribute "Almost Ideal".

general specification; the IAIDS can be retrieved from the Q-GAITL by setting $\lambda_i = 0\ \forall i$ and $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$; the Translog by setting $\lambda_i = 0\ \forall i$ and $\beta_i = 0\ \forall i$ (see Figure 1).

3. *The Negativity Property within Quadratic Lewbel Demand Systems*

While symmetry, adding-up and homogeneity can be imposed globally by means of parametric restrictions, the negativity property involves inequality constraints and pertains to the negative semi-definiteness of the matrices of Slutsky (direct demands) $[s_{ij}]$ and Antonelli (inverse demands) $[a_{ij}]$ substitution terms. Negativity can be checked after estimation at any point in the data sample. Alternatively, we may impose such constraints in the estimation; however, since these terms in the Q-GAITL and IQ-GAITL involve shares, prices/quantities and income, there do not exist parameter values ensuring that negativity will be satisfied globally. Thus negativity can be imposed only locally, at a given point. In Table 1 we report formulas for elasticities and substitution terms in the Q-GAITL and the IQ-GAITL.

Taking without loss of generality as a point of reference the point where variables are scaled (prices/quantities and income are scaled, i.e. $z = \mathbf{1}$ and $m = 1$, and given $\alpha_0 = 0$), the local Slutsky/Antonelli terms have the same parametric representation:

$$s_{ij} = \gamma_{ij} - \alpha_i \sum_k \gamma_{jk} - \alpha_j \sum_k \gamma_{ik} + \alpha_i \alpha_j - \delta_{ij} \alpha_i = a_{ij} \tag{16}$$

where δ_{ij} is the Kronecker delta, i.e. $\delta_{ij} = 1$ if $i = j$, $\delta_{ij} = 0$ otherwise.

At the point of reference, the Slutsky/Antonelli terms exactly duplicate those of the GAITL specification; furthermore, they are exactly the same as the Slutsky/Antonelli terms of the (linear) translog specifications. Of course, given the restrictions $\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$, we get the Slutsky terms of the AIDS/IAIDS models. In other words, the imposition of concavity in the Q-GAITL/IQ-GAITL does not involve more complexity than the imposition of concavity in the translog specifications.

Table 1. Main properties of Quadratic Generalised Lewbel Demand Sistems

Parametric restrictions for integrability of Q-GAITL and IQ-GAITL

$$\sum_i \alpha_i = 1 \qquad \sum_i \beta_i = 0 \qquad \sum_i \sum_j \gamma_{ij} = 0 \qquad \sum_i \lambda_i = 0 \qquad \gamma_{ij} = \gamma_{ji}$$

Q-GAITL: generalisation of preferences of the PIGLOG-type. It allows for perfect aggregation across consumers (rank three).
Linear specifications (AIDS and translog) have Working-Leser Engel curves; quadratic specifications have more flexible specifications of Engel curves.

Income elasticity

$$\varepsilon_i = \frac{1}{w_i}\frac{1}{c(\mathbf{p})}\left[-\sum_{k=1}^{n}\gamma_{ik} + \beta_i c(\mathbf{p}) + \frac{2\lambda_i}{b(\mathbf{p})}(c(\mathbf{p})\ln m - \ln a(\mathbf{p}))c(\mathbf{p})\right] + 1$$

Price elasticity

$$\varepsilon_{ij} = -\frac{1}{c(\mathbf{p})}\left[\sum_{k=1}^{n}\gamma_{kj}\right] + \frac{1}{w_i}\frac{1}{c(\mathbf{p})}\left[\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{b(\mathbf{p})}(c(\mathbf{p})\ln m - \ln a(\mathbf{p}))\right)\left(-\sum_{k=1}^{n}\gamma_{kj}\ln m + \alpha_j + \sum_{k=1}^{n}\gamma_{jk}\ln p_k\right)\right.$$

$$\left. - \frac{\lambda_i\beta_j}{b(\mathbf{p})}(c(\mathbf{p})\ln m - \ln a(\mathbf{p}))^2\right] - \delta_{ij}$$

Slutsky term

$$s_{ij}\frac{p_i p_j}{m} = \varepsilon_{ij} w_i + \varepsilon_i w_i w_j$$

IQ-GAITL: quadratic specifications have more flexible specifications of the Scale curves.

Scale elasticity - flexibility

$$f_i = \frac{1}{w_i}\frac{1}{c(\mathbf{q})}\left[\sum_{k=1}^{n}\gamma_{ik} - \beta_i c(\mathbf{q}) - \frac{2\lambda_i}{b(\mathbf{q})}(\ln a(\mathbf{q}))c(\mathbf{q})\right] - 1$$

Quantity elasticity – Price flexibility

$$f_{ij} = -\frac{1}{c(\mathbf{q})}\left[\sum_{k=1}^{n}\gamma_{ki}\right] + \frac{1}{w_i}\frac{1}{c(\mathbf{q})}\left[\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{b(\mathbf{q})}\ln a(\mathbf{q})\right)\left(\alpha_j + \sum_{k=1}^{n}\gamma_{jk}\ln q_k\right) + \frac{\lambda_i\beta_j}{b(\mathbf{q})}(\ln a(\mathbf{q}))^2\right] - \delta_{ij}$$

Antonelli term

$$a_{ij}\frac{q_i q_j}{m} = f_{ij} w_i + f_i w_i w_j$$

To impose concavity, Lau (1978) proposed a Cholesky decomposition; a necessary and sufficient condition for a matrix $\boldsymbol{R} = [r_{ij}]$ to be negative semi-

definite is to write it as $\boldsymbol{R} = -\Gamma'\Gamma$ (Diewert and Wales, 1987), where $\Gamma = [\tau_{ij}]$ is an upper triangular matrix. Ryan and Wales (1998 and 1999), working on different specifications of both linear and quadratic (direct) demand systems, show that this procedure (i.e. reparameterisation of demand equations) preserves the flexibility of the functional form, and this is also true in the case of our generalisations. Although they claim that this procedure cannot be extended to the translog specification, and therefore to the Q-GAITL, Moschini (1999) shows how the procedure can also be applied to the translog case. Ryan and Wales (1998 and 1999) also show that, although the procedure guarantees that negativity will be satisfied only at the reference point, choosing appropriately this point may allow the curvature conditions to be satisfied globally within the sample.

However, the estimation of a model with curvature imposed commonly gives problems of convergence, therefore making the estimation of the fully concave model difficult. In order to obtain concavity and reach convergence, we may need to impose restrictions on the substitution possibilities among goods. This is the idea in Diewert and Wales (1988), and further developed in Moschini (1998) and Ryan and Wales (1998 and 1999). The solution is that of restricting the rank of the substitution matrix, thus constraining substitution possibilities and destroying flexibility of the chosen functional form. This can be done by restricting the rank of the matrix $\Gamma'\Gamma$: if we want to restrict such matrix to a rank $p<$(*maximum rank*), we just need to set to zero all the τ_{ij} elements for $i > p$ (that is to set to zero all the rows of Γ from $(p + 1)$ to *maximum rank*). The resulting model is semiflexible in the sense of Diewert and Wales (1988): thus, the notion of semiflexibility pertains to the possibility of restricting the substitution matrix and reducing the parameter space, and it may be a solution when the estimation of the fully concave model gives problems of convergence. This procedure does not restrict substitution possibilities according to a priori subjective beliefs, while allowing for a more parsimonious model, and may be extremely useful with large demand systems, and even more when we resort to more flexible functional forms, as it is the case of the Q-GAITL or the IQ-GAITL.

4. *Concluding Remarks*

This note presents a simple generalisation of quadratic direct and inverse demand systems, following the work by Lewbel (1989), for both direct and inverse demand systems. Such generalised quadratic Lewbel systems provide a tool for model selection, since they nest two of the most popular demand

specifications (the almost ideal and the translog) and their quadratic generalisations. Standard econometric testing procedures can be employed to discriminate among different specifications. We also discuss the issue of imposing the negativity property, showing that it does not imply more difficulties than within linear (rank two) demand systems.

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ABSTRACT

In this paper, quadratic generalisations of Lewbel demand systems are derived for both direct and inverse demand systems. Lewbel demand systems are flexible specifications that nest two of the most popular demand systems: the Almost Ideal specification and the Translog specification. Thus, Lewbel demand systems may be helpful in model specification, while their quadratic generalisation allows for further flexibility in the income-scale term. The issue of imposing the negativity property is also discussed.

JEL classification: *D11,D12*
Keywords: *quadratic demand systems, demand specification*

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ADJUSTMENT COSTS AND UNBOUNDED CAPITAL GROWTH

by
MARIO MENEGATTI*

1. *Introduction*

The traditional neoclassical analysis of investment theory with adjustment costs, examined in Abel (1979 and 1982), Hayashi (1982) and Summers (1981),[1] studies the dynamics of capital stock and of its value, generated by firms investment decisions. One of the common conclusions of this literature is the result that, in the long run, the system analysed reaches a steady state where capital and investment are constant.

An extensive literature in the so-called endogenous growth approach suggests, however, that capital growth can be unbounded if the system studied exhibits constant returns to capital. This conclusion is not true in the traditional adjustment costs framework. In this context, indeed,[2] even assuming a constant marginal productivity of capital, capital cannot grow without limits since this would imply paying unlimitedly increasing marginal adjustment costs. The existence of adjustment costs thus seems to exclude the possibility of unbounded capital growth.

A mechanism which lies at the basis of endogenous growth in many

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* Department of Economics, University of Parma, Parma (Italy). E-mail: mario.menegatti@unipr.it

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[1] For a complete analysis of adjustment costs theory see also Abel (1990) and Jorgenson (1996).

[2] See Abel (1982) and Romer (1995, chapter 8).

models (Romer, 1986 and 1987, and Barro and Sala-i-Martin, 1995, section 4.3) is given by the introduction of learning by doing and knowledge spillovers in the firms production function. These externalities make the productivity of each individual firm an increasing function of the aggregate capital since they imply that the learning by workers depends on the capital stock and that individual productivity is increasing in overall learning.

This work purports to introduce in investment theory a mechanism similar to the one just described by assuming the existence of learning by doing and knowledge spillovers acting on adjustment costs and making these costs decreasing in the aggregate capital level. It can be shown that, in this context, the steady state of the traditional model is substituted by a balanced growth path where capital and investment grow at a constant rate. Thus, in this new framework, adjustment costs can be compatible with unbounded capital growth.

The paper is organised as follows. Section 2 analyses the model and shows the dynamics of investment and capital. Section 3 examines the economic interpretation of the main results. Section 4 concludes.

2. *The Model*

Following the traditional formulation we examine the optimal investment path chosen by a representative firm in any sector. By assuming that production occurs under constant returns to scale and in a perfectly competitive framework, we get that operative profits (i.e. profits gross of the cost of capital acquisition) are given by

$$(1)^3 \qquad \pi_t = \pi(k_t) \quad \text{where} \quad \frac{d\pi_t}{dk_t} > 0, \quad \frac{d^2\pi_t}{dk_t^2} = 0$$

where k_t is individual capital. The traditional formulation assumes that firms investments (i_t) are subject to adjustment costs represented by a function[4]

$$(2) \quad C_t = C(i_t) \qquad \text{with} \quad \begin{cases} C(i_t) > 0 & \text{for } i_t \neq 0 \\ C(i_t) = 0 & \text{for } i_t = 0 \end{cases} \qquad \text{and} \quad \frac{d^2C}{di_t^2} > 0$$

[3] For a complete analysis of this framework see also Abel (1982).

[4] The function includes both purchasing and installation costs.

These assumptions are the standard ones made in adjustment costs theory. They imply that the marginal adjustment costs of investment (or disinvestment) are increasing in the investment (disinvestment) level.

By using a quadratic formulation of costs we would finally have

$$C_t = \frac{1}{2} i_t^2 \tag{3}$$

The model studied in this work introduces in the traditional framework an externality generated by learning by doing and knowledge spillovers which influences adjustment costs. The phenomenon generating externalities is analogous to that proposed in some endogenous growth models (Romer, 1986 and 1987, and Barro and Sala-i-Martin, 1995, section 4.3). These models assume, in particular, that an increase in the capital stock of a single firm raises workers productivity in the same firm because of learning by doing effects and that the increase in individual productivity also raises the productivity level of all other firms through knowledge spillovers. These hypotheses imply that productivity is increasing in overall learning and thus in the aggregate capital stock.

The model proposed in this work assumes that a similar mechanism acts on adjustment costs rather than on productivity. We assume, in particular, that an increase in the capital of a single firm raises, in the same firm, workers ability in testing, assembling and using new capital goods, thus reducing adjustment costs. We assume, furthermore, that an increase in workers ability in a single firm raises, through knowledge spillovers, workers ability in all other firms. These assumptions imply that in each firm workers ability is increasing in overall learning, and thus in the aggregate capital (K_t), while adjustment costs are decreasing in it.

The structure described above can be formalised by assuming that adjustment costs are represented by the function

$$C_t = C(i_t, K_t) \text{ with } \begin{cases} C(i_t, K_t) > 0 & \forall K_t \text{ for } i_t \neq 0 \\ C(i_t, K_t) = 0 & \forall K_t \text{ for } i_t = 0 \end{cases} \tag{4}^{5}$$

[5] Before examining the model it is interesting to notice that part of the adjustment costs literature (for instance Abel and Blanchard, 1984) introduces a negative effect of capital on adjustment costs which is not associated with learning by doing and is related to individual capital. The analytical formulation of adjustment costs and the framework adopted in that literature, however, are different from the ones used in this paper and do not generate an

$$\text{and} \quad \frac{\partial^2 C}{\partial i_t^{\,2}} > 0, \quad \frac{\partial C}{\partial K_t} < 0$$

We use a quadratic form for the investment effect as in (3) and we assume

$$C_t = C\left(i_t, K_t\right) - \frac{1}{2}\frac{i_t^{\,2}}{K_t} \tag{5}$$

The assumption used on the form of the externality is similar to that made in many AK growth models concerning the features of learning by doing effects.[6]

We examine the optimisation problem of the representative firm maximising the sum of its total profits through time. Under the previous assumptions, this problem is given by

$$\max_{i_t} \int_0^{\infty} \left[\pi_t - \frac{1}{2}\frac{i_t^2}{K_t} \right] e^{-rt} dt \tag{6}$$

subject to the constraint

$$\dot{k}_t = i_t - \delta k_t \tag{7}$$

The Hamiltonian associated to the problem is

$$H_t = \pi_t - \frac{1}{2}\frac{i_t^2}{K_t} + q_t\left(i_t - \delta k_t\right) \tag{8}$$

and the maximisation conditions are given by

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unbounded capital growth.

[6] In those models it is assumed, in particular, that the effect of the externality is exactly to make the production function linearly homogeneous in the aggregate capital. Since in this work the relationship between adjustment costs and aggregate capital is decreasing we simply assume that the degree of homogeneity is −1 instead of 1 (i.e. that the adjustment costs function is linearly homogeneous in the inverse of the capital stock). It is important to notice that the possible limitations of this assumption are the same regarding the analogous hypothesis made in the AK growth literature.

(9) $$\frac{i_t}{K_t} = q_t$$

(10) $$\dot{q}_t = (r+\delta)q_t - \frac{d\pi_t}{dk_t} = (r+\delta)q_t - A$$

(where A is the constant marginal productivity of capital)[7] and by the transversality condition

(11) $$\lim_{t\to\infty} e^{-rt} q_t k_t = 0$$

It is possible to show that the costate variable q_t can be interpreted as the value of a marginal unit of capital.[8]

By normalising the number of firms[9] and remembering that they are assumed to be identical and by considering together equations (7) and (9), we get

(12) $$\dot{K}_t = q_t K_t - \delta K_t$$

This equation, together with (10), forms a system of differential equations describing the dynamics of q_t and K_t. From these equations it is easy to compute the two conditions associated to the $\dot{q} = 0$ locus and to the $\dot{K} = 0$ locus which are respectively

(13) $$q_t = \frac{A}{(r+\delta)}$$

and

(14) $$q_t = \delta$$

Under the assumption that the marginal productivity of capital is

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[7] Output price is normalised to 1.

[8] The adjustment costs literature also showed that the costate variable can be seen as a marginal formulation of Tobin's q (Tobin, 1969).

[9] For instance assuming that firms are defined in a *continuum* between 0 and 1.

sufficiently large (i.e. $A > (r+\delta)\delta$),[10] the phase diagram associated with this system is the one represented in Figure 1.

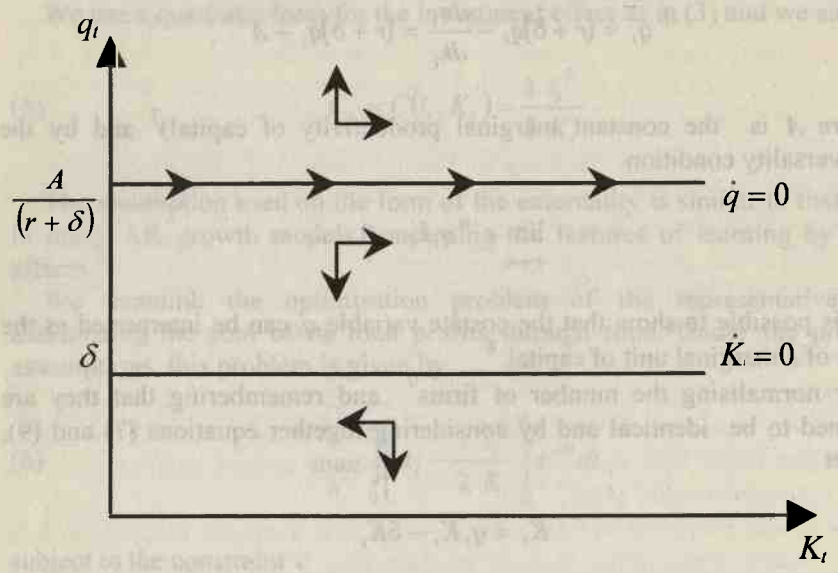

Figure 1. The phase diagram

As shown in the diagram, the path of q_t and K_t follows the $\dot{q}=0$ locus.[11] This result implies that, while the capital value is constant at the level $\frac{A}{(r+\delta)}$, the capital stock exhibits an unbounded growth.[12]

By (12) and (13), furthermore, we get that K_t grows at the constant rate

$$\frac{\dot{K}_t}{K_t} = \frac{A}{(r+\delta)} - \delta \tag{15}$$

[10] It is important to note that a similar (and usually stronger) assumption is also necessary in AK endogenous growth models (see Barro and Sala-i-Martin, 1995, chapter 4, and Rebelo, 1991).

[11] Since all other paths violate the transversality condition (11).

[12] Note that in the traditional model the $\dot{K}=0$ locus has a positive slope. This fact implies that the system exhibits a saddle path stable steady state (see Abel, 1982, figure 4).

Equation (9) and the path of the system finally imply that

$$\dot{i}_t = q_t \dot{K}_t \tag{16}$$

and that investment also grows at the rate given in equation (15).

3. *The Economic Interpretation of Capital Dynamics*

The traditional analysis showed that, even if the marginal product of capital is constant, the presence of adjustment costs makes the long run equilibrium of the system a steady state where the capital stock is constant. The previous section analysis, on the contrary, showed that introducing in the model learning by doing and knowledge spillovers[13] in adjustment costs generates an unbounded capital growth.

The reason for this different conclusion can be understood by examining more deeply the meaning of the condition associated to the locus $\dot{q} = 0$. This condition is the same one in the traditional framework and in the model proposed in this work and can be written in the form

$$A = (r + \delta) q_t \tag{17}$$

It represents an arbitrage equation saying that in equilibrium the marginal product of capital A must be equal to the marginal opportunity cost of capital $(r + \delta) q_t$.

In order to understand the role of adjustment costs we assume condition (17) to hold (i.e. we move along the $\dot{q} = 0$ locus) and we study the features of capital growth both in the traditional formulation and in the model

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[13] It is worthwhile to notice that, in the framework proposed, the presence of knowledge spillovers (making the effect of learning by doing "economy-wide" instead of letting it work at the individual firm level) is a key assumption for the result obtained. Indeed, if learning by doing acted at the individual firm level, then, by modifying equation (5) accordingly, it could be proved that in this case the system would exhibit an equilibrium path only under an implausible restrictive assumption about the parameters values. This result would occur because, for most sets of parameters values, learning by doing working at the individual firm level would completely nullify the disincentive to invest related to adjustment costs, thus making total profit always increasing in the investment level and pushing the optimal investment value to infinity. Furthermore, even introducing the restriction which ensures the existence of an equilibrium dynamics, the interpretation of the results obtained would appear awkward because of the possibility of multiple balanced growth paths.

proposed in this work.[14]

Starting from the traditional model, if we substitute the capital growth equation (7) in (17) by using the first order condition, we get [15]

$$A = (r+\delta)(\delta K_t + \dot{K}_t) \tag{18}$$

where $(r+\delta)(\delta K_t + \dot{K}_t)$ is the marginal opportunity cost of capital.

This cost is composed of two terms: the marginal opportunity cost of capital replacement $(r+\delta)\delta K_t$ and the marginal opportunity cost of additional capital $(r+\delta)\dot{K}_t$. The marginal opportunity cost of capital replacement is increasing in the capital stock since an increase in capital determines an increase in capital depreciation and, because of the form of adjustment costs, an increase in the marginal cost of investment for replacement purposes. Since the marginal productivity of capital is constant by assumption, we then have that capital accumulation is convenient if the capital stock is small[16] while it is disadvantageous if the capital stock is large.[17] This conclusion implies that capital accumulation cannot be unlimited and that the long run equilibrium is a steady state.

A completely different result is obtained in the new framework proposed in this work. In the new context, indeed, by substituting the capital growth equation (7) in (17) through equation (9), we get

$$A = (r+\delta)\left(\delta + \frac{\dot{K}_t}{K_t}\right) \tag{19}$$

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[14] Note that, while in this work the $\dot{q} = 0$ locus is the long run path of the system, in the traditional framework it is the saddle path of the steady state.

[15] In the traditional model the optimisation problem of the representative firm is $\max_{i_t} \int_0^{\infty} \left[\pi_t - \frac{1}{2} i_t^2\right] e^{-rt} dt$ subject to (7) and the maximisation conditions are (10), (11) and the first order condition $i_t = q_t$. By this equation and by (7) we have that $q_t = \delta K_t + \dot{K}_t$. Substituting this result in (17) we get (18).

[16] And in particular if $(r+\delta)\delta K < A$.

[17] When $(r+\delta)\delta K > A$.

where the marginal opportunity cost of capital is equal to $(r+\delta)\left(\delta+\frac{\dot{K}_t}{K_t}\right)$ and the marginal opportunity cost of capital replacement is equal to $(r+\delta)\delta$ and is constant.

This outcome occurs because the effect of the increase in the capital level on the cost of investment for replacement purposes is now exactly compensated by the learning by doing effect. Owing to this result, since the marginal productivity of capital is constant and, by assumption, sufficiently large, we have that there is always a positive incentive to increase the capital stock so that its growth becomes unbounded.

4. *Conclusions*

This work studied the effect on investment theory of introducing an externality in adjustment costs generated by the presence of learning by doing and knowledge spillovers. The analysis showed that the long run equilibrium, which is a steady state in the traditional formulation, becomes, in the new framework, a balanced growth path where capital and investment grow at the same constant rate. This result is due to the fact that, while in the traditional model the marginal opportunity cost of capital replacement is increasing in the capital stock, in the new context it is constant.

This conclusion indicates, finally, that the structure examined in this work generates an unbounded capital growth, similar to that obtained in endogenous growth models, also in a framework where adjustment costs are taken into account.

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ABSTRACT

This work examines the effects on investment theory of introducing learning by doing externalities in adjustment costs. It is shown that under this hypothesis the model exhibits an equilibrium path where capital and investment grow at a constant rate. This conclusion suggests that adjustment costs can be compatible with unbounded capital growth It is shown, finally, that this result is due to the fact that, in this new context, the marginal opportunity cost of capital replacement is constant while in the traditional model it is increasing in the capital stock.

JEL Classification: *E22*
Keywords: *adjustment costs, capital accumulation, learning by doing*

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TECHNOLOGICAL DIFFUSION AND MANUFACTURING PRODUCTIVITY CONVERGENCE: A DISAGGREGATE STUDY FOR THE OECD

by
DIRK FRANTZEN*

1. *Introduction*

A large empirical literature by now exists on the issue of per capita income or labour productivity convergence between countries. Most of this work bases itself on the transitional dynamics of the standard neo-classical model of economic growth with exogenous technical progress. As is well known, this dynamics is characterised by conditional convergence, due to the property of decreasing returns to capital inputs in the production function. Equations are estimated that relate the rate of growth of per capita income or labour productivity to the log of their initial level and to the rates of accumulation of the considered types of capital, as well as to other variables that condition the steady state. When estimated on cross-sections of countries over an entire period of time, the results confirm the predictions of the neo-classical model, provided that this includes human capital as a factor input (for a survey, see Sala-i-Martin, 1996).

More recent studies that perform estimation on panel data of similar equations allowing for country-specific fixed effects have challenged this view, however. These fixed effects are found to be highly statistically significant and their inclusion vastly reduces the measured impact of the

* Department of Economics, Free University of Brussels (VUB), Brussels (Belgium). E-mail: Dirk.Frantzen@vub.ac.be

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other conditioning variables. Moreover, and most important, the estimated convergence speed is now found to be much higher than implied by the cross-section results. In fact, it is found far higher than explainable by the operation of the mechanism of decreasing returns to capital (see especially Islam, 1995; Canova and Marcet, 1995; Caselli et al., 1996; de la Fuente, 2000).

This would clearly suggest that other convergence mechanisms are at work, besides the neo-classical one. We think here in the first place of the process of technological diffusion between countries. Economic historians have since long emphasised its importance in helping to explain the catching-up by laggards with respect to countries at the technological frontier, because imitation is easier than innovation. They have, thereby, stressed the conditional nature of this process, which is highly dependent upon factors that stimulate physical and human capital accumulation and, more generally, allow for an appropriate institutional setting that fosters the operation of market forces (Gerschenkron, 1952; Abramovitz, 1979, 1986; Rosenberg, 1982). These ideas have more recently been formalised and taken-up in open economy versions of new innovation-driven theoretical growth models (Grossman and Helpman, 1991, ch. 11, 12; Segerstorm, 1991; Barro and Sala-i-Martin, 1995, ch. 8; Aghion and Howitt, 1998, ch. 12).

The empirical work on convergence through technological diffusion is still limited, however. Most reliable are probably a set of regression studies on panel data, allowing for country-specific fixed effects, by de la Fuente (1996) and de la Fuente and Doménech (2001). They estimate equations that relate the rate of growth of total factor productivity (TFP) to the initial level of technology gap between the technological frontier and the non-frontier country under consideration. Their results provide evidence of significant conditional convergence at a relatively high speed. A drawback of these studies is, however, their aggregate nature. This prevents to identify the sectors responsible for convergence. And it cannot let us know whether technological convergence occurs especially in internationally tradable goods sectors, such as manufacturing, as implied by most open economy innovation-driven growth models.

Earlier cross-section estimates of comparable TFP growth equations by Bernard and Jones (1996a) on large sub-aggregates, such as manufacturing as a whole, agriculture, mining, services, utilities and construction, find, surprisingly, no evidence of convergence in the case of manufacturing during the 1970s and 1980s. In another study, Bernard and Jones (1996b) pursue by also analysing the time series properties of the technology gap variable, by testing for its non-stationary nature by applying a unit root test for panel data on a sample of yearly observations during the same period. The results

suggest the presence of a unit root and provide, according to the authors, further evidence of TFP divergence in manufacturing. They argue that this may be due to the fact that international trade tends to lead to specialisation between countries.

One has to be careful with the interpretation of these results, however. If it is indeed the case that they are caused by differences in product composition of the manufacturing aggregates, this calls for further disaggregation. The regression estimates on cross-sections may, moreover, vastly underestimate the convergence speed. More appropriate estimates on disaggregate panel data may, possibly, find evidence of a transitional dynamics characterised by significant convergence. If so, the evidence provided by time series tests on the same period of time may be misleading, since it may mainly reflect transitory movements to equilibrium growth paths, rather than the evolution of these paths themselves.

In this study, we present a more systematic investigation of this issue on disaggregate panel data with respect to 22 manufacturing sectors in 14 OECD countries during the period 1970-1995. We first estimate alternate technology gap productivity growth equations, both on a global panel of sector-country five yearly annual data and on 22 sub-samples, sector by sector. We pursue by considering the evolution of the standard deviation of the log of TFP as well as of variables that condition long-run growth, such as the level of human capital per worker and the proportion of R&D expenditure over income. Finally, we perform a panel data unit root test on a corresponding sample of yearly observations of our technology gap variable. When considered in conjunction, the results indicate that, during the period under consideration, TFP growth performances are dominated by a transitional dynamics characterised by strong conditional, and even absolute convergence, through technological diffusion.

The paper is organised as follows. Section 2 presents the empirical growth equations. Section 3 exposes the econometric methods. The estimates are reported in Section 4 and Section 5 concludes. The data sources and measurement issues are mentioned in a separate Appendix.

2. *Technology Gap Productivity Growth Equations*

The purpose of this section is to present empirical growth equations that allow for productivity convergence through technological diffusion. As a starting point, we follow common practice and assume that the production of output occurs with a technology of the Cobb-Douglas type, with constant

returns to the traditional factor inputs and augmented by a variable reflecting the level of total factor productivity (TFP). This can be represented as:

$$(1) \qquad Y_{ijt} = A_{ijt} K_{ijt}^{\alpha} L_{ijt}^{1-\alpha}$$

where Y_{ijt} is the product or income in country i in sector j at time t, measured by value added at factor costs; K_{ijt} is the corresponding physical capital stock, L_{ijt} the labour input and A_{ijt} the level of Hicks-neutral TFP.

In the traditional neo-classical model the rate of growth of A_{ijt} is determined by the rate of exogenous technical progress. To the extent that it is equally accessible, this is assumed to be the same for all countries in each sector under consideration. Once one does, however, allow for technological diffusion between countries, one has to allow for the fact that countries with a less advanced technology can, moreover, benefit from the possibility of imitation from countries that are technologically more advanced. Other things equal, one should expect that the further a country's technology lays behind the technological frontier, the greater are its possibilities of technological advance through imitation, and, therefore, the stronger will be its TFP growth. This also implies that, other things equal, the growth differential between countries will gradually decrease, as the initial laggards see their possibilities of imitation gradually reduce as they catch up.

Re-writing the production function (1) in labour intensive form, expressing the variables in growth terms and including a technology gap variable, one can obtain a reduced form empirical growth equation as follows:

$$(2) \qquad \Delta y_{ijt} = \varepsilon_t + \gamma_{ij} + \alpha \Delta k_{ijt} + \lambda[(y_{fjt} - \alpha k_{fjt}) - (y_{ijt} - \alpha k_{ijt})]$$

where a variable in small letters stands for the (natural) log of the corresponding variable represented by a majuscule per unit of labour; a variable preceded by Δ stands for 1/5 of its first difference between t and t+5, or, in other words for the 5-yearly average annual growth rate of the corresponding majuscule variable per unit of labour; the subscript f stands for the frontier country; ε_t is a time dummy and γ_{ij} is a sector-country specific intercept. The inclusion of time dummies is justified for econometric reasons, given below. The term between square brackets represents the technology gap at time t and its coefficient, λ, measures the rate of technological convergence. In the case of the technological frontier $i = f$ the term between square brackets vanishes. In this case the intercept terms $\gamma_{ij} = \gamma_{fj}$ represent the sector-specific rates of exogenous technical progress. In the case of the non-

frontier countries, the sector-country specific intercepts, γ_{ij}, do, in addition, condition the steady states to which the sector-countries supposedly converge.[1]

Equation (2) covers at the same time the special case where there is only a single common intercept, $\gamma_{ij} = \gamma_0$, as a nested equation. This constraint can be tested for. It will hold in the case of a common rate of exogenous technical progress across sectors and a similar steady state path to which all countries converge. If we find the technology gap coefficient, λ, to be positive and statistically significant in a specification that allows only for a single common intercept, γ_0, this would imply that the TFP convergence is absolute in nature. Countries that are technologically backward grow in this case more rapidly than the more advanced ones. If a similar result can only be obtained on the basis of a specification that includes sector-country specific intercepts, γ_{ij}, this would suggest that the convergence is at most conditional in nature, in the sense that countries converge to their own steady states. But even if the hypothesis of a common intercept is rejected, it may still be interesting to find out whether $\lambda > 0$ holds in an equation that only includes a single intercept, since convergence may at the same time be absolute and conditional in nature during the period under consideration. This may be the case if the levels of TFP of the technological laggards tend to lay further below their steady states than is the case of the technologically more advanced countries. Or it may reflect the fact that the sector-country specific intercepts are, in fact, capturing variables that move slowly through time and tend themselves to converge.[2]

Following Mankiw et al. (1992), most traditional work on per capita income or labour productivity convergence assumes a human capital extended production function. This assumption also underlies de la Fuente and Doménech 's (2001) reduced form technology gap growth equation. This is justified provided that human capital mainly affects output as an input in the production process itself. In order to find out whether this is indeed the case, we extended our production function (1) by including a human capital term, H_{ijt}, with an exponent β, while adapting the exponent of the labour term, L_{ijt}, from $1-\alpha$ to $1-\alpha-\beta$. The corresponding reduced form growth equation then becomes:

[1] Note that since these intercepts are constants and, in this representation, the only conditioning variables, the equilibrium paths of TFP are here assumed to be parallel between countries.

[2] In the latter case one may, to quote Cohen (1992), refer to 'quasi steady states', which are themselves converging.

$$(3) \qquad \Delta y_{ijt} = \varepsilon_t + \gamma_{ij} + \alpha \Delta k_{ijt} + \beta \Delta h_{ijt} + \\ + \lambda[(y_{fjt} - \alpha k_{fjt} - \beta h_{fjt}) - (y_{ijt} - \alpha k_{ijt} - \beta h_{ijt})]$$

where h_{ijt} stands for the log of human capital per worker in county i in sector j at time t. As seen below, the regression estimate of β was, however, found non-significant, so that we do not pursue along this road.

Another potentially interesting extension of the bench mark equation (2) is to include, explicitly, the TFP growth of the technological frontier in the case of the non-frontier countries, such as:

$$(4)\ \Delta y_{ijt} = \varepsilon_t + \gamma_{ij} + \alpha \Delta k_{ijt} + \gamma(\Delta y_{fjt} - \alpha \Delta k_{fjt}) + \lambda[(y_{fjt} - \alpha k_{fjt}) - (y_{ijt} - \alpha k_{ijt})]$$

with $\gamma = 0$ for $i = f$.

This allows to estimate, explicitly, the long-run influence of frontier technological growth on non-frontier productivity. It should be noted that this specification, as we view it, does, however, not necessarily imply a strict leader-follower relationship, since the technical diffusion may follow indirect routes, over several countries.

In the new innovation-driven theoretical growth literature, technological progress is assumed to be at least partly endogenous in nature, as a product of commercially motivated innovation efforts by firms. Following Romer (1990), human capital is, hereby, most often considered as a major input in the research process. Moreover, as stressed by Redding (1996), a dynamic complementarity between the level of innovation efforts by firms and the level of qualifications of the labour force at large is likely to exist. Firms will be more prepared to innovate when they expect to find workers that are able to operate with new, more sophisticated technologies. Whereas (potential) workers will be prepared to invest more in schooling and additional training when they expect to find jobs with a higher level of qualification, made possible by the new technologies. To the extent that successful imitation requires some further research efforts by imitators, a similar reasoning holds to a lesser extent for countries below the technological frontier. And it goes without saying that this will even more be the case when, at the considered level of aggregation, there is still some product differentiation and countries may at the same time be innovators as well as imitators in the same sector.

Inspired by the new innovation-driven growth literature, we will therefore consider a reduced form growth equation that includes the level of human capital per worker as a variable, besides the other variables of equation (4), so that:

$$(5) \qquad \Delta y_{ijt} = \varepsilon_t + \gamma_{ij} + \alpha\Delta k_{ijt} + \psi(H/L)_{ijt} + \gamma(\Delta y_{fjt} - \alpha\Delta k_{fjt}) + \\ + \lambda[(y_{fjt} - \alpha k_{fjt}) - (y_{ijt} - \alpha k_{ijt})]$$

where $(H/L)_{ijt}$ is the level of human capital per worker in country i in sector j at time t. Notice the different manner of entering human capital than in equation (3). There, human capital per worker is entered symmetrically with physical capital per worker, under the assumption that human capital is an input in the production process of material output. Here, it is the level of human capital per worker as such, $(H/L)_{ijt}$, that matters, and not its rate of growth, Δh_{ijt}. Its log, h_{ijt}, does, moreover, not appear in the technology gap term.[3]

We then pursue by assuming that the research process does not only use human capital as an input, but also physical capital. We extend, therefore, our reduced form growth equation by including, in addition, the proportion of R&D expenditure over income as a variable, thus obtaining:

$$(6) \quad \Delta y_{ijt} = \varepsilon_t + \gamma_{ij} + \alpha\Delta k_{ijt} + \psi(H/L)_{ijt} + \theta(R/Y)_{ijt} + \gamma(\Delta y_{fjt} - \alpha\Delta k_{fjt}) \\ + \lambda[(y_{fjt} - \alpha k_{fjt}) - (y_{ijt} - \alpha k_{ijt})]$$

where $(R/Y)_{ijt}$ stands for the proportion of R&D expenditure over income in country i in sector j at time t. The human capital variable will in this case capture the quality of the labour component of R&D expenditure as well as of the labour force at large.

Furthermore, in line with the empirical literature on intersectoral R&D spillovers, we may also want to take account of the influence of outsectoral R&D efforts on sector productivity. We, therefore, further extend our reduced form growth equation by including a R&D spillover variable, so that:

$$(7) \qquad \Delta y_{ijt} = \varepsilon_t + \gamma_{ij} + \alpha\Delta k_{ijt} + \psi(H/L)_{ijt} + \theta(R/Y)_{ijt} + \mu(\tilde{R}/Y)_{ijt} + \\ + \gamma(\Delta y_{fjt} - \alpha\Delta k_{fjt}) + \lambda[(y_{fjt} - \alpha k_{fjt}) - (y_{ijt} - \alpha k_{ijt})]$$

[3] Note further that by considering the level of human capital per worker, rather than the level of human capital as such, we avoid including a counterfactual growth scale effect, as present in early innovation-driven endogenous growth models. Our specification is in this respect consistent with a semi-endogenous type of growth model, in the sense of Jones (1995), as well as with an endogenous growth model without growth scale effects, such as proposed by Aghion and Howitt (1998).

with $(\tilde{R}/Y)_{ijt} = \sum_{l \neq j} \delta_{lj} (R/Y)_{ljt}$, where $(\tilde{R}/Y)_{ijt}$ stands for domestic intersectoral R&D spillovers, as measured by a weighted average of the other sectors' proportions of R&D over income, where the weights, δ_{lj}, reflect the technical proximity in the knowledge space. More precisely, δ_{lj} is approximated by the share of patented inventions made in sector l spilling over to sector j. These weights were derived from a patent-based technology flow matrix, mentioned in the Appendix below.

It should be noted that we keep it here deliberately to a domestic R&D spillover variable, since we assume that international technological diffusion is captured by the frontier TFP growth and technology gap terms. By including a domestic R&D spillover variable, besides the international technological diffusion terms, we can, however, also capture to some extent, international intersectoral spillovers. This is so because domestic outsectoral R&D efforts in a frontier country will not only affect its own productivity in the sector under consideration, but also that of the non-frontier countries. One should keep in mind, however, that the purpose of the empirical equations here is not to trace the precise routes through which the international technological diffusion occurs, but rather to analyse its convergence effects. The present type of analysis has, therefore, to be viewed as complementary to that undertaken in disaggregate studies on international and intersectoral R&D spillovers, such as by Verspagen (1997b) and Frantzen (2002a, b).

Finally, it is worth emphasising that evidence of a significant influence on TFP growth by conditioning variables such as the level of human capital or of R&D efforts may, but does not necessarily imply long-run productivity divergence between countries. Whether it actually does so will depend on whether the evolution of these variables does itself actually diverge, or otherwise. It will, therefore, be interesting to find out whether these forces acted in the direction of divergence, or convergence, during the period of investigation and to assess their importance relative to the catching-up process through technological diffusion.

3. *Methods of Estimation*

Our first purpose will be to estimate equations (2) to (7) on a global panel of pooled 5-yearly annual time series with respect to all sector-countries under consideration, and then, having done so, to re-estimate the key equations on sub-samples, sector by sector. Such estimation poses several problems.

Consider first the form of our equations, say for example that of the bench mark equation (2) presented above. As noticed, the equation is non-linear in nature and it implies that the same parameter, α, appears twice in the expression within brackets, as the coefficient of k_{fjt} and k_{ijt}, and once outside this expression, as the coefficient of Δk_{ijt}. This equation can, in principle, be vastly simplified for estimation purposes by making use of outside information and imposing an exogenous given value of α. This allows to obtain explicit TFP constructs and the equation can, in this case, be re-written as a linear relation between the growth of the TFP construct under consideration and the corresponding initial technology gap, measured in terms of these TFP constructs. A straightforward manner for doing so is to follow a widely used practice in empirical work on TFP and to assume competitive output and factor markets. Our Cobb Douglas exponents of capital and labour, α and $1-\alpha$, can in this case be approximated by revenue-based figures on the average income shares of capital and labour during the period of investigation.

A major drawback of this procedure is, however, that the available revenue-based information may be unreliable and that the underlying assumption of perfect competition may be unwarranted. Moreover, when human capital is entered as an additional factor input, such as in equation (3), obtaining information on its separate income share may be problematic. We, therefore, choose to estimate our equations directly as such, by means of non-linear least squares, thereby obtaining a parameter estimate of α simultaneously with the other parameter estimates.

This does, however, pose the problem of the identification of the frontier. Since the frontier country in a sector is defined as the country with the highest log of TFP and the log of TFP is itself given by $y_{ijt} - \alpha k_{ijt}$, we would have to know α beforehand in order to identify the frontier. In order to solve this problem, we follow an iterative procedure. In a first step, we choose a country as the frontier, say the US, and perform the estimation of equation (2), thus obtaining an estimate of α. We then use this to derive the log of TFP as $y_{ijt} - \alpha k_{ijt}$ and choose for each sector the frontier country as the one with the highest log of TFP. We then re-estimate equation (2) with this frontier, obtaining a new estimate of α, and so on, until the frontier remains the same. Alternatively, one can start by choosing a plausible value of α, say 0.3, choose the frontier consequently, perform estimation of (2), thereby obtaining a new value of α, re-choose the frontier, etc. We applied both procedures and found each time the same frontier after 2 iterations.

Since our data relate to 5 different points in time, the frontier countries may, however, differ through time. Other authors who have estimated

technology gap productivity growth equations have either chosen the frontier on the basis of the beginning of the period of observation of TFP, or on the basis of all successive considered observations during the period of investigation, or on the basis of their average value. The beginning of the period of observation has the advantage that here the TFP differences will be largest in the case of convergence and, therefore, most easy to identify. The consideration of all successive observations has for it that it allows for leap frogging, in the sense that countries may overtake one another and act successively as the frontier during the period of investigation. A drawback of this procedure is, however, that, even more than in the case of the former method, its results may be affected by short-term noise in the TFP figures. For this reason, preference was given to the third method, which considers the average value of the TFP levels during the period of investigation. In order to check the robustness of the parameter estimates in this respect, we re-performed the estimation of our respective equations while using the other two methods in turn. Although not presented here due to space constraints, the results implied each time slightly different frontiers, but this did not affect the parameter estimates. All conclusions reached in this study remained, therefore, unchanged.

A possible objection to our estimation procedure is that by estimating the coefficient of capital, α, as a single parameter, we cannot allow it to vary between sectors when the estimation is performed on the global panel. This is true and it is one of the reasons why we complement our global panel estimates by estimates sector by sector, which do allow for sector-specific estimates of α. In order to assess the extent to which the use of a common average value of α may affect the results, we do also re-perform the sector-wise estimation while imposing the estimated common average value of α as a constraint.[4]

Another problem of estimation of equations of the type considered in this study concerns the possibility of a simultaneity bias, caused by common exogenous shocks to the left- and right-hand-side variables, such as brought about by oil price shocks. This may especially affect the parameter estimates of our variables expressed in growth terms, since they relate to the same periods as the left-hand-side variable. Even in the case of our variables in

[4] It is worth noting in this respect that the consideration of TFP constructs making use of revenue-based information with respect to the income share of capital may, in addition, also have allowed for a variation of α between countries. Allowing for such variation is, however, not advisable for our purpose, since this will, by itself, affect the estimates of Hicks-neutral TFP and, therefore, prevent unambiguous comparisons of the actual levels of productivity between countries.

level terms, such as the level of human capital per worker or the proportion of R&D over income, which relate to the initial year of the subsequent growth periods, there is still a possibility of simultaneity bias. Income shocks may affect expectations of economic agents and, thereby, their human capital and R&D investment decisions. Furthermore, as emphasised by de la Fuente (1998), the estimated coefficient of the technology gap variable may itself capture, in part, short-term adjustments to such shocks, rather than the actual transitional growth dynamics we are interested in.

In order to control for such effects, we have included time dummies, ε_t, in the equations. It should be noted, however, that when equations (5), (6) and (7), which include the growth of frontier TFP, are estimated sector by sector the vector of observations of this variable contains a set of figures that are each time the same for all countries. This poses a problem of singularity of the data. In order to avoid this, one has to perform estimation without time dummies in this case. This should, however, not greatly affect the coefficient of the technology gap variable presented in Table 2 below, since the growth of frontier TFP will in this case play the role of the time dummies and control for the simultaneity bias in the parameter estimates of the other variables.

As noted above, the finding of a positive and statistically significant estimate of the coefficient of the technology gap, λ, in the benchmark equation (2) estimated with a common intercept would imply absolute convergence. It would suggest that countries with an initial lower level of TFP grow, on average, faster than those with a higher level. In order to find out whether this actually implies a reduction in the inequality of the levels of TFP between countries during the period of investigation, we consider the evolution of the standard deviation, σ, of the log of TFP, sector by sector. It should be noted that absolute λ-convergence is a necessary condition for sustained σ-convergence. But it is not a sufficient condition, however, since a positive value of λ is compatible with a temporary increase in productivity dispersion, due to random shocks. In order to assess whether the human capital and R&D variables included in equations (5) to (7) formed a cause of productivity divergence during the period of investigation, we do, moreover, also consider the evolution of their own standard deviation.

Finally, we also consider a time series approach to convergence analysis. As is well known, this approach defines convergence as transitory deviations from identical or parallel long-run stochastic trends. Tests in this framework look for a permanent drifting apart of the productivity trends by searching for the presence of a unit root in their difference. In our case, we concentrate hereby on our technology gap variable, which measures the difference between the logs of frontier and non-frontier TFP. As emphasised by Bernard

and Durlauf (1995, 1996), this time series approach is, in principle, only a valid manner of testing for convergence if the economies under consideration are close to their steady state. If this is not the case and their growth performances are dominated by transitory movements to equilibrium paths, such tests may be highly misleading. Our results with respect to λ- and σ-convergence should give an indication in this respect. But even if they suggest that the productivity growth performances are dominated by transitional dynamics, it will still be interesting to find out whether applying unit root tests on our data can confirm earlier findings in this respect by Bernard and Jones (1996b). If so, this would put their findings in a new light.

In order to do so, we will concentrate on a panel of pooled annual time observations over the period 1970-1995 of our technology gap variable, derived under the assumption that the coefficient of capital, α, is equal to its average value implied by the parameter estimates of the growth equations.

Since there is no reason why the data generation process of our TFP and, therefore, the technology gap variable should have similar autoregressive coefficients across individual sector-countries, we want to make use of a test based on a model that allows not only for individual-specific intercepts (as the Levin-Lin, 1992, test used by Bernard and Jones, 1996b), but also for individual-specific slopes. Our choice fell thereby on Im et al.'s (1997) group mean augmented Dickey-Fuller (ADF) test, which has been shown to be highly powerful in accepting the null when it is true. It is an average ADF test derived from the ADF test performed for each individual separately. When expressed in standardised form, its test statistic has been shown to possess an asymptotic standard normal distribution when both the number of time units and the number of individuals in the panel tend to infinity. We apply this test both on the global panel of sector-countries and on 22 sub-panels, sector by sector.

4. *Estimates*

Table 1 presents the results of estimation of the respective growth equations on our global sample.

Equation (i) is equation (2) presented above, under the assumption that there is only one common intercept, $\gamma_{ij} = \gamma_0$. The adjusted R^2 suggests that the statistical fit is rather low, but this is not surprising in view of the fact that data in growth terms are highly noisy at the considered level of disaggregation. The parameter estimate of the coefficient of capital, α, has a plausible value of about 0.33 and its t-value implies that it is highly

Table 1. Productivity growth equations: estimates on pooled sector-country 5-yearly annual time series (1970-95, 14 OECD countries, 22 sectors)

Coefficient	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
α	0.326 (11.20)*	0.328 (9.41)*	0.328 (9.41)*	0.329 (9.71)*	0.327 (9.71)*	0.339 (10.03)*	0.337 (9.96)*
β			0.134 (0.37)				
ψ					0.016 (2.86)*	0.015 (2.66)*	0.014 (2.06)*
θ						0.079 (3.23)*	0.078 (3.22)*
μ							0.059 (1.80)*
γ				0.312 (7.79)*	0.316 (7.91)*	0.312 (7.87)*	0.313 (7.88)*
λ	0.027 (12.04)*	0.061 (14.47)*	0.061 (14.45)*	0.072 (16.58)*	0.073 (16.83)*	0.072 (16.54)*	0.071 (16.33)*
Time dummies	yes	yes	yes	yes	yes	yes	yes
Fixed effects	no	yes	yes	yes	yes	yes	yes
LR test fixed eff.	-	542.16*	539.52*	557.20*	562.38*	572.48*	574.92*
Number obs.	1490	1490	1490	1490	1490	1490	1490
Adjusted R^2	0.145	0.257	0.257	0.293	0.297	0.303	0.304
Stand. err. regr.	0.040	0.037	0.037	0.036	0.036	0.036	0.036

Notes: The time dummies and the sector-country specific fixed effects are not presented. The method of estimation is non-linear least squares. The t-tests on the parameter estimates are one-tailed tests and their statistics are presented between parentheses underneath. The likelihood ratio (LR) test on the joint significance of the fixed effects has a Chi-square distribution with 297 degrees of freedom.
* Denotes statistical significance at the 5% level.

statistically significant. This is also the case of the coefficient of the technology gap, λ, which has itself an estimated value of 0.027. This would imply that during the period under consideration manufacturing TFP growth is, on average, characterised by absolute productivity convergence, with a speed in the order of 2.7% a year. This finding is highly interesting when considered in the light of the earlier results in this respect presented by Bernard and Jones (1996a). It shows that disaggregating the data allows to find clear evidence of significant convergence in manufacturing, which was not possible when one considers aggregate manufacturing data as such.

Equation (ii) is again equation (2), but now with sector-country specific intercepts, γ_{ij}, included. The likelihood ratio test easily accepts the joint significance of the individual specific fixed effects and this translates into a clear improvement in statistical fit. Whereas the estimated coefficient of

capital, α, is unaffected, the coefficient of the technology gap, λ, is now found clearly higher, as expected. Its value of 0.061 would imply a conditional convergence speed of about 6% per year. This is, interestingly enough, a similar order of magnitude as that found by de la Fuente and Doménech (2001) in their comparable fixed effect panel data estimates with respect to a sample of OECD economies as a whole.

Equation (iii) is equation (3) above, which assumes a production function that includes human capital as a factor input. The estimate of the coefficient of the rate of growth of human capital, β, has a plausible sign, but it is found statistically non-significant. This contradicts the results in this respect by de la Fuente and Doménech (2001) and it would imply that in the case of manufacturing human capital does not affect output and labour productivity by being a factor input in the production process. One has to be careful with this interpretation, however. As described in the Appendix, data constraints compelled the use of aggregate figures with respect to educational attainment, such as used by these authors. These may in, our case, be inappropriate for capturing the actual level of qualifications of the workers employed at the considered level of sectoral aggregation.

Equation (iv) is equation (4) above, which adds an expression depicting the rate of growth of frontier TFP to the bench mark equation in the case of the non-frontier countries. Its coefficient, γ, is found substantial and highly statistically significant. This confirms that non-frontier TFP growth is, indeed, positively affected by frontier TFP growth in the long run through technological diffusion. Interestingly enough, the estimated coefficient of the technology gap, λ, is hardly affected by this inclusion and, if anything, even raises somewhat. This confirms our expectation that, during the transitional dynamics, the benefits of technological diffusion are especially high in the countries with technologies further behind the frontier and with, therefore, greater possibilities of technological advance through imitation.

Equation (v) is equation (5) above, which adds the level of human capital per worker to the previous equation. Its coefficient, ψ, is found of the correct sign and statistically significant. This would conform to the predictions of the new innovation-driven growth theory. It suggests that human capital mainly affects productivity through the innovation and imitation process, rather than as an input in the production process of physical output, as in equation (iii). It should be noted, however, that the aggregate nature of the used human capital data is probably better suited in this case. It allows to capture externalities due to human capital intersectoral knowledge spillovers and the dynamic complementarity between the innovation process and the level of qualifications of the population at large.

Equation (vi) is equation (6), which includes, in addition, the proportion of R&D expenditure over income as a variable. Its coefficient, θ, is again found positive and statistically significant. Interestingly enough, its inclusion hardly affects the estimated coefficient of human capital per worker, ψ. This would suggest that there is more to the research effort than simply its human capital input and that our human capital variable mainly captures the above mentioned externalities. But again, this result may be exaggerated by the fact that whereas our measure of R&D is sector specific, this is not the case of our measure of human capital. The level of qualification of the researchers is probably partly captured by the R&D expenditure variable itself, to the extent that their wages are related to this level of qualification.

Finally, equation (vii) is equation (7), which includes, moreover, a domestic intersectoral R&D spillover variable. Its coefficient, μ, is found positive and statistically significant. It is worth noting, however, it is only just so at a 5% level, and this because a one-tailed test is used. In fact, the finding that its estimated value is slightly lower than that of the coefficient of own sector R&D, θ, conflicts with the evidence in this respect provided by the existing disaggregate international panel data studies on R&D spillovers, such as Frantzen (2002a, b). These studies do, however, consider equations with variables in level terms and exploit their cointegrating properties. Here, the considered equations are growth equations instead, and the averaging out of the research/income proportion of other sectors leads to an artificially smooth R&D spillover variable in relation to the dependent variable. Part of the effect of R&D spillovers on productivity growth is, therefore, probably captured by the included intercept terms.

Table 2 presents the estimates of the technology gap coefficient, λ, obtained from some of our most representative productivity growth equations estimated sector by sector.

The precise coverage of the sectors indicated in the first column is given in the Appendix. Equation (i) is our bench mark equation (2), under the assumption that there is only a common intercept. The non-presented coefficient of capital, α, is thereby allowed to vary between sectors. The results indicate that the coefficient of technology gap, λ, is each time positive and in 19 out of 22 cases also statistically significant. This clearly confirms the evidence of absolute convergence obtained on the basis of our global panel estimates.

Equation (ii) is the same equation, but now with the non-presented coefficient of capital constrained to be equal to its average value estimated on the global panel ($\alpha = 0.33$). As indicated by the $^\circ$ sign, this constraint is accepted in 17 out of 22 cases. And even when it is not, the estimates of the

technology gap coefficient, λ, do hardly differ from those in equation (i).

This is comforting, since it implies that the assumption of a common value of α across sectors in our global panel estimates is largely justified and does, in any case, not affect the convergence results.

Table 2. Technology gap coefficient λ: obtained from productivity growth equations estimated on sector-country 5 yearly annual time series sector by sector (1970-95, 14 OECD countries)

Sector	(i)	(ii)	(iii)	(iv)	(v)	(vi)
FO	0.019 (3.76)*	0.025 (3.11)*	0.062 (2.28)*	0.073 (2.93)*	0.043 (1.77)*	0.042 (1.78)*
TX	0.005 (0.37)	0.009 ° (0.68)	0.134 # (4.20)*	0.135 °# (4.49)*	0.169 # (5.19)*	0.166 °# (5.15)*
WO	0.058 (5.16)*	0.057 ° (4.80)*	0.102 (4.32)*	0.102 ° (4.32)*	0.114 (4.63)*	0.117 ° (4.68)*
PA	0.042 (3.49)*	0.045 ° (3.75)*	0.132 # (5.03)*	0.113 # (4.06)*	0.177 # (6.26)*	0.147 # (5.00)*
CH	0.036 (4.19)*	0.035 ° (3.89)*	0.084 # (4.64)*	0.085 °# (4.94)*	0.084 # (4.22)*	0.088 °# (4.51)*
DR	0.033 (4.52)*	0.031 ° (3.50)*	0.089 (3.44)*	0.093 ° (3.67)*	0.064 (2.43)*	0.071 ° (2.41)*
PET	0.006 (0.98)	0.006 ° (0.94)	0.141 # (6.21)*	0.162 # (6.37)*	0.150 # (6.09)*	0.165 # (6.16)*
RP	0.040 (3.07)*	0.040 ° (3.09)*	0.095 # (4.07)*	0.098 °# (4.34)*	0.079 # (3.34)*	0.083 °# (3.53)*
NM	0.024 (2.04)*	0.024 ° (2.26)*	0.106 # (5.00)*	0.106 °# (5.17)*	0.095 # (4.40)*	0.096 °# (4.57)*
ST	0.090 (6.81)*	0.074 (5.35)*	0.160 # (7.22)*	0.168 # (7.61)*	0.169 # (7.50)*	0.175 # (7.89)*
NF	0.053 (4.38)*	0.041 ° (3.57)*	0.198 # (8.11)*	0.204 °# (8.86)*	0.186 # (8.29)*	0.188°# (8.62)*
Time dum.	yes	yes	yes	yes	no	no
Fixed eff.	no	no	yes	yes	yes	yes
α=0.33	no	yes	no	yes	no	yes

(continues)

Notes: The coefficients of the other variables in the equations are not presented. The method of estimation is non-linear least squares. The t-test on λ is one-tailed and its statistic is presented between parentheses below.

* Denotes statistical significance of the t-statistic at the 5% level.

° Denotes acceptance at the 5% level by the likelihood ratio test of the constraint α = 0.33 on the coefficient of capital.

# Denotes acceptance at the 5% level by the likelihood ratio test of the joint significance of the fixed effects.

Table 2. *(continued)*

Sector	(i)	(ii)	(iii)	(iv)	(v)	(vi)
MET	0.047 (4.73)*	0.044 ° (4.31)*	0.053 # (2.77)*	0.054 °# (2.94)*	0.037 # (1.96)*	0.040 °# (2.12)*
MA	0.023 (1.38)	0.041 (2.89)*	0.063 # (2.59)*	0.072 # (3.07)*	0.053 # (2.02)*	0.057 # (2.41)*
CO	0.101 (4.59)*	0.101 ° (4.68)*	0.168 # (6.09)*	0.158 (5.82)*	0.162 (5.36)*	0.154 (5.13)*
EG	0.070 (6.29)*	0.068 ° (6.30)*	0.086 (4.92)*	0.086 ° (4.99)*	0.092 (4.83)*	0.092 ° (4.97)*
CE	0.044 (3.70)*	0.039 (3.10)*	0.040 # (2.13)*	0.061 (2.88)*	0.011 # (0.46)	0.047 # (1.89)*
SH	0.066 (3.75)*	0.059 ° (3.68)*	0.108 # (4.27)*	0.108 °# (4.60)*	0.092# (3.51)*	0.094 °# (3.81)*
AUT	0.068 (4.43)*	0.069 ° (4.55)*	0.118 (4.57)*	0.121 ° (4.98)*	0.098 (3.69)*	0.101 ° (3.79)*
AE	0.040 (4.99)*	0.044 ° (4.35)*	0.070 (3.21)*	0.087 ° (3.66)*	0.084 (2.95)*	0.104 ° (3.70)*
OTR	0.037 (5.78)*	0.043 (4.10)*	0.013 (0.64)	0.081 (2.96)*	0.011 (0.54)	0.088 (2.84)*
IN	0.055 (4.54)*	0.054 ° (4.60)*	0.100 # (4.95)*	0.097 °# (5.17)*	0.111 # (5.23)*	0.106 °# (5.46)*
OTM	0.015 (1.81)*	0.015 ° (1.81)*	0.118 # (4.85)*	0.114 °# (4.81)*	0.087 # (4.09)*	0.088 °# (4.14)*
Time dum.	yes	yes	yes	yes	no	no
Fixed eff.	no	no	yes	yes	yes	yes
α=0.33	no	yes	no	yes	no	yes

Equation (iii) is equation (2) with country-specific intercepts included. As indicated by the # sign, the hypothesis of country-specific fixed effects is accepted in 15 out of the 22 cases. As expected, the effect of including these fixed effects is nearly always to raise the estimate of the technology gap, λ, which now becomes statistically significant in 21 out of 22 cases. This, again, confirms the finding of strong conditional convergence obtained from our global panel estimates. Equation (iv) is the same equation with the coefficient of capital again constrained to its average global panel estimate. This constraint is now accepted in 14 out of 22 cases and, just as before, even when it is not, its imposition does hardly affect the estimates of λ.

The last two columns in the table, (v) and (vi), present the corresponding estimates of λ, obtained from equation (7), under similar assumptions with respect to α. To remember, this equation includes, in addition, the growth of frontier TFP, the level of human capital per worker, the R&D/income

proportion and the R&D spillover variable. The results imply a comparable picture as that provided by columns (iii) and (iv). They confirm, thereby, our conclusions with respect to the occurrence of conditional convergence through technological diffusion.

The evidence of not only conditional but also of absolute λ-convergence, obtained from the regression estimates on the global panel and in a great majorities of sectors, implies that, on average, countries with low initial levels of TFP grow more rapidly than those with higher initial levels. In principle, one should also expect this to imply that the average growth of TFP of non-frontier countries substantially exceeds that of the frontier. This does, however, not necessarily have to be the case, since the regression results may be dominated by convergence among the non-frontier countries or among sub-samples of these countries. Table 3 presents the average annual rates of growth of TFP of the frontier and of the non-frontier countries for the sample as a whole, as well as sector by sector.

Table 3. Average annual rates of growth of total factor productivity of the technological frontier and non-frontier countries (%, 1970-95)

Sector	Frontier (i)	Non-frontier (ii)	Sector	Frontier (i)	Non-frontier (ii)
All sectors	1.32	2.25	MET	2.87	2.04
FO	0.77	1.66	MA	0.47	2.49
TX	2.00	1.94	CO	2.94	3.25
WO	–0.83	1.26	EG	3.47	5.45
PA	–0.18	1.29	CE	2.67	5.23
CH	3.57	3.58	SH	–5.08	1.60
DR	3.62	3.72	AUT	–0.34	1.52
PET	0.19	1.52	AE	–1.81	–0.48
RP	2.55	2.55	OTR	1.63	2.80
NM	0.92	1.78	IN	1.40	2.37
ST	1.66	3.22	OTM	5.08	1.85
NF	1.33	2.80			

Notes: Total factor productivity was derived under the assumption that $\alpha = 0.33$.

The figures show that, for the sample as a whole, non-frontier TFP growth is nearly twice as large as frontier TFP growth. The sector-wise figures confirm, for their part, that the growth of non-frontier TFP exceeds that of the frontier in no less than 18 out of 22 cases. When we compare this with the sector-wise estimates of the coefficient of technology gap, λ, in Table 2, we

see that it is indeed most often the case that sectors characterised by absolute λ-convergence (significant λ in column (i)) show a stronger average growth of non-frontier TFP than of frontier TFP. In fact, there are only two cases where the reverse is true, Metal Products (MET) and Other Manufacturing (OTM). Moreover, there are also two sectors, Petrochemicals (PET) and Machinery (MA), where non-frontier TFP growth exceeds frontier TFP growth even though there is only conditional convergence (non-significant λ in column (i) and significant λ in columns (iii) and (v)). Here the data show that although the majority of non-frontier countries grow more rapidly than the frontier, they do not so according to the respective initial technology gaps because they only converge to their own distinct steady states.

In order to find out whether the evidence of absolute λ-convergence does, indeed, imply a decrease in inequality between the levels of TFP during our period of investigation, we also consider the evidence with respect to σ-convergence. Columns (i) and (ii) of Table 4 present the standard deviation of the log of TFP, sector by sector, at the beginning and at the end of the period of investigation. Figures 1, 2 and 3 depict, for their part, its evolution over the entire period.

The results provide clear evidence of σ-convergence in 18 out of 22 cases. Comparing with the evidence with respect to absolute λ-convergence in Table 2 (significance of λ in column (i)), it is comforting to find that the results are broadly consistent in that, in essence, the same sectors where there is clear evidence of absolute λ-convergence also show σ-convergence. The pictures in Figures 1, 2 and 3 show, moreover, that the convergence was especially strong during the first part of the period (until 1985). This would indicate that the economies are still far away from their steady state during these years and that they are at most nearing it by the end of the period (in the 1990s).

Our regression estimates of equations (5), (6) and (7) presented in columns (v), (vi) and (vii) of Table 1 showed that the level of human capital per worker and the proportion of R&D expenditure over income were each time clearly significant. These may, possibly, cause long-run productivity divergence between countries. Whether they actually do so will depend upon whether they do themselves diverge. In order to assess whether they actually do so during the period of investigation, we consider also the evolution of their standard deviation. Columns (iii) and (iv) in Table 4 present the standard deviation of the level of human capital per worker at the beginning and at the end of the period. Since use was made of the same aggregate data in all sectors, the standard deviation is each time the same. The results indicate that there is a slight decrease in inequality of the levels of human

Table 4. Standard deviation sector by sector in 1970 and 1995 (14 OECD countries)

Sector	Log total factor productivity		Human capital per worker		R&D /income proportion	
	1970 (i)	1995 (ii)	1970 (iii)	1995 (iv)	1970 (v)	1995 (vi)
FO	0.288	0.191	1.856	1.719	0.005	0.007
TX	0.192	0.267	1.856	1.719	0.003	0.004
WO	0.327	0.167	1.856	1.719	0.001	0.002
PA	0.254	0.147	1.856	1.719	0.004	0.007
CH	0.409	0.265	1.856	1.719	0.022	0.036
DR	0.566	0.376	1.856	1.719	0.085	0.122
PET	0.714	0.719	1.856	1.719	0.041	0.045
RP	0.282	0.224	1.856	1.719	0.015	0.015
NM	0.216	0.193	1.856	1.719	0.008	0.012
ST	0.412	0.154	1.856	1.719	0.009	0.016
NF	0.428	0.284	1.856	1.719	0.018	0.020
MET	0.352	0.224	1.856	1.719	0.004	0.006
MA	0.319	0.300	1.856	1.719	0.013	0.021
CO	0.363	0.349	1.856	1.719	0.208	0.163
EG	0.730	0.290	1.856	1.719	0.046	0.037
CE	0.542	0.436	1.856	1.719	0.197	0.371
SH	0.527	0.375	1.856	1.719	0.012	0.013
AUT	0.363	0.191	1.856	1.719	0.036	0.060
AE	0.675	0.345	1.856	1.719	0.259	0.169
OTR	0.593	0.216	1.856	1.719	0.016	0.071
IN	0.535	0.322	1.856	1.719	0.062	0.114
OTM	0.605	0.536	1.856	1.719	0.030	0.034

Notes: Total factor productivity was derived under the assumption that $\alpha = 0.33$. In the case of human capital per worker the same aggregate data had to be used for all sectors.

capital per worker between countries, so that this variable did, if anything, strengthen the tendency of productivity convergence during the period of investigation. Columns (v) and (vi) do, for their part, show that the standard deviation of the R&D/income proportion does, on the contrary, increase in a great majority of sectors from 1970 to 1995. This variable worked, therefore, toward divergence. Our clear evidence of productivity convergence suggests, however, that the impact of the R&D divergence did not weigh up against the forces acting toward convergence during the period of investigation.

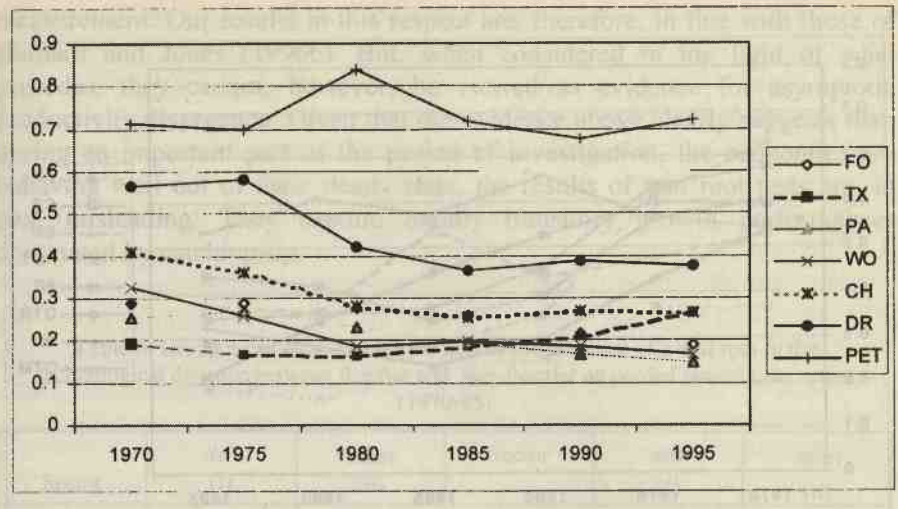

Figure 1. Standard deviation log (TFP)

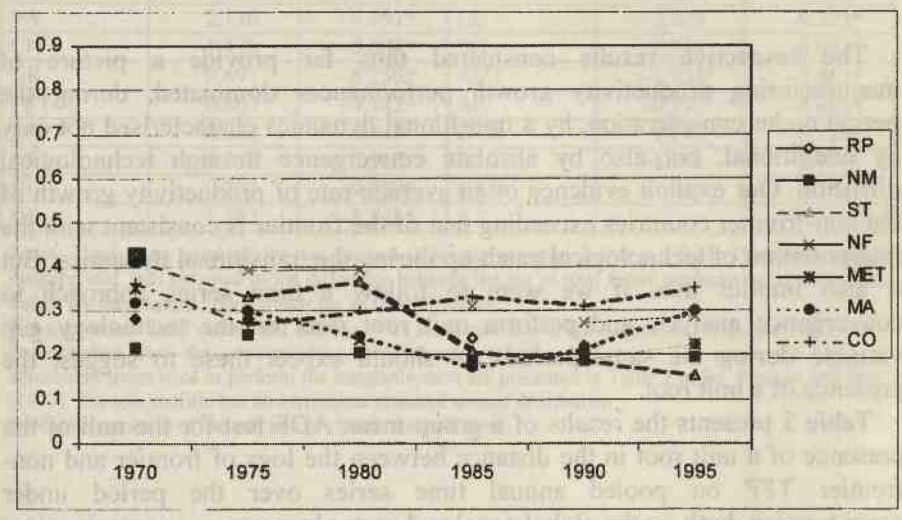

Figure 2. Standard deviation log (TFP)

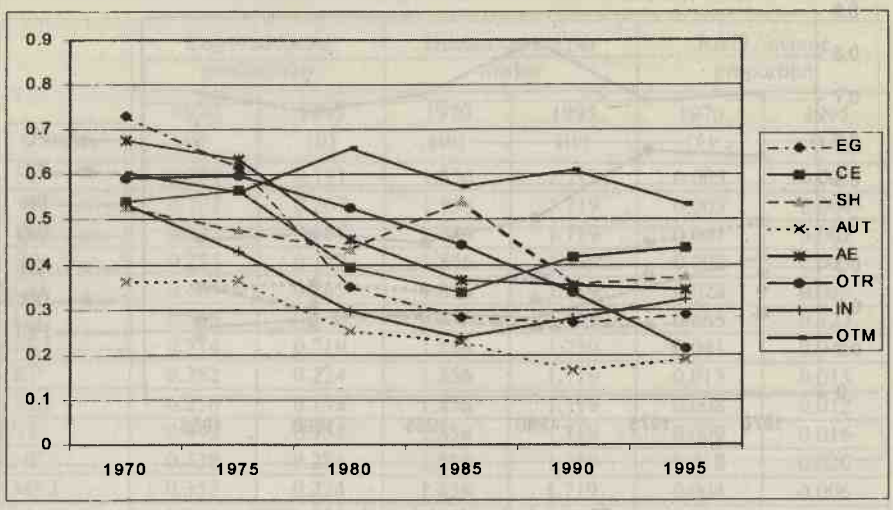

Figure 3. Standard deviation log (TFP)

The respective results considered thus far provide a picture of manufacturing productivity growth performances dominated, during the period under consideration, by a transitional dynamics characterised not only by conditional, but also by absolute convergence through technological diffusion. Our explicit evidence of an average rate of productivity growth of the non-frontier countries exceeding that of the frontier is consistent with the interpretation of technological catch-up during the transitional dynamics. But it also implies that, if we were to follow a time series approach to convergence analysis and perform unit root tests on the technology gap variable during the same period, we should expect these to suggest the presence of a unit root.

Table 5 presents the results of a group mean ADF test for the null of the presence of a unit root in the distance between the logs of frontier and non-frontier TFP on pooled annual time series over the period under consideration, both on the global panel and sector by sector.

The results clearly suggest the presence of a unit root, both for the panel as a whole and for all but two sectors separately. And even in these, Wood (WO) and Automobiles (AUT), a closer look at the unreported underlying individual country-wise ADF tests shows that the rejection of the null is only caused by one or two outliners, most likely explainable by errors of

measurement. Our results in this respect are, therefore, in line with those of Bernard and Jones (1996b). But, when considered in the light of what precedes, they cannot, however, be viewed as evidence for asymptotic productivity divergence. Given that our evidence above clearly suggests that, during an important part of the period of investigation, the economies are behaving well out of their steady state, the results of unit root tests are, in fact, misleading. They capture mainly transitory growth performances dominated by catching-up.

Table 5. Group mean ADF test for the null of the presence of a unit root in the technological distance between frontier and non-frontier on pooled annual time series (1970-95)

Sector	*dist* (i)	*Δdist* (ii)	Sector	*dist* (i)	*Δdist* (ii)
All sectors	0.897	−38.939*	MET	−0.084	−10.321*
FO	3.862	−6.889*	MA	3.728	−6.772*
TX	−1.047	−6.163*	CO	−1.149	−11.380*
WO	−2.971*	−10.505*	EG	−0.466	−5.856*
PA	2.130	−4.997*	CE	2.074	−9.525*
CH	−1.470	−8.001*	SH	0.944	−8.053*
DR	0.697	−8.250*	AUT	−1.928*	−7.863*
PET	0.867	−9.182*	AE	−0.742	−8.685*
RP	−0.022	−7.948*	OTR	1.276	−8.128*
NM	−0.353	−7.365*	IN	−1.182	−8.177*
ST	−0.283	−9.559*	OTM	−1.330	−7.164*
NF	1.407	−8.243*			

Notes: Total factor productivity was derived under the assumption that $\alpha = 0.33$. The technological distance. *dist.* was obtained as the difference between the log of total factor productivity of the fontier and of the non-frontier. *Δdist* stands for its first difference.
The used test is Im. Pesaran and Shin's (1997) standardised average Augmented Dickey-Fuller (ADF) test obtained from the corresponding sector-country specific ADF tests. The mean and variance adjustment terms used to perform the standardisation are presented in Table 2 of Im, Pesaran and Shin (1997). The test-statistic has an asymptotic standard normal distribution.
* Denotes rejection of the null at a 5% level of significance.

5. *Conclusions*

In this paper, we analyse the issue of manufacturing productivity convergence through technological diffusion on a panel of 22 sectors in 14 OECD countries during the period 1970-1995. We present regression estimates of alternate equations relating TFP growth to initial technology gap

and different variables that condition long-run equilibrium growth paths. The estimated coefficient λ of the technology gap variable was nearly always found positive and statistically significant, both in equations that do and that do not include conditioning variables. This implies the occurrence not only of conditional, but also of absolute productivity convergence through technological diffusion.

A sector-wise analysis of the evolution of the standard deviation of the log of TFP provides, moreover, evidence of σ-convergence in a large majority of sectors, and this essentially in these sectors where there was evidence of absolute λ-convergence. When viewed in the light of the open economy new innovation-driven growth theory, this suggests that during the period of investigation the economies under consideration were behaving well out of their steady state and their productivity growth performances were dominated by transitional dynamics.

Equally conforming to the predictions of this new growth theory, we find evidence, furthermore, that the level of human capital per worker and the R&D/income proportion have also a role to play in the explanation of productivity growth. Although these variables may cause productivity divergence between countries in the long run, the evolution of their standard deviation suggests that only R&D acted toward divergence during the period under investigation. In view of the dominance of the transitional dynamics driven by technological diffusion, this was, however, not sufficient to prevent absolute productivity convergence during these years.

Finally, the dominance of the transitional dynamics implies that a time series approach to convergence analysis is, in fact, inappropriate for the period under consideration. The evidence in favour of the presence of a unit root in the measured technology gap between frontier and non-frontier is misleading, since it captures mainly transitory movements, characterised by stronger TFP growth of the non-frontier than of the frontier due do catching-up.

APPENDIX

The 14 countries considered in this study were chosen for reasons of data availability with respect to the variables under consideration. They are Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the UK and the USA. They account for more than 90% of manufacturing value added and for more than 95% of manufacturing R&D expenditures in the OECD. Manufacturing is disaggregated into the following 22 sectors (abbreviation, ISIC codes): Food, Beverage and Tobacco (FO, 31), Textiles, Leather and Footwear (TX, 32), Wood and Wooden Products (WO, 33), Paper, Printing and Publishing (PA, 34), Chemicals exclusive Drugs (CH, 351+352-3522), Drugs

(DR, 3522), Petrochemicals (PET, 353+354), Rubber and Plastic Products (RP, 355+356), Non Metallic Minerals (NM, 36), Steel (ST, 371), Non Ferrous Metals (NF, 372), Simple Metal Products (MET, 381), Machinery (MA, 382-3825), Computers (CO, 3825), Electrical Goods (EG, 383-3832), Radio, TV and Telecommunication Equipment (CE, 3832), Ships and Boats (SH, 3841), Automobiles (AUT, 3843), Aerospace (AE, 3845), Other Transport Equipment (OTR, 384-3841-3843-3845), Instruments (IN, 385), Other Manufacturing (OTM, 39).

The main data with respect to income (value added at factor costs), $Y_{i,t}$, physical capital, $K_{i,t}$, and labour (employment), $L_{i,t}$, were obtained from the *OECD Stan Database*. In the case of physical capital, we only dispose of figures on nominal capital investment. We had, therefore, first to deflate these in order to obtain figures in real terms. We did so by using the business sector value added price deflator, obtained from the *OECD Business Sector Database*. We then constructed the corresponding capital stock figures by applying the perpetual inventory method, while using a depreciation rate of 5%. All income and capital stock figures are expressed in dollars at 1990 purchasing power parity (PPP).

The chosen rate of capital depreciation of 5% has unavoidably something arbitrary to it. It does however lay in between the rate of 3% generally assumed in the aggregate work on convergence (where the capital stock includes a large part of long-lived buildings and infrastructure) and the average value of the estimated rates with respect to manufacturing of about 7% presented by Jorgenson and Landau (1993, Table A) (where capital mainly contains equipment goods). Experimentation with alternate rates of 3 and 7% did hardly affect our regression results. More important probably is the fact that sudden increases in the rate of obsolescence, such as caused by the oil price shocks, cannot be captured in this manner. This may cause underestimation of the coefficient of capital. As far as labour is concerned, the lack of data on hours worked in the case of a majority of countries compelled the use of unadjusted employment data. This may have caused an underestimation of the actual long-run growth of productivity to the extent that the working time was reduced somewhat during the period of investigation.

Human capital per worker is measured by the educational attainment of the working age population in terms of years of schooling. Use was thereby made of the data computed by de la Fuente and Doménech (2000), that mainly consist of an improved version of earlier data in this respect constructed by Barro and Lee (1996). As mentioned in the text, its main drawback is that it is only available at the aggregate level rather than sector by sector. It is, therefore, probably better suited for estimating a new growth type of specifications, that emphasise the presence of knowledge spillovers and other externalities, rather than more traditional ones, that conceive human capital as an input in the production process of physical output.

The R&D/income proportion was measured by dividing nominal R&D expenditure by nominal value added at factor costs. The figures with respect to nominal R&D expenditure were obtained from the *OECD Science and Technology Database* (for 1970) and from the *OECD ANBERD Database* (from 1975 onwards). The use of such a proportion between nominal figures avoids the difficulty of having to deflate the R&D data in the absence of a reliable price deflator. It is strictly speaking only justified if the relative price of R&D and value added does not change. We did, therefore, also experiment with an R&D/income variable based on real figures. Nominal R&D expenditure was thereby deflated by a price index, *prd*, defined as $prd = 0.5\ p + 0.5\ w$, where p is the deflator of value added and w is an index of average wages in the business sector, obtained from the *OECD Business Sector Database*. Such a definition of *prd* would imply that about half of expenditures on R&D is on labour costs. This R&D/income variable based on real figures performed worse, however, in the growth equations than our used proportion between nominal figures.

Finally, the domestic R&D spillover variable, $(\tilde{R}/Y)_{ijt}$, was constructed as a weighted average of the R&D/income proportions of the other sectors, where the weights, δ_{lj}, reflect the technical proximity between sectors in the patent space. The weights δ_{lj} are the same for all countries and invariable through time. They are derived from the patent-based technology flow matrix A presented in Verspagen (1997a). It makes use of data from the European Patent Office, which assigns the respective patented inventions to a main technology class and to several supplementary technology classes taken as by-products of the main goal of the invention. The matrix assumes that the main class indicates the knowledge producing sector and the supplementary classes the sectors to which the knowledge spills over. The underlying data relate to approximately 400,000 patent applications over the period 1979-1994. The use of common fixed δ_{lj} weights, based on patent data covering an entire period of time, is strictly speaking only justified if the inter-sector technical distance is the same across countries and does not change over time. The use of such common fixed weights has, however, the advantage of avoiding bias caused by differences in the propensity to patent through time.

For reasons of data availability, the starting date of the respective series is 1970 and the period of investigation 1970-1995. In some countries entire series of certain variables were missing in certain sectors. These sectors were therefore dropped.

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ABSTRACT

In this paper we present a disaggregate panel data analysis of the issue of manufacturing productivity convergence through technological diffusion with respect to a set of major OECD countries during the period 1970-1995. Regression estimates of alternate equations relating TFP growth to initial technology gap imply not only conditional, but also absolute convergence in a great majority of manufacturing industries. The evolution of the standard deviation of the log of TFP confirms that there is also evidence of σ-convergence in the same industries. It is argued that these results suggest that, during the period of investigation, manufacturing productivity growth performances were dominated by transitional dynamics. A time series approach to convergence analysis, based on the same data, is, therefore, inappropriate.

JEL classification: *031, 040*
Keywords: *total factor productivity, growth, technological diffusion, convergence*

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EXPORTS AND ECONOMIC GROWTH IN LESS DEVELOPING COUNTRIES OF THE EUROPEAN UNION

by
MELINA DRITSAKI* and ANTONIOS ADAMOPOULOS*

1. *Introduction*

In the last decades economic development literature has mainly focused on the relationship between exports expansion and economic growth. The issue of economic growth promoting exports has been the central theme in trade and development theory. Numerous studies have been conducted dealing with different aspects of this effect. Many of these studies have focused on testing whether export expansion leads to improved growth performance, while others have attempted to find how exports affect economic growth, by identifying the paths through which the effects of exports are transmitted to output growth (Romer, 1989; Basu and McLeod, 1991; Edwards, 1992). Economic theory suggests that export expansion is believed to promote economic growth via two paths: by improving efficiency in the allocation of productive resources and by increasing the volume of productive resources through capital accumulation.

All the empirical studies on the causal relationship between exports and economic growth, refer to developing countries economies. Some of these empirical studies have confirmed this relationship (Michaely, 1977; Balassa, 1978; Heller and Porter, 1978; Tyler, 1981; Kavoussi, 1984; Feder, 1983; Esfahani, 1991), while other empirical studies that have adopted the concept of causality proposed by Granger (1969), such as Sims (1972), Kunst and

* University of Macedonia, Economics and Social Sciences. Department of Applied Informatics, Thessaloniki (Greece). E-mail: mdritsaki@yahoo.gr

Marin (1989), do not confirm it thoroughly.

There are at least three arguments that can be used for providing a theoretical rationale to adopt the hypothesis that exports and economic growth are interrelated. First, up to Keynesian theory, exports expansion leads through the trade multiplier to economic growth promotion. Second, exports increase the national capacity to import capital products resulting in economic growth promotion. Finally, competition leads to scale economies development and technology acceleration, two important sources of economy growth.

Edwards (1992) in order to test empirically if exports promote economic growth used regression analysis and showed that there is a positive relationship between exports expansion and economic growth. In the light of these developments, the evidence in support of the positive effect of exports on economic growth was considered as spurious. Consequently, the interest shifted to the use of causality analysis to determine the relationship between exports growth and economic growth.

The application of the causal model between exports and economic growth has important implications for the development strategies of LDCs. (Less Developing Countries). If exports promotion causes economic growth, then export-led growth strategy is appropriate for the country concerned. But if the causative process runs in the opposite direction, then the achievement of a certain degree of development may be a prerequisite for the country to expand its exports (Chow, 1987; Moshos, 1989). A bilateral causality between exports and economic growth implies that one reinforces the other.

Bahmani-Oskooee et al. (1991) using the cointegration technique and error correction models proved that there is a positive bilateral causal relationship between exports and economic growth for seven developing countries. In other words exports expansion leads to economic growth promotion.

This paper tries to investigate the direction of causality between exports and economic growth in four European Union countries (Greece, Spain, Portugal and Ireland). These countries which are developing less than the others of the European Union have managed to improve their economic growth during the last years and to become its members. In the empirical analysis we used quarterly data for all countries for the period 1960:IV to 2000:IV for the variables used. The remainder of the paper proceeds as follows: Section 2 applies the Dickey-Fuller tests and investigates the stationarity of the used data. The cointegration analysis between the used variables is implied in Section 3. Section 4 reports the estimations of error correction models, while Section 5 presents the Granger causality tests. Finally, Section 6 concludes this study.

2. *Data Stationarity Tests*

The data used in this investigation are quarterly, cover the period from 1960:1 to 2000:IV and are taken from the OECD Business Sector Data Base employing the year 1995 as constant.

Examining the stationarity of the mentioned variables we have used the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) tests (1979,1981). The results of these tests appear in Table 1. The minimum values of the Akaike (AIC) (1973) and Schwartz (SC) (1978) statistics indicated that the 'best' ADF equations were those including an intercept and trend and the corresponding numbers of lagged terms. As far as the autocorrelation disturbance term test is concerned, the Lagrange Multiplier LM(4) test has been used.

The results of Table 1 suggest that the null hypothesis of a unit root in the time series cannot be rejected in variable levels and in their first differences at a 5% level of significance. Therefore, no time series appear to be stationary in variable levels and in their first differences. When the time series are transformed into second differences they become stationary and consequently the related variables can be characterized as integrated of order 2, so they are I(2). Moreover, for all variables the LM(4) test on second differences shows that there is no serial correlation in the disturbance terms.

3. *Cointegration Test*

In this section in order to test if the GDP is cointegrated with the related exports for the four countries (since all variables are integrated of order two), the Engle-Granger approach (1987) will be used. The Engle-Granger cointegration approach is preferable in the case of two variables. The steps we employed are the following:

Initially we estimate the long-run equilibrium equation with the OLS method:

$$GDP_t = \alpha_0 + \alpha_1 EXP_t + u_t \text{ where } i = 1,2,3,4.$$

Table 2 presents the results of the estimates of the cointegrating vectors. From these estimates, we obtained the corresponding equilibrium errors u_t. For the two variables to be cointegrated the equilibrium errors must be stationary.

Table 1. DF/ADF unit root tests

Variables	In levels			1st differences			2nd differences		
	Lag	Test statistic (DF/ADF)	LM(1)	Lag	Test statistic (DF/ADF)	LM(1)	Lag	Test statistic (DF/ADF)	LM(1)
GDPGR	3	−1.5714	10.430 [.034]	2	−2.1468	10.430 [.034]	1	−7.2808	10.363 [.035]
EXPGR	2	−2.5215	83.121 [.000]	4	−2.6497	45.032 [.000]	4	−6.3242	39.720 [.000]
GDPSP	2	−1.0191	13.357 [.010]	1	−2.8334	13.357 [.010]	0	−18.3473	24.578 [.000]
EXPSP	1	1.2343	50.239 [.000]	0	−3.3866	50.239 [.000]	1	−12.4684	8.833 [.065]
GDPPOR	3	−1.4879	19.685 [.001]	2	−3.0034	19.685 [.001]	1	−16.1442	22.593 [.000]
EXPPOR	2	1.5897	73.504 [.000]	4	−2.8908	40.793 [.000]	4	−5.8599	25.513 [.000]
GDPIRE	3	2.3511	9.225 [.056]	1	−3.0972	17.173 [.002]	0	−11.0839	15.106 [.004]
EXPIRE	1	1.8741	113.286 [.000]	1	−3.1929	29.338 [.000]	2	−8.7246	7.824 [.098]

Critical value: −3.4387.
Numbers in brackets show the levels of significance

Table 2. Cointegrating regression

Variables	Constant	EXP	R^2
GDPGR	–6955623	6164.3	0.82156
GDPSP	–7184346	4527.4	0.95441
GDPPOR	–3790838	4194.6	0.96058
GDPIRE	407.7234	1282.2	0.96600

To test this stationarity we applied the DF/ADF unit root methodology to the estimated equilibrium errors. However, the DF/ADF equations did not include a constant term, because by construction the OLS residuals u_t are centred around zero. Table 3 presents the results of the stationarity equilibrium errors. The DF/ADF statistics in Table 3 show that all second differenced residuals are stationary. In other words, the equilibrium errors are integrated of order 2, so they are I(2). This means that the initial variables that included in the cointegrating regressions for all countries gross domestic product and exports, are cointegrated.

Table 3. Unit root test for equilibrum errors

Variables	Lag	DF/ADF*	LM(1)	Lag	DF/ADF	LM(1)	Lag	DF/ADF	LM(1)
U1	2	0.18480	81.778 [.000]	4	–2.8882	52.600 [.000]	4	–6.2665	38.383 [.000]
U2	1	–1.0243	73.882 [.000]	0	–2.8482	73.882 [.000]	1	–12.7365	11.919 [.018]
U3	2	–2.4185	12.870 [.012]	1	–2.6216	12.870 [.012]	0	–16.869	12.029 [.017]
U4	1	0.68651	109.279 [.000]	0	–3.0595	109.279 [.000]	0	–13.4211	1.933 [.748]

Critical value: –3.4387; numbers in brackets show the levels of significance

4. *Error Correction Models*

According to the Granger (1986) representation theorem if two variables are cointegrated there is a long-run relationship between them. Of course in the short-run these variables may be in disequilibrium. This short-run disequilibrium relationship between these two variables can always be described by an error correction model (ECM). In this case this error correction model which connects the short-run and the long-run behaviour of the two variables is given by:

$$GDP_t = b_1\, EXP_t + b_2\, e_{t-1} + v_t \qquad -1 < b_2 < 0$$

where b_2 = short-term adjustment coefficient.

Because all the variables included in the above equation are stationary in second differences we could use the OLS methodology in estimating this equation. Table 4 presents the results of the estimation of both short-term and long-term parameters as well as the estimation of the disequilibrium error coefficient.

Table 4. Estimation of short-term and long-term trends

Variables	Short–term trend	**Coefficient error**	Long–term trend
GDPGR	0.3950311	–0.0041867	0.553977
GDPSP	0.1148097	–0.0059454	0.639289
GDPPOR	0.3846843	–0.016006	0.721799
GDPIRE	0.424430	–0.012989	0.834665

From Table 4 we can infer that the estimations of coefficients are statistical significant with the expected signs. This means that the quarterly variations of exports do affect economic growth. The deviation in GDP from its long-term level is corrected per quarter from –0.004 for Greece to –0.016 approximately for Portugal.

5. *Granger Causality Test*

The model that was estimated in the previous section, was used in order to examine the Granger causal relationships between the two variables under examination. As a testing criterion the F statistic was used. With the F statistic the hypothesis of the statistic significance of the explanatory variables was tested. The results relating to the Granger causal relationships between the variables: economic growth (*GDP*) and exports (*EXP*) appear in Table 5.

The results of Table 5 suggest the following :

- There is a unidirectional causal relationship between exports and economic growth for Greece with direction from exports to economic growth.
- There is a unidirectional causal relationship between exports and economic growth for Spain with direction from economic growth to exports.
- There is a unidirectional causal relationship between exports and economic

growth for Portugal with direction from economic growth to exports.
- There is a bilateral causal relationship between exports and economic growth for Ireland.

Table 5. Granger causality tests

Dependent variable	Testing hypothesis	F_1*	F_2*
GDPGR	there is unidirectional relationship (*GDPGR* ⇐ *EXPGR*)	4.025	1.326
GDPSP	there is unidirectional relationship (*GDPSP* ⇒ *EXPSP*)	0.649	9.103
GDPPOR	there is unidirectional relationship (*GDPPOR* ⇒*EXPPOR*)	0.47	4.186
GDPIRE	there is bilateral relationship (*GDPIRE* ⇔ *EXPIRE*)	3.222	3.843

Critical value: 3.08

6. *Conclusions*

The purpose of this paper was to investigate the relationship between exports and economic growth for the four less developing countries in the European Union (Greece, Spain, Portugal and Ireland) and to measure their effect on quarterly terms. With the cointegration analysis that was used, we concluded that there is a long-term relationship between exports and economic growth. In relation to the deviation part of real variables from the long-run equilibrium level that is corrected every quarter, Portugal indicated the major quarterly adjustment and Greece the minor. Finally, with the Granger causality approach we infer that there is a bilateral relationship between exports and economic growth only in Ireland, while there is a unidirectional causal relationship for the other countries.

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ABSTRACT

This paper attempts to analyze the relationship between exports and economic growth in the less developing countries of the European Union such as Greece, Spain, Portugal and Ireland. For the search of this relationship we use the analysis of causality, based on error correction model. The results of this paper showed that there is a bilateral causality between exports and economic growth in the case of Ireland, whereas for the other three countries there is a unidirectional causal relationship.

Jel classification: *A10, C22*
Keywords: *exports, economic growth, cointegration- Granger causality*

This paper attempts to analyze the relationship between ...

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BUSINESS CYCLE SYNCHRONIZATION IN TRANSITION ECONOMIES THE CASE OF SLOVENIA AND CROATIA

by
TIMOTEJ JAGRIČ* and SEBASTJAN STRAŠEK**

1. *Introduction*

A recent study (Artis and Zhang, 1999) of the relationship of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) to the international business cycle in terms of linkage and synchronization of cyclical movements found that the business cycles of ERM member countries have become more synchronized with the German cycle. In our paper we follow the same assumption as we analyze the business cycles in Slovenia and Croatia. Therefore we set up the following hypotheses:

H1: The series for Slovenia and Croatia should contain the cyclical component, which corresponds to the definition of the business cycle proposed by Burns and Mitchell (1946, p. 6-20) and has the same frequency as the business cycle in Germany.

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* Department for quantitative economic analysis and Department for economic policy, School of Economics and Business, University of Maribor, Maribor, (Slovenia). E-mail: timotej.jagric@uni-mb.si

** Department for economic policy, School of Economics and Business, University of Maribor, Maribor (Slovenia). E-mail: sebastian.strasek@uni-mb.si

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H2: The business cycle of Slovenia and Croatia should be synchronized with the German cycle.

Such findings would confirm a general view in the business cycle literature that business cycles in the approach phase of integration become more synchronized with the target integration bloc as a result of increased international trade, openness of financial markets and global capital flows. Artis and Zhang (1999) suggest a high degree of synchronization of the business cycle between EU and Germany. Therefore we decided to choose Germany as an anchor country.

We test the hypothesis of the synchronization of cyclical movements on monthly data for the period 1991-2001. As seen in some applications, spectral analysis can be a valuable tool for studying business cycles (see for example Sargent, 1987, pp. 113-127; Englund, Persson, and Svensson, 1992; Reiter, 1995, pp. 15-39; and Woitek, 1997, pp. 10-13). Spectral analysis has been used to study the existence of cycles in Real Business Cycle (RBC) models by Watson (1993), Söderlind (1994), Cogley and Nason (1995), and Wen (1998), and it has been suggested as an econometric method for measuring the goodness-of-fit for RBC models (Watson, 1993). We choose multivariate spectral analysis to study the relationship between the business cycles of Germany, Slovenia and Croatia. The selected method is used to estimate the strength of wavelength relationships between economic indicators.

The remainder of the paper is organized as follows: after the introduction, the analytical framework is set out in Section 2. In Section 3 we present basic procedures which we apply to selected time series. Section 4 summarizes the main findings and concludes.

2. *Analytical Framework*

The task of quantifying co-movements with the business cycle is conceptually difficult. Burns and Mitchell (1946) quantified co-movements in terms of leads or lags at turning points of each series relative to the reference cycle and in terms of their index of conformity. More recent work has focused on the second moment of the joint distribution of the series of interest. For example, Hymans (1973) summarized cyclical timing by estimating phases in the frequency domain at business cycle frequencies. This perspective – focusing on the second moment properties of the series – is adopted here.

To apply the multivariate spectral analysis, it is desirable to have a

minimum of 200 observations, and the economic indicators must be stationary. Let $\{y_t\}_{t=-\infty}^{\infty}$ be a stationary, stochastic n-dimensional vector process with mean vector $E(y_t) = \mu$ and the τ'th autocovariance matrix given by:

$$\Gamma(\tau) \equiv E[(y_t - \mu)(y_{t-\tau} - \mu)] \tag{1}$$

If the sequence of matrix autocovariances $\{\Gamma_\tau\}_{\tau=-\infty}^{\infty}$ is absolutely summable and if z is a complex scalar, the matrix autocovariance generating function of y_t is given by:

$$F_y(z) = \sum_{\tau=-\infty}^{\infty} \Gamma(\tau) z^{\tau} \tag{2}$$

where $F_y(z)$ is an $(n \times n)$-dimesional matrix of complex numbers.

If we evaluate the matrix autocovariance generating function at the value $z = e^{-i\omega\tau}$ and divide by 2π, we have the multivariate spectrum – cross-spectral density function:

$$S_y(\omega) = \frac{1}{2\pi} \sum_{\tau=-\infty}^{\infty} \Gamma(\tau) e^{-i\omega\tau} \tag{3}$$

where $S_y(\omega)$ is an $(n \times n)$ matrix. The diagonal elements are the power spectrum of the individual processes, which are real-valued and non-negative for all ω. The off-diagonal elements are the cross spectra. The cross spectrum is in general a complex number at each frequency. If we consider the case for $y = [y_t \quad x_t]$, where $\{y_t\}_{t=-\infty}^{\infty}$ and $\{x_t\}_{t=-\infty}^{\infty}$ are two jointly stationary stochastic processes with continuous power spectra, then the multivariate spectrum is given by:

$$S_y = \begin{bmatrix} S_{yy}(\omega) & S_{yx}(\omega) \\ S_{xy}(\omega) & S_{xx}(\omega) \end{bmatrix} = \frac{1}{2\pi} \begin{bmatrix} \sum_{\tau=-\infty}^{\infty} \gamma_{yy}(\tau) e^{-i\omega\tau} & \sum_{\tau=-\infty}^{\infty} \gamma_{yx}(\tau) e^{-i\omega\tau} \\ \sum_{\tau=-\infty}^{\infty} \gamma_{xy}(\tau) e^{-i\omega\tau} & \sum_{\tau=-\infty}^{\infty} \gamma_{xx}(\tau) e^{-i\omega\tau} \end{bmatrix} \tag{4}$$

As stated before, the cross-spectrum is a complex quantity. In order to estimate it, we will use a polar decomposition. So it is possible to reformulate

the cross-spectrum in terms of two real quantities, the co-spectrum and quadratic spectrum:

$$(5) \qquad S_{yx}(\omega) = co_{xy}(\omega) + i\, qu_{yx}(\omega) = \frac{1}{2\pi} \sum_{\tau=-\infty}^{\infty} \gamma_{yx}(\tau)\cos(\omega\tau) + i\frac{1}{2\pi} \sum_{\tau=-\infty}^{\infty} \gamma_{yx}(\tau)\sin(\omega\tau)$$

The co-spectrum between y_t and x_t at frequency ω has the interpretation of the covariance between y_t and x_t that is attributable to cycles with frequency ω. The quadratic spectrum from x_t to y_t at frequency ω is proportional to the portion of the covariance between x_t and y_t due to cycles of frequency ω. Cycles of frequency ω may be important for both x_t and y_t individually as reflected by large values for $S_x(\omega)$ and $S_y(\omega)$, yet fail to produce much contemporaneous covariance between the variables because at any given date the two series are in different phases of the cycle. For example, the variable x_t may respond to economic recession later than y_t. The quadrature spectrum looks for evidence of such out-of-phase cycles.

Business cycles are characterized by a high correlation between several macroeconomic variables over the business cycle. Multivariate time series analysis in the frequency domain can be used to analyze this phenomenon by using coherence (*Coh*) and phase (*Ph*):

$$(6) \qquad Coh(\omega) = \frac{\left|S_{yx}(\omega)\right|^2}{S_{yy}(\omega)S_{xx}(\omega)} \qquad 0 \le Coh(\omega) \le 1$$

$$Ph(\omega) = \operatorname{atan}\left(\frac{qu(\omega)}{co(\omega)}\right) \qquad lead/lag = \frac{Ph(\omega)}{\omega}$$

The coherence between two or more time series can be used to measure the extent to which multiple time series move together over the business cycle. The phase gives the lead of y over x at frequency ω. There is a close relationship between the phase of two time series and the isolation of leading, coincident and lagging indicators. Furthermore, the concept of phase is closely connected to the concept of Wiener-Granger causality (Granger, 1980 and 1988).

It is common for the cross-spectrum to show no regularities. This is because there is not enough information in the original signals to obtain a

well-behaved curve. Using a longer series does nothing to alleviate this problem. The answer is to use smoothing and filtering procedures. Filters are normally applied to the input signals. They are used for two general purposes: separation and restoration. Signal separation is needed when a signal has been contaminated with noise. Signal restoration is used when a signal has been distorted in some way. An example of this problem can be seen in Lucas (1972), where rational agents solve a signal separation and restoration problem in order to react optimally to an observed price change where it is unknown whether the price change reflects a change in the general price level or a change in real demand on the individual market.

Although the spectral density diagram is an asymptotically unbiased estimate of the spectrum, it is not consistent. A body of literature has been developed on smoothing methods, referred to as spectral windows, for the spectral density function. However, care must be exercised not to introduce a cyclical peak due solely to the smoothing technique.

When analyzing economic variables, it is a common problem to have short and particularly volatile time series. To check if the spectrum of individual variables is stable (for cross-spectrum we use the Welch estimation procedure, which belongs to nonparametric methods), we introduce subspace methods, also known as super-resolution methods. They generate frequency component estimates for a signal based on an eigenanalysis or eigendecomposition of the correlation matrix. These methods are best suited for short signals and are effective in the detection of sinusoids buried in noise, especially when the signal to noise ratios are low. In our example we selected the multiple signal classification method (MUSIC), which is normally used in digital signal processing (see Appendix). To additionally confirm the results obtained by estimation of coherence and phase, we will also use the Granger causality test.

3. *Data*

The monthly indexes of industrial production were obtained from the Bank of Slovenia (2001), the European Central Bank (2001), Bundesbank (2001) and the Economic Institute of Zagreb (2001). Data cover the time-span from January 1991 to September 2001.

Nearly every time series includes the impact of seasons on its movement. The use of such original monthly series can lead us to absolutely wrong conclusions about the further development of the observed phenomenon. It is therefore reasonable to employ special procedures in order to separate the

Table 1. Results of the stationarity test for industrial production

Coefficient	(ρ–1)	Λ	α	ADF
SLOSA	–0.102138 (–1.705967)	–0.486705 (–5.624749)	9.945391 (1.726474)	–1.705967
SLOSAHP	–0.680244 (–5.744431)	–0.205232 (–2.227017)	–0.122836 (–0.405501)	–5.744431
CROSA	–0.125676 (–2.080821)	–0.398333 (–4.379440)	13.54788 (2.090006)	–2.080821
CROSAHP	–0.622601 (–5.256318)	–0.157049 (–1.612279)	–0.001295 (–0.003852)	–5.256318
GERSA	0.014685 (0.420257)	–0.521215 (–5.881761)	–1.263067 (–0.378521)	0.420257
GERHP	–0.375271 (–4.174619)	–0.364768 (–4.138464)	–0.061358 (–0.415437)	–4.174619

Critical values by MacKinnon ($N = 106$):
–3.4928 at 1% significance level
–2.8887 at 5% significance level
–2.5811 at 10% significance level
Note: In each field we have first the value of the coefficient and then t-statistics.
SLOSA Industrial production (Slovenia) – deseasoned data
SLOSAHP Industrial production (Slovenia) – deseasoned data and HP trend removed
CROSA Industrial production (Croatia) – deseasoned data
CROSAHP Industrial production (Croatia) – deseasoned data and HP trend removed
GERSA Industrial production (Germany) – deseasoned data
GERSAHP Industrial production (Germany) – deseasoned data and HP trend removed

seasonal component from other components. Of course, it is desirable as well as necessary that the series does not lose its characteristics in this process. A well-known example of the use of the method of moving averages is the Method II – version X11 from 1968. The main weakness of this method, and also the weakness of all other traditional procedures, lies in neglecting the fact that the seasonal component has a stochastic character and is related to other components. It is thus better to use ARIMA seasonal models (Bundesbank, 1999). Despite the fact that numerous programs have been developed, which enable the use of the mentioned methods, we use program X11ARIMA (Statistics Canada, 2000) in the empirical part of our research.

Stationarity of time series is a common phenomenon, especially in periods with stable conditions. Nonstationary time series may have the "typical spectral shape" of Granger (1966), which makes impossible to detect business cycle frequencies. Differentiation of time series can eliminate the presence of nonstationarity, but also has its drawbacks (Charemza and Deadman, 1992, pp. 40-65). Differentiation also affects long-term relationships among economic variables.

The testing of stationarity has been done in two steps. In the first step, we tested the original series. In the second step, we removed the trend. The testing of de-seasoned data showed that the series are not stationary if the model does not include the trend. With the inclusion of the trend, the series become stationary. This is why the observed series need to be adjusted in subsequent testing. As the use of different forms of differentiation may have a negative influence on the results of further testing we decided to eliminate the long-term linear trend by using Hodrick-Prescott filter (λ = 14400, suggested value for monthly data).

The discussions in Canova (1998) and Burnside (1998) make clear that different detrending methods emphasize different frequency ranges in the data, and that many stylized facts are sensitive to the choice of the detrending method. As we apply the same procedure to all series, it seems that in our application, this method yields good results.

4. *Results and Concluding Remarks*

A main finding from a recent study (Bergman, Bordo, and Jonung, 1998) of contemporaneous correlations of output for developed countries is that correlations tend to increase over time. Most of the significant correlations are reported from the post-Bretton Woods period. The cyclical comovements for real GDP across countries suggest growing international linkages over time. Some authors have researched changes over time in correlation patterns. Angeloni and Dedola (1998, pp. 10-15) find that GDP correlations between Germany and other EU countries were much higher during the period 1993-97 than during 1986-92. As noted by Clark and Shin (2000), Imbs (1998, pp. 4-7), and Krugman (1993), among others, greater similarity in production structures is likely to increase business cycle correlations. Industry-specific shocks will create more co-movement among regions with similar production structures than among regions with dissimilar structures. Industry structures of transition economies are increasingly adapting to the structures of developed economies. Slovenia and Croatia are the outliers among them in this process of synchronization.

Virtually all economies experience recurrent fluctuations in economic activity that persist from several quarters to several years. There is a definite tendency for the business cycles of developed countries to move together. In our research we try to find out if Slovenia and Croatia correspond to this trend.

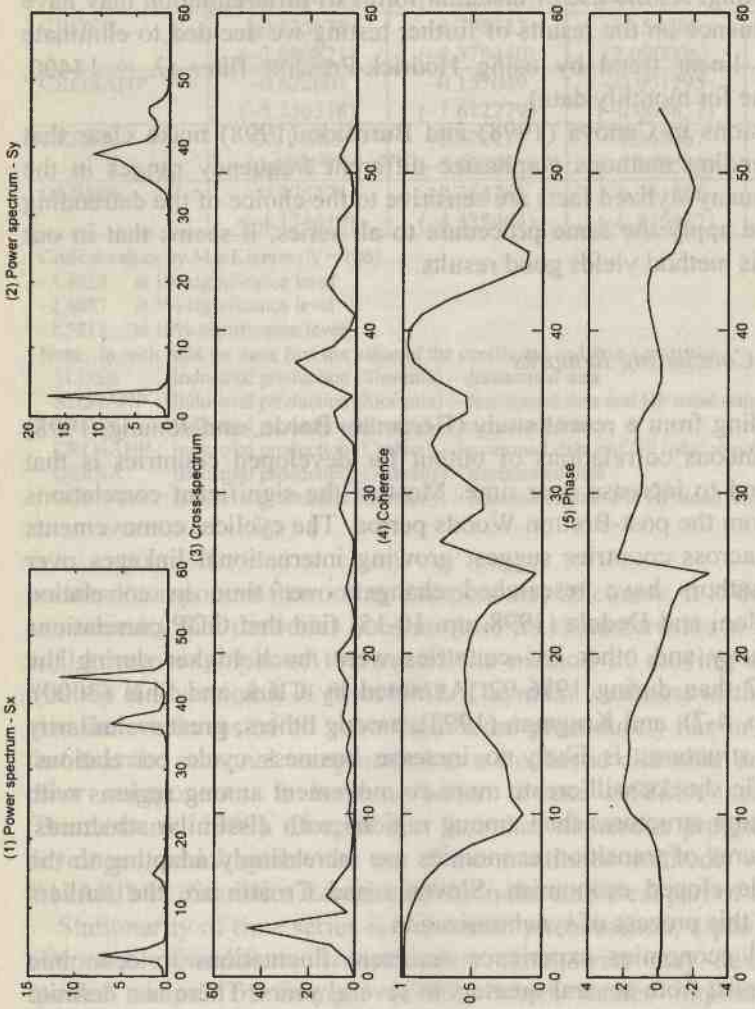

Figure 1. Cross-spectral analysis results (Slovenia – Germany)
Note: Frequency values are on the x-axes.

In our analysis we employed the monthly index of industrial production (1999 = 100) under the assumption that the selected series represent economic activity. Such a choice allowed for a sufficient number of observations for empirical testing. Since time series have to be stationary and must not include the trend, the long-term trend was subtracted from the original time series.

The results of testing data for Slovenia are presented in Figure 1. The first graph presents the spectral density diagram for the index of industrial production in Slovenia (1999 = 100). We find one spectral peak at the frequency of 36 months. The spectrum of industrial production also has two additional peaks at higher frequencies, which can be attributed to the strong stochastic component of selected time series. In the second graph the spectral density diagram for German industrial production is presented. We find again one spectral peak with the same frequency, but the peak diverges more strongly. As in the case of Slovenia, an additional spectral peak can be found at the frequency range, which is typical for a stochastic component. In this way the first hypothesis for Slovenia is confirmed: the frequency of the cyclical component corresponds to the length of the typical business cycle proposed by Burns and Mitchell (1946, pp. 6-20) and is significant for both countries.

By using spectral analysis, we were able to estimate the length of the business cycle in the Slovenian economy from 1991 to 2001. Following the results of our analysis, we can conclude that the first years of Slovenian transition were marked by typical transformation depression. This is not surprising, since the Slovenian economy was hit by a series of market losses: the collapse of CMEA markets, the Gulf War, and the collapse of the Yugoslav internal market. These events have had a strong influence on the economic activity and financial position of the economy. Production declined rapidly, to 9.3 percent in 1991 and 6.0 percent in 1992.

Our analysis identifies June 1993 as a trough and as the start of a new cycle (we used inverse real discrete Fourier transform). This was confirmed by Mencinger (1995), who also found that in the middle of 1993 Slovenia suddenly reached the lowest point of its depression. The revival, which followed, can be explained by an increase in aggregate demand in which moderate growth of foreign demand coincided with fast growth of domestic demand. The peak was reached in January 1995. The turnaround could be attributed to Dutch disease and to a debt crisis in the Slovenian economy. The peak was also preannounced by *Surveys on Business Trends* published by the Statistical Office of the Republic of Slovenia (1994), which reported on continued worsening of export demand from October 1994 (the diffuse index

was steadily growing from 34 percent in October to 43 percent in December).

The end of the first cycle was reached in June 1996. After reaching a trough, economic conditions improved in the second part of the year due mainly to the economic recovery in Europe and improved export competitiveness. According to the Institute of Macroeconomic Analysis and Development (1997), export competitiveness (measured in terms of unit labor costs in the basket of currencies) improved in 1996 by 7.3 percent after a market drop of 11.9 percent in 1995. Competitiveness improved as a consequence of increased productivity, the lower tax burden on wages, and the real depreciation of the Slovenian currency.

The acceleration in the rate of growth of the world economy as a whole, and of the European Union in particular, enables the Slovenian economy to extend its expansion into 1997. The improved economic performance of main economic partners was the primary factor allowing exports to rise in 1997 without an increase in export competitiveness. This was also the year when the social partners (trade unions, government, and employers) reached a consensus on wages on time. Thus adequate income policy mechanisms were adopted, which succeeded in keeping the growth in wages lagging behind the growth in labor productivity.

The slowdown in economic growth and export market growth in the most important trading partners in the last quarters of 1997 and 1998 held back growth in Slovenian exports and, with some lag, economic activity as well. The extremely high value of the export multiplier for the Slovenian economy (0.6) explains the high degree of sensitivity of Slovenian macroeconomic activity to the changes in export growth. The deceleration of the cycle in 1998 was therefore not a surprise, since contagion effects of the Asian crisis spread to Europe.

The cross-spectral density diagram (third graph in Figure 1) confirms the hypothesis of a strong link between the cyclical component of industrial production in Slovenia and Germany. The spectral peak is again at a frequency of 36 months. The peak is statistically significant, which is confirmed with the maximum value of coherency at the selected frequency (fourth graph in Figure 1).

The fifth graph shows the time lag between oscillations of cyclical components of Slovenia and Germany. At the significant frequency of 36 months, the Slovenian cyclical component lags with an average lag-time of 1.2 months. The time lag between cyclical components is short, so our results seem to provide strong support for our second hypothesis.

The results of testing data for Croatia are presented in Figure 2. The spectral density diagram for the index of industrial production in Croatia

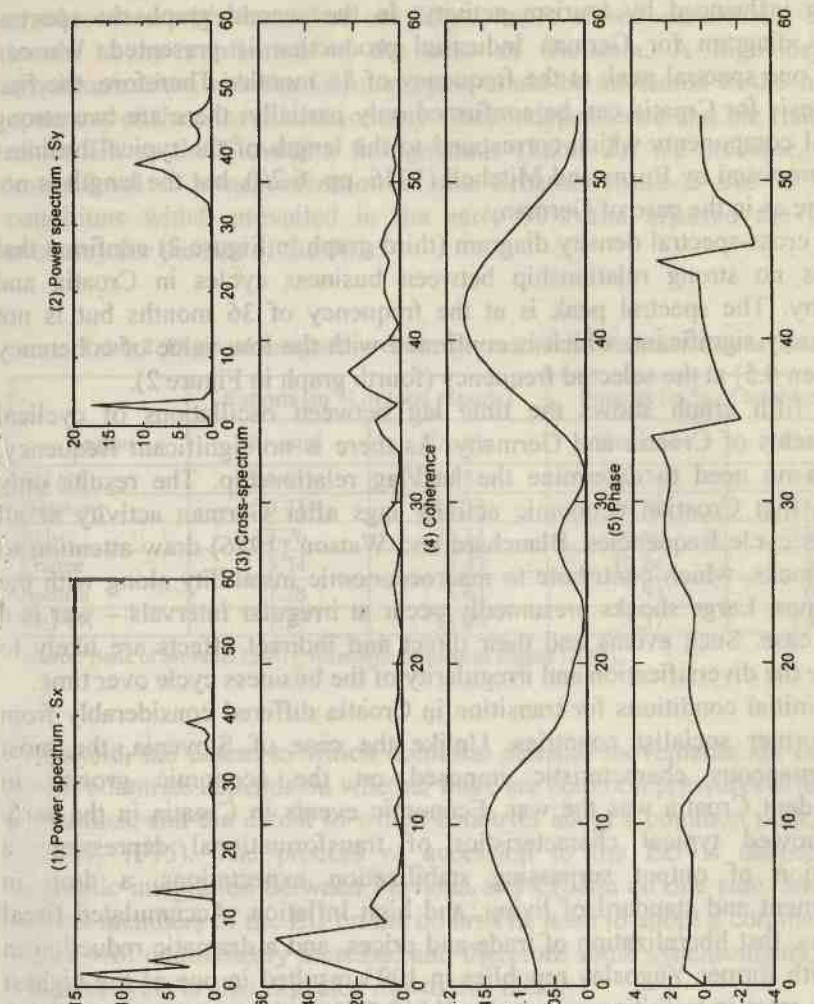

Figure 2. Cross-spectral analysis results (Croatia – Germany)
Note: Frequency values are on the x-axes.

(1999 = 100) suggests that there are two significant spectral peaks at the frequency of 54 and 27 months. The spectrum of industrial production has also additional peaks at higher frequencies, which can be attributed to the strong seasonal and stochastic components of selected time series. These results seem to confirm the presumption that Croatian business cycle is heavily influenced by tourism activity. In the second graph the spectral density diagram for German industrial production is presented. We can isolate one spectral peak at the frequency of 36 months. Therefore, the first hypothesis for Croatia can be confirmed only partially: there are two strong cyclical components which correspond to the length of the typical business cycle proposed by Burns and Mitchell (1946, pp. 6-20), but the length is not the same as in the case of Germany.

The cross-spectral density diagram (third graph in Figure 2) confirms that there is no strong relationship between business cycles in Croatia and Germany. The spectral peak is at the frequency of 36 months but is not statistically significant, which is confirmed with the low value of coherency (less then 0.5) at the selected frequency (fourth graph in Figure 2).

The fifth graph shows the time lag between oscillations of cyclical components of Croatia and Germany. As there is no significant frequency, there is no need to determine the lead/lag relationship. The results only suggest that Croatian economic activity lags after German activity at all business cycle frequencies. Blanchard and Watson (1986) draw attention to large shocks, which contribute to macroeconomic instability along with the small ones. Large shocks presumedly occur at irregular intervals – war is a typical case. Such events and their direct and indirect effects are likely to increase the diversification and irregularity of the business cycle over time.

The initial conditions for transition in Croatia differed considerably from other former socialist countries. Unlike the case of Slovenia, the most disadvantageous characteristic imposed on the economic growth in independent Croatia was the war. Economic events in Croatia in the early 90's showed typical characteristics of transformational depression: a contraction of output surpassing stabilization expectations, a drop in employment and standard of living, and high inflation. Accumulated fiscal problems, fast liberalization of trade and prices, and a dramatic reduction in trade with former Yugoslav republics in 1993 resulted in one of the highest inflation rates in transition economies (1149.7%), and in a strong cumulative drop of output (37%) in the period 1989-1993. Economic recovery started in 1994, one year behind Slovenia. The economic damages inflicted on Croatia by the war dampened economic activity so much that in the 1995 the GDP level and industrial production level were 71.4% and 61.1%, respectively, of

their 1990 performance (WIIW, 1996). The unusually long trough of the business cycle is undoubtedly related to these facts.

Several factors affect the degree of synchronization of business cycles in different economies. First, business cycles in small open economies, which have strong trade links with major economies, are likely to be more synchronized with them than are larger, more closed economies. This fact seems to be confirmed in the case of Slovenia. A high degree of synchronization with the German cycle could be attributed to the increased openness of the Slovenian economy since independence and the rising share of the EU in the Slovenian foreign trade (Table 2). We presume, that the lower level of synchronization of the Croatian cycle is due to the war conditions which prevailed in the early 90's and affected the Croatian economy for the rest of the 90's.

Table 2. Regional composition of foreign trade for Slovenia and Croatia (2000)

Region	Exports (in % of total exports)		Imports (in % of total imports)	
	Slovenia	Croatia	Slovenia	Croatia
EU (15)	66.11	54.51	67.74	55.59
Germany	30.73	14.25	19.88	16.37
Italy	13.76	22.31	16.60	17.01
France	5.74	2.47	10.84	5.03
Austria	7.28	6.61	7.93	6.67
CEFTA	7.27	13.80	8.37	14.77

Source: Bank of Slovenia (2001), Economic Institute of Zagreb (2001).

Second, the extent to which domestic demand movements are correlated across countries depends on whether there are common pressures affecting all economies, and the extent to which countries adopt a common policy stance (OECD, 1995). The process of accession to the EU is deepening the economic integration between Slovenia and Croatia on one side, and among present members of the EU on the other. The need to adopt a common policy stance will undoubtedly increase, and therefore some synchronization of the business cycle is also expected due to this factor.

Third, the shift to an exchange rate regime in which currencies float against each other has been an important facilitator of desynchronization. Fixed rates or a single currency is therefore a factor of synchronization. The exchange rate systems and movements in the coming years in Slovenia and Croatia will serve to adjust the economies to EU and EMU, so we may expect

synchronization with German and EU cycles also from this point of view. Such trends would be in line with current trends in Europe, where ERM membership has promoted a shift of business cycle affiliation to that of the anchor country of the system.

The conclusions of this paper are based on the results of empirical testing. As we described earlier, in our example we adopted multivariate spectral analysis. This type of tool works best when analysing long stretches of high frequency data in stable regimes. In our case data can cover only the period after 1990. Since former Yugoslavia broke apart in 1990, this year could not be included in the sample. On the other hand, the results seem to be very stable. We tested the single spectrum for each time-series with two different methods: the nonparametric Welch method, and the Multiple Signal Classification (MUSIC) method, which belong to parametric methods. All these procedures yield the same results.

Table 3. Granger causality test for the period 1991 - 2001

	Lags					
Null Hypothesis:	**1**	**2**	**3**	**4**	**5**	**6**
SLO does not Granger cause GER	1.38727 (0.24190)	1.18045 (0.31190)	0.67938 (0.56703)	0.54216 (0.70519)	0.43592 (0.82222)	0.61354 (0.71878)
GER does not Granger cause SLO	**8.32234 (0.00488)**	2.11344 (0.12685)	1.33921 (0.26700)	2.17244 (0.07917)	2.73332 (0.02484)	2.55124 (0.02630)
CRO does not Granger cause GER	0.01715 (0.89611)	0.61365 (0.54365)	0.85827 (0.46603)	1.56926 (0.19015)	1.40618 (0.23099)	1.22004 (0.30527)
GER does not Granger cause CRO	1.98100 (0.16265)	1.36546 (0.26056)	1.54365 (0.20905)	1.53074 (0.20080)	1.78101 (0.12616)	1.50703 (0.18707)
	Lags					
Null Hypothesis:	**7**	**8**	**9**	**10**	**11**	**12**
SLO does not Granger cause GER	0.80490 (0.58587)	1.14268 (0.34614)	0.92287 (0.51107)	0.97720 (0.47179)	0.87371 (0.56988)	0.77864 (0.66963)
GER does not Granger cause SLO	4.60091 (0.00026)	3.84072 (0.00084)	4.15609 (0.00027)	3.34080 (0.00148)	2.70915 (0.00646)	2.20308 (0.02301)
CRO does not Granger cause GER	1.01854 (0.42547)	0.87960 (0.53797)	0.69059 (0.71492)	0.59668 (0.81085)	0.50827 (0.89061)	0.41309 (0.95267)
GER does not Granger cause CRO	1.78001 (0.10404)	1.66300 (0.12274)	1.60219 (0.13221)	1.13168 (0.35309)	1.22044 (0.29297)	1.11893 (0.36278)

Note: In each field we have first the value of F-statistic and then the significance level.
SLO Industrial production - Slovenia
CRO Industrial production - Croatia
GER Industrial production - Germany

To additionally support the results obtained with multivariate spectral analysis, we also employed the Granger causality test. The results are presented in Table 3. According to the lag selection criteria presented in Table 3, economic activity in Slovenia lags behind German economic activity by 1 month. Additional significant lags were discovered, however the value of F-statistic is significantly lower. The Granger causality test also supports the results for Croatia. We could not find any significant connection between economic activity in Croatia and Germany.

An important assumption of the applied method is time-invariance. The data come from economies in transition, whose structures are changing. When more data are available, it may be useful to extend our testing with procedures used by Sargent and Cogley (2002). They use Bayesian methods to estimate vector autoregressions with drifting parameters, and impute drift in spectral densities from the VAR estimates. The application of such methods would enable us to analyse how the coherence across selected countries has changed in the observed period.

APPENDIX

Multiple signal classification method (MUSIC)

Let us first consider the "weighted" spectral estimate (Marple, 1987, pp. 373-378):

(A1) $$P(f) = \sum_{k=p+1}^{M} w_k \left| s^H(f) v_k \right|^2$$

where $\{v_k, k = p+1, \ldots, M\}$ are the eigenvectors in the noise subspace, $\{w_k\}$ are a set of positive weights, and $s(f)$ is a complex sinusoidal vector

(A2) $$s(f) = \left[1, e^{j2\pi f}, e^{j4\pi f}, \ldots, e^{j2\pi(M-1)f}\right]$$

Note that at $f = f_i$, $s(f_i) \equiv s_i$, so that at any one of the p sinusoidal frequency components of the signal we have

(A3) $$P(f_i) = 0, i = 1,2,\ldots,p$$

Hence, the reciprocal of $P(f)$ is a sharply peaked function of frequency and provides a method for estimating the frequencies of the sinusoidal components. Thus

(A4) $$\frac{1}{P(f)} = \frac{1}{\sum_{k=p+1}^{M} w_k \left| s^H(f) v_k \right|^2}$$

Although theoretically $1/P(f)$ is infinite of $f = f_i$, in practice the estimation errors result in finite values for $1/P(f)$ at all frequencies.

The estimate of the sinusoidal frequencies are the peaks of $P_{MUSIC}(f) = 1/P(f)$, where $w_k = 1$ for all k. Once the sinusoidal frequencies are estimated, the power of each of the sinusoids may be obtained by solving

(A5)
$$\begin{bmatrix} \cos 2\pi f_1 & \cos 2\pi f_2 & \dots & \cos 2\pi f_p \\ \cos 4\pi f_1 & \cos 4\pi f_2 & \dots & \cos 4\pi f_p \\ \vdots & \vdots & & \vdots \\ \cos 2\pi p f_1 & \cos 2\pi p f_2 & \dots & \cos 2\pi p f_p \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_p \end{bmatrix} = \begin{bmatrix} \gamma_{yy}(1) \\ \gamma_{yy}(2) \\ \vdots \\ \gamma_{yy}(p) \end{bmatrix}$$

In order to estimate the spectrum, we have to decide on the number of sinusoidal frequency components. We therefore apply order selection criteria, which are based on the extension and modification of the AIC criterion to the eigen-decomposition method. This approach was introduced by Wax and Kailath (1985) and is guaranteed to be consistent.

If the eigenvalues of the sample autocorrelation matrix are ranked so that $\lambda_1 \geq \lambda_2 > \dots \geq \lambda_M$, where $M > p$, the number of sinusoids in the signal subspace is estimated by selecting the minimum value of $MDL(p)$, given as

(A6)
$$MDP(p) = -\log\left[\frac{G(p)}{A(p)}\right]^N + E(p)$$

where

$$G(p) = \prod_{i=p+1}^{M} \lambda_i, \quad p = 0,1,\dots,M-1$$

(A7)
$$A(p) = \left[\frac{1}{M-p}\sum_{i=p+1}^{M} \lambda_i\right]^{M-p}$$

$$E(p) = \frac{1}{2} p(2M-p)\log N$$

N: number of samples used to estimate the M autocorrelation lags

In our example, we selected $p = 7$ for the case of Germany and Slovenia, and $p = 9$ for the case of Croatia.

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ABSTRACT

This paper studies cyclic patterns in the Slovenian and Croatian economies with multivariate spectral analysis. It examines if the transitions in Slovenia and Croatia

were marked by a significant movement of aggregate economic activity, which corresponds to the definition of the business cycle proposed by Burns and Mitchell (1946) and if the cycles are synchronized with the cycle of Germany as a proxy for the EU cycle. For Slovenia, we find a very close synchronization with the German cycle. The testing for Croatia, however, suggests that there is no typical German component in its business cycle. To additionally support the results obtained with multivariate spectral analysis, we also employed the Granger causality test. According to lag selection criteria, economic activity in Slovenia lags behind German economic activity by 1 month. Additional significant lags were discovered; however, the value of F-statistic is significantly lower. The Granger causality test also supports the results for Croatia. We could not find any significant connection between economic activity in Croatia and Germany.

JEL classification: *C22, E32*
Keywords: *business cycle, multivariate spectral analysis, Granger causality synchronization*

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IMPACTS OF THE EXCHANGE RATE AND INTEREST RATE POLICIES ON OUTPUT IN SOUTH KOREA: A VAR MODEL

by
YU HSING*

1. *Introduction*

Recently, movements in exchange rates and interest rates in South Korea (Korea, hereafter) have brought renewed interest in their potential impacts on real output. To follow the recent depreciation of the Japanese yen and to remain competitive in international trade, Korean won per U.S. dollar also began to depreciate from 1,106 in 2000.Q1 to 1,313.5 in 2001.Q4 or 18.8%. Comparing with 914.8 won per U.S. dollar by the time of the Asian financial crisis in 1997.Q3, import prices were much higher than before. However, the current exchange rate was less than 1,695.0 in 1997.Q4, which was the most turbulent quarter in the Asian financial crisis. Whether the depreciation of won would help or hurt the Korean economy depends on the relative impacts on aggregate supply and aggregate demand. On the one hand, won depreciation stimulates net exports because Korean-made goods are cheaper and more attractive. On the other hand, potential higher domestic prices reduce real income and wealth and shift aggregate demand to the left. Won depreciation raises the price of imported goods and services and shifts aggregate supply to the left. An open macroeconomic model may measure the net impact empirically.

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* Department of General Business, College of Business and Technology, Southeastern Louisiana University, Hammond, LA (U.S.A.). E-mail: yhsing@selu.edu

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Another development is the decline in interest rates in Korea and many other developing countries (Hsing, 2003). For example, the deposit rate decreased from 16.42% in 1998.Q1 to 5.58% in 2001.Q3 or 66.0%. Because of the relatively high saving rate in Korea, the loss of interest income for savers may be substantial. Less interest income is expected to reduce consumption spending. On the other hand, a lower deposit rate is expected to reduce the incentive to save and increase current consumption. The lending rate also dropped from 16.93% in 1998.Q2 to 7.52% in 2001.Q3. Because of the lower cost of borrowing by households and firms, it is expected to increase aggregate demand and real output. These different effects of lower deposit and lending rates may need to be examined in order to provide policymakers with useful reference.

The purpose of this paper is to analyze the impacts of won depreciation, lower interest rates, and other macroeconomic variables on Korean output. This study has several different aspects. First, the deposit rate and the lending rate are separated so that potential different impacts on real output can be measured. The conventional approach of using one representative interest rate may not capture potential behavioral differences for savers and borrowers. Second, to capture the dynamic nature of the impacts of monetary policy and won depreciation, the vector autoregressive (VAR) model is applied, and variance decompositions and impulse response functions are estimated and analyzed.

2. *Literature Survey*

Several recent articles examined the effects of currency depreciation or monetary policy on real output or other related economic variables. Edwards (1986) considered the real exchange rate, the money supply, federal government expenditures, etc. in an econometric model using a pooled sample of twelve developing countries during the period of 1965-1980. He found currency devaluations to have a contractionary impact in the first year, an expansionary effect in the second year, and no impact in the long run. He also showed that real GDP would rise if the deviation of actual money growth from the expected money growth increases or if the government spending as a percent of GDP rises.

Bahmani-Oskooee (1998) employed quarterly data for 23 less developed countries during 1973-1988 to examine the long-run relationship between devaluations and real output. Based on the full model with the real exchange rate in the regression, he showed that for most of the countries under study,

there is no cointegration between devaluations and real output. Barbados is the only exception.

Moreno (1999) studied the impacts of depreciation, the quantity of money, government spending, world output, and the real fed funds rate on real output and other macroeconomic variables based on the pooled data from 6 East Asian countries during the period of 1975-1996. The impacts on real GDP depend upon the selected sample periods and the econometric methodologies used. For the regressions concentrating on sharp depreciation episodes and banking crises with instrumental variables, depreciation of the real exchange rate has no effect on real GDP. Foreign output and real government spending are significant. Nominal M2 and the real federal funds rate are insignificant. However, in the OLS regression with the full sample, depreciation is contractionary.

Upadhyaya (1999) found that short-run and long-run effects of devaluations on real output for 6 selected nations are different. In the short run, devaluations raise real output for the Philippines and India but reduce real GDP for Pakistan. In the long run, currency devaluation has a negative impact on real output for Thailand and Pakistan and has no effect for India, Malaysia, the Philippines, and Sri Lanka. Based on the VAR model, Kamin and Rogers (2000) found that the peso depreciation in Mexico caused decline in real output and inflation and that it may be highly risky to target the peso to promote exports without paying attention to possible negative impacts.

There are several interesting recent studies using Korea as the sample or including Korea in the sample. Baig and Goldfajn (2002) showed that during the Asian financial crisis, a pure contagion effect was present and that Korea was vulnerable to the currency crisis. Soyoung Kim (2000) indicated that a shock of contractionary monetary policy results in won appreciation and a decrease in output in the short run and that monetary policy only plays a minor role in these variations. Hoffmaister and Roldos (2001) found evidence that output variation is mainly caused by domestic supply shocks. Chou and Chao (2001) found that the devaluation of won has a contractionary effect in the short run and is not effective in raising real output in the long run. Wilson (2001) reported that the real exchange rate affects real trade balance between Korea and the U.S., suggesting that won depreciation is expected to increase real net exports to the U.S. He also showed that a J-curve is found between Korea and the U.S. or Japan, indicating that after won depreciation, trade balance worsens off in the short run and gradually improves in the long run. Ginil Kim (2000) presented the empirical result that the prescription of a high interest rate policy for Korea by the International Monetary Fund did not cause the anticipated appreciation of won but led to won depreciation. On the

other hand, Dekle, Hsiao and Wang (2001) and Basurto and Ghosh (2001) revealed that during the currency crisis, the tighter monetary or high interest rate policy resulted in the appreciation of Korea won.

To the author's knowledge, few studies separated the deposit rate from the lending rate in the regression in order to measure potential different effects on real output. Because the impact of currency depreciation spills over to many sectors, its effect on real GDP may better measure the well-being of a country under study. Because short-term variation in real output is affected by several variables, a theoretical model needs to be specified. Due to the interrelationships among the variables in the regression and adjustment lags, a more dynamic model may need to be considered.

3. *Theoretical Model*

Suppose that consumption spending is a function of disposable income and the real interest rate, that investment spending is determined by the real interest rate, and that net exports are determined by the real exchange rate and world output. Real output is determined by the equilibrium in aggregate demand and aggregate supply and can be described by the following reduced-form equation:

$$Y = f(EX, IR, GE, TX, WO) \quad (1)$$

where

Y = real GDP;
EX = real exchange rate;
IR = real interest rate;
GE = real government expenditures;
TX = real government tax revenues; and
WO = real world output.

To relax the assumption of one representative interest rate for both savers and borrowers in Irving Fisher's intertemporal budget constraint, IR is replaced with the deposit rate for savers and the lending rate for borrowers. To reduce the multicollinearity problem because GE and TX are highly correlated, we combine TX and GE into the government deficit variable (DE) (Kamin and Rogers, 2000). The regression to be estimated can be expressed as

$$Y = f(EX, DR, LR, DE, WO) \quad (2)$$

where

DR = real deposit rate;
LR = real lending rate; and
$DE = TX - GE$.

The partial derivative of real GDP (Y) with respect to each of the right-hand-side variables is

$M(Y)/M(EX)$?
$M(Y)/M(DR)$?
$M(Y)/M(LR) < 0$
$M(Y)/M(DE) < 0$ or $= 0$
$M(Y)/M(WO) > 0$

As mentioned, won depreciation has positive and negative impacts on real GDP. The former may include more exports and fewer imports. The latter may comprise higher import or domestic prices, lower real income, lower real wealth, lower consumption spending, higher real interest rates, lower investment spending, outflows of funds, and higher cost of capital, among others.

For savers, an increase in the deposit rate is expected to have a negative substitution effect and a positive income effect on current consumption. The net impact is uncertain depending upon whether the substitution effect is greater or less than the income effect. In studying U.S. household consumption, Campbell and Mankiw (1989) found that the impact of an increase in the interest rate on savings is negative. However, Boskin (1978) showed the empirical result of a positive effect on savings. Most other studies reported that the effect is quite small. For households, an increase in the real lending rate is expected to have a negative substitution effect and a negative income effect on current consumption and real GDP. Therefore, the total effect on current consumption is expected to be negative. For firms, an increase in the real lending rate is likely to increase the cost of borrowing and reduce investment spending.

Theoretically, the sign of budget deficits, $DE = (TX - GE)$, is expected to be negative because an increase in budget deficits may be caused by a decrease in TX or an increase in GE or both. Aggregate demand will increase under either one of the cases. On the other hand, Ricardian's equivalence theory (Barro, 1974) indicates that the effect of deficit-financed government spending may be neutral in the long run.

4. *Empirical Results*

The data came from the *International Financial Statistics* published by the International Monetary Fund. The sample ranges from 1981.Q3 to 2000.Q3. Some of the data earlier than this period are not available. The real exchange rate is defined as the ratio of Korean won that one U.S. dollar can exchange divided by the ratio of the price in the U.S. to the price in Korea. Therefore, an increase in real exchange rates means depreciation for Korean won. The industrial output for twenty-two advanced countries is used as a proxy for world output.

The unit root is tested first. Based on the ADF test, one finds that each variable has a unit root in the level form but is stationary in the difference form. According to the Johansen cointegration test, the null hypothesis of one cointegrating relationship between real output and the right-hand side variables cannot be rejected allowing for linear deterministic trend in data with intercept and trend or with intercept and no trend. Thus, real GDP and the explanatory variables have a long-run stable relationship.

Table 1. Variance decompositions of RGDP

Period	S.E.	*Y*	*EX*	*DR*	*LR*	*DE*
1	1240.668	100.000	0.000	0.000	0.000	0.000
2	2102.120	73.675	21.426	0.752	3.991	0.156
3	2695.643	55.433	33.453	3.335	4.938	2.840
4	3428.256	36.855	47.284	9.626	3.853	2.382
5	3930.719	36.454	42.070	15.581	3.209	2.685
6	4366.778	32.234	39.600	21.899	3.980	2.286
7	4763.449	28.986	37.346	27.170	4.224	2.274
8	5225.644	25.419	36.071	32.206	4.331	1.974
9	5562.352	28.119	32.135	33.001	4.804	1.942
10	5821.156	28.554	29.770	33.001	6.890	1.785
11	6022.531	28.594	28.377	32.713	7.901	2.416
12	6208.024	27.764	28.224	33.012	8.137	2.863

Cholesky Ordering: *Y EX DR LR DE*

Estimated variance decompositions of real GDP based on the vector autoregressive (VAR) model are presented in Table 1. World output is regarded as exogenous. Based on the AIC or SC criterion, a lag interval of five quarters is selected. The real exchange rate accounts for up to 47.3% of the variation in real GDP. The real deposit rate can explain up to 33.0% of

output variance. Up to 8.1% and 2.9% of output variation can be attributable to real lending rates and real budget deficits, suggesting that both variables play minor roles. Variance decompositions may vary with the order of the variables. If the Cholesky ordering is rearranged as *Y*, *DR*, *LR*, *EX*, and *DE*, at the twelfth quarter, 43.8% of output variation can be explained by the real deposit rate whereas 17.4% of output variation is attributable to the real exchange rate. Therefore, we need to be cautious in interpreting variance decompositions in the VAR model.

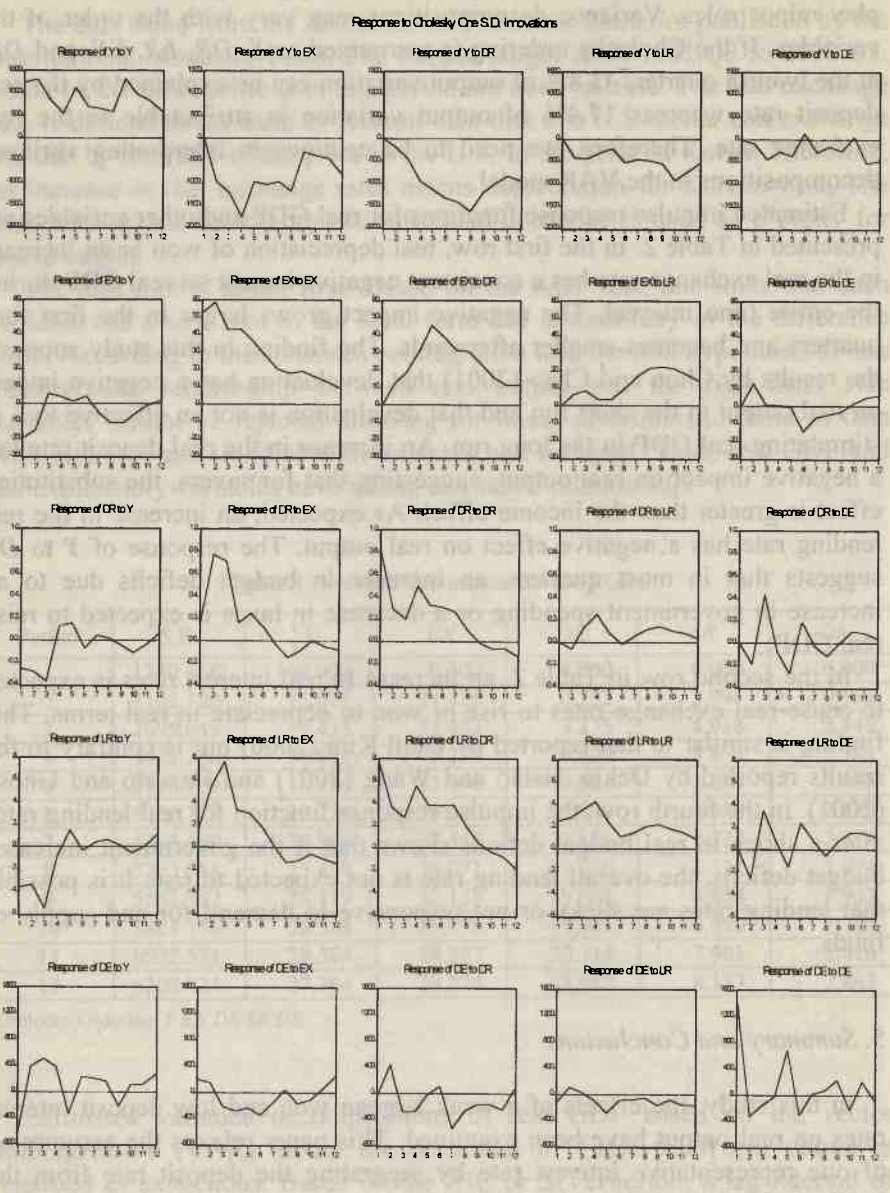
Estimated impulse response functions for real GDP and other variables are presented in Table 2. In the first row, real depreciation of won or an increase in the real exchange rate has a consistent negative impact on real GDP during the entire time interval. The negative impact grows larger in the first four quarters and becomes smaller afterwards. The finding in this study supports the results by Chou and Chao (2001) that devaluation has a negative impact on real output in the short run and that devaluation is not an effective tool in stimulating real GDP in the long run. An increase in the real deposit rate has a negative impact on real output, suggesting that for savers, the substitution effect is greater than the income effect. As expected, an increase in the real lending rate has a negative effect on real output. The response of *Y* to *DE* suggests that in most quarters, an increase in budget deficits due to an increase in government spending or a decrease in taxes is expected to raise real GDP.

In the second row in Table 2, an increase in real interest rates is expected to cause real exchange rates to rise or won to depreciate in real terms. This finding is similar to that reported by Ginil Kim (2000) but is contrary to the results reported by Dekle, Hsiao and Wang (2001) and Basurto and Ghosh (2001). In the fourth row, the impulse response function for real lending rates after a shock to real budget deficits shows that if the government increases budget deficits, the overall lending rate is not expected to rise. It is possible that lending rates are sticky or not responsive to demand for and supply of funds.

5. *Summary and Conclusions*

In this study, the effects of a weak Korean won and low deposit interest rates on real output have been examined. This paper relaxes the assumption of one representative interest rate by separating the deposit rate from the lending rate. Several major findings are summarized below. All the variables have unit roots in the level form but are stationary in the difference form.

Table 2. Impulse response functions



Real GDP and other variables are cointegrated. Won depreciation is expected to hurt real GDP mainly because the losses due to higher import or domestic prices and other adverse effects outweigh the gains in net exports. Lower deposit rates are likely to increase consumption spending because the substitution effect is greater than the income effect. An increase in deficit spending is expected to raise real output. The real deposit rate and the real exchange rate have greater influences on output variation than the real lending rate and real budget deficits.

There are several policy implications. The government may need to reconsider the use of won depreciation as a policy tool to stimulate the economy because the overall net impact is negative. The substantial decline in deposit rates appears to have had the effect of stimulating household consumption. During an economic slowdown or recession when actual real GDP is below potential real GDP, a tax cut or an increase in government spending may be considered to stimulate aggregate spending.

There may be areas for potential research. If the data is available, financial wealth may be included in the model. The recent decline in financial wealth may affect household consumption spending and firms' investment decisions. A general equilibrium model including more than one sector may be considered.

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ABSTRACT

Relaxing the assumption of one representative interest rate in Irving Fisher's intertemporal budget constraint and applying the VAR model, the author finds that higher real GDP is associated with won appreciation, lower deposit rates, lower lending rates, less taxes, more government spending, and more world output. Real exchange rates and real deposit rates play more important roles than real lending rates and real budget deficits in influencing the variation in real output. There is a long-run stable relationship between real GDP and other variables. For savers, the substitution effect is greater than the income effect, suggesting that an increase in the deposit rate is expected to reduce consumption spending.

JEL classification: *E5, E6, F4, H6*
Keywords: *currency depreciation, interest rates, variance decompositions, impulse response functions, VAR*