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THE SUCCESSFUL IMITATION OF THE JAPANESE LEAN PRODUCTION SYSTEM BY AMERICAN FIRMS: IMPACT ON AMERICAN ECONOMIC GROWTH

Abstract: This paper provides some quantitative evidence about the strong links between the Lean Production System (LPS) or equivalently the holistic Just-in-Time/Quality Control (JIT/QC) system and sectoral (micro) economic growth. This evidence is supported by qualitative arguments that present the LPS or the JIT/QC philosophy as a major and fundamental organizational feature of modern economies. Though the implementation of such a system originated in Japan, the USA have been in the process of catching up in the last fifteen years. Subsequently, recently published American sectoral data (for the period between 1958 and 1996) are used to provide ample quantitative evidence of the role the JIT/QC organizational philosophy played in shaping and leading the American macro and sectoral economies in the last 40 years. The implications for the theory of economic growth and economic policy are also briefly stated.

Key words: Lean Production, Just-in-Time, Quality Control, organization, American, Japanese, transaction costs, sectors, regression, error correction model, stationarity, total factor productivity, labor productivity, economic growth.

INTRODUCTION

"The Machine that Changed the World" (Womack *et al*, 1990) has been the lean production system (LPS), devised and implemented in Japan in the 1960s and 1970s, then transplanted in the USA in the late 1980s and 1990s. Whether this system is replacing the mass production system, as the authors strongly suggest, or not, is debatable and outside the scope of this paper. However, much research has taken place in the last 20 years to provide evidence of the benefits of the LPS to the Japanese and American economies. An equivalent system, which initially was extensively analyzed by authors such as Schonberger (1982, 1986, and 1996), and which is intrinsically related to the LPS is the Just-in-Time cum Quality Control (JIT/QC) system. Kenney and Florida (1993) in their extensive analysis of the transfer of the Japanese system of production to the USA summarized the LPS in three elements: efficient use of resources through the elimination of waste, low inventories, and just-in-time production and delivery practices (p. 8). In what follows I will mainly refer to the JIT/QC system, though this can easily be replaced by the LP system.

The transplanting of the initially implemented LP system to the American firms has been difficult and slow. It took about ten years from the late 1970s to the late 1980s before the American managers seriously decided to implement the JIT/QC system in a systematic and scientific way (a good reference in this respect are Liker *et al* 1999). The second section explores the chronology of imitation in some more detail.

In the first section of this paper I identify the JIT/QC system and unearth its importance. In the second section, I briefly trace the historical evolution and implementation of this system in Japan and the USA. Finally, in the third section I provide some ample econometric evidence as to the role of JIT/QC (and hence the LPS) in the growth and revival of the American economy.

A. JUST-IN-TIME (JIT) MANUFACTURING: IDENTITY AND IMPORTANCE IN ECONOMIC GROWTH

Historically, the JIT system became known to the Western world through the Toyota's rigorous implementation of JIT principles as these were developed by the two Japanese pioneers Taichi Ohno and Shigeo Shingo from the mid 1950s to the late 1970s. However, as Schonberger (1982, p. 17) remarked, according to his own sources, the shipbuilding industry was the starter of the JIT idea with inventories "…20 years ago…", and subsequently this idea spread to other Japanese companies; and all this took place before T. Ohno and others started writing about JIT in the mid-1970s.

However, it was mainly through Toyota's experience (and the other car producers) that in the 1970s, the JIT system spread rapidly to other industries. For instance, "…In the electrical industry, Matsushita (a much larger but less well-known company than Sony) developed its own version. Shingo thought that the Matsushita production system was better than Toyota's. Instead, of using *kanban* to signal the need for more parts between separated operations, Matsushita concentrated on placing operations next to each other so that there was no need for signaling…" (Harrison, 1994, p.180). Furthermore, it must be emphasized that QC in general has started in Japan immediately after the end of WWII; hence many Japanese companies were ready to adopt the complementary system of JIT later in their evolution.

A succinct but holistic definition of JIT is given in Harrison (1994, p.175). This author distinguishes three fronts of quest for excellence regarding the JIT philosophy or as it is also called 'Lean Production', or 'World Class Manufacturing':

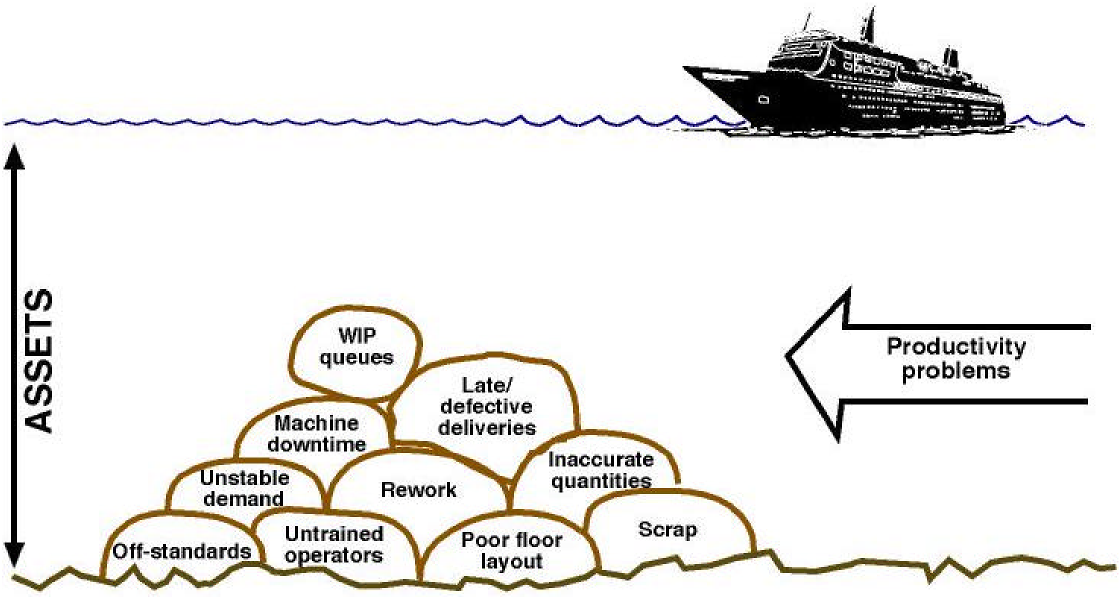
- Techniques, which are systematically put in place to attack all sources and causes of waste.
- Everybody is included and participates in the JIT process and management.
- Continuous improvement searches for the ideal case of zero scrap, defects, and inventories.

So, briefly the aim of JIT is to meet demand instantaneously with perfect quality and no waste. Hence, total quality management (TQM) or total quality control (TQC) and JIT are complementary strategies in order to excel in manufacturing. Since Total Quality primarily means that "…The customer is the next process…" (Ishikawa, 1985), the

JIT/QC course of action involves many areas of the production chain, and especially it involves the design part, sales/distribution, and the supply component.

The JIT/QC system can be part of the larger 'seabed' shown in the famous drawing in Figure 1 (Harrison, 1994). In relation to this figure Harrison (ibid, p. 190) comments: "…Problems such as late and defective materials and machine downtime (the rocks) have been covered with a sea of inventory so that the boat can float. Enforced improvement aims deliberately to confront the problems, and by finding solutions to the basic causes of the problems allow the water level to be reduced…" This reduction of the 'sea of inventory' is the very visible result that any efficient JIT/QC company achieves. Thus, it makes sense to use this gauge (reduction or not of inventories) in order to measure the efficiency of firms, sectors, industries and the whole economy.

Figure 1 The JIT/QC system in relation to the 'rocks' of organization



Source: (Harrison, 1994)

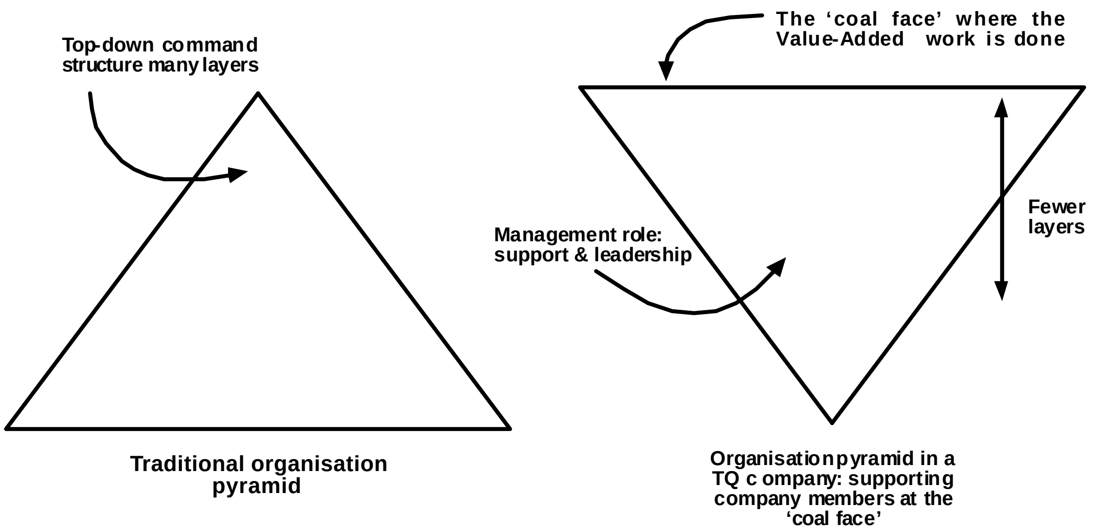
One of the experts on JIT/QC and operations management R. Schonberger (1986, p. 4) has described the following three major events during the history of American manufacturing management:

1. The beginning of scientific management around 1900 with the suggestions and experiments of F. Taylor, F. Gilbert and others.
2. The Hawthorne Studies of motivation at Western Electric, around 1930.
3. The beginning of JIT/QC implementation in some pioneering companies in the USA in the 1980s.

When Schonberger wrote this in 1986, it was still difficult to assess the importance of the JIT/QC system. However, almost 20 years later, as it will be shown in the next sections that system played a leading role in reviving and strengthening most industrial sectors in the USA, as well as accelerating economic growth in that country during the 1990s.

The impact if JIT/QC on manufacturing management can also be seen by examining the organization pyramid as it was properly shown in a diagram by A. Harrison (1994, p.196). This Figure 2 is reproduced below. This new organizational pyramid in a JIT/QC company can only work if there is cooperation at all levels of economic activities: between employees and employers, between employees, between managers, between the company and its suppliers, between the firm and other firms in the same industry or in the same industrial district or in the same *keiretsu.* With such universal cooperation, the motivation process of everybody increases with the aim to grow as much as possible by producing quality products.

Figure 2 Organizational pyramids



Source: (Harrison, 1994)

The JIT/QC system is actually as important as the mass production system has been in many countries especially since the advent of scientific management and Fordism in the USA and other countries. The two systems are not though unrelated to each other. For example, McMillan (1996, p. 285) remarked:

> *"…As it turns out, the Toyota system has theoretical origins in scientific management. More than fifty years ago, Taylor's student and assistant, Henry Gantt, developed planning tools which today look at the total production sequence in an attempt to develop assembly balancing techniques. The kanban system requires higher levels of fixed costs for additional tooling, materials handling, and factory layout, but operating costs are substantially lower than the traditional mass assembly system…"*

The following Table 1 summarizes the differences and similarities between the JIT/QC system and the non- JIT/QC system:

Table 1: Comparison between the JIT/QC and non-JIT/QC systems

Characteristics	JIT/QC System	Non- JIT/QC System
Labor division	Flexible work teams	Rigid work segmentation
Setting standards	Standardization methods	Standardization methods
Inventories	Low inventories (high stocks are a waste)	High inventories (large stocks add flexibility)
Discipline	Self-discipline of workers	Discipline imposed through strict hierarchical organization
Production runs	Small batch sizes	Long runs
Planning flow	Last stage first	First stage first
Set up times	Frequent	Infrequent
Operating control	Decentralized	Centralized
Interdependence	Increased	Lowered

Source: This table was based and adapted on information collected from various sources such as Harrison (1994), McMillan(1996), Schonberger (1982,1986,1996).

Another way of looking at the integration of the JIT/QC system within the overall Japanese management apparatus is through the way J.B. Keys *et al* (1994) suggested. As the authors remarked (p. 386):

> *"…If Japanese management practices are superior to Western practices, the advantages should be observable in terms of productivity, product quality, and the utilization of human resources…"*

This is exactly what happened after WWII in the USA and Japan but in different directions. The productivity and product quality and the utilization of human resources were much higher in the latter country than in the former.

One of the experts in QC, the author of "*Kaizen*" M. Imai in his second major book entitled "*Gemba Kaizen*" (1997) summarizes the relation between JIT/QC and benefits from its implementation as follows (p. 45):

> *"…Opportunities for cost reduction on-site may be expressed in terms of muda. The best way to reduce costs in gemba is to eliminate excess use of resources. To reduce costs, the following seven activities should be carried out simultaneously, with quality improvement being the most important. The other six major cost-reduction activities may be regarded as part of the process quality in a broader sense:*
>
> 1. *Improve quality.*
> 2. *Improve productivity.*
> 3. *Reduce inventory.*
> 4. *Shorten the production line.*
> 5. *Reduce machine downtime.*
> 6. *Reduce space.*
> 7. *Reduce lead-time.*
>
> *These efforts to eliminate muda will reduce the overall cost of operations…"*

Note that *muda* means waste and *gemba* means shop floor or work place in general. Quality refers to both process quality and *gemba* quality. The former includes the quality of work in developing, making, and selling products or services. The latter refers to managing resources and it includes the five M's, namely man, machine, material, method, and measurement. Although the author M. Imai does not advocate firing employees, the JIT/QC will tend to "…reduce the number of people on the line; the fewer line employees, the better…" (Ibid, p. 46). As I will show in the last section, this is exactly what happened to the leading sectors of the American economy in the 1990s, namely a substantial increase in productivity with a concurrent decrease in employment.

Overall, the system JIT is closely related to quality control procedures, such as TQC and quality control circles (QCC), as well as to other organizational systems such as the flexible manufacturing system (FMS) and computer-integrated manufacturing (CIM). The latter two are "…important tools for manufacturers moving toward the goal of mass customization" (Lau, 1995). In addition, the close link between JIT and TQC was immediately recognized by non-Japanese scholars (see for instance the classic book on this matter by Schonberger, 1982). In brief, the lower the inventories, the higher the quality of inputs used in the production process. As Coriat and Dosi (1998, p. 121) remarked:

> *"…Producing almost without inventories (of either inputs or outputs) implies that product quality of semi-finished products either ordered or received by core companies must be very high…"*

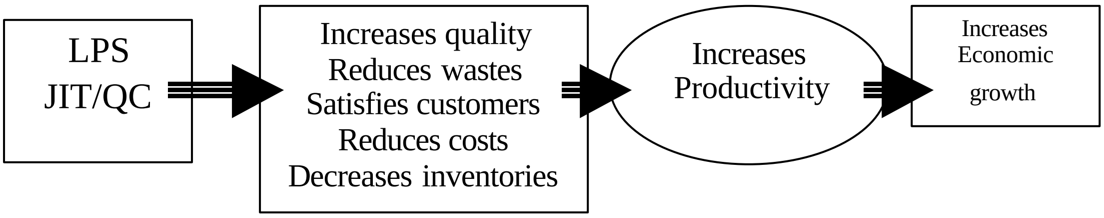
Furthermore, as M. Imai explains, the two aims of improving quality and reducing costs are not incompatible, and a JIT system encompasses both issues of cost and delivery. Once *kaizen* is started in *gemba*, shortcomings in upstream management will be identified in the process and eventually a good quality system will be in place, thus embracing everybody and everything in the company and also its suppliers. "…By eliminating all kinds of non-value-adding activities, JIT helps reduce costs…" (Ibid, p. 49).

I can now link this reducing costs JIT/QC process to a fundamental economic theory introduced by Coase (e.g. 1937, 1992). This author explains the 'black box' through the existence and impact of transactions costs. Indeed, the elimination of 'all kinds of non-value-adding activities' generated by the JIT/QC process reduces various types of transaction costs and raises productivity. The LPS not only reduces transaction costs and uncertainty between firms (hence outsourcing has been increasingly important), but also within firms. Also it is worthwhile noting that Coase's transaction costs contribution is re-enforced by the evolution of institutions set out by North (e.g. 1992) (also see Coase, 1992). However, overall, the increased importance of the JIT/QC system has not been sufficiently acknowledged by economists (Dietrich, 1993).

Further evidence of the substantial benefits the JIT/QC system offers to firms and eventually to the whole economy is provided by numerous other researchers. The following paragraph is just a small sample of this evidence.

McMillan (1985) in his book "The Japanese Industrial System" mentions that, "…Estimates vary, but amount may be as high as $500-$700 per car, depending on how various factors are aggregated…" (p. 218). Kim and Takeda (1996), tested in their study the hypothesis: "The implementation of a JIT system will not improve the effectiveness of the production control management system", and found that, like numerous other authors, JIT techniques are effective in promoting productivity. Kobu and Greenwood (1991) remarked: " Increased living standards in industrialized nations and some of the developing countries have made customers more selective. One component of this new competition is that many markets are being quality driven rather than price driven…". Hence, the role of the JIT system is paramount in this respect (p.58). Abbeglen and Stalk's (1985) book is of course always a good source to quote for the contribution of the JIT/QC system to the Japanese economic growth.

The following schema summarizes the relationship between the LP or the JIT/QC system and economic growth.



Furthermore, this schema implies that the traditional growth models, endogenous or not, should also incorporate this new factor influencing the production function, namely organization. Thus, this function (Y) should have at least four components: the quantities of labor (L), physical capital (C), human capital (H), and organization (O): Y = f (L, C, H, O). A formal analysis of this new growth function is, of course, outside the scope of this paper.

B. IMPLEMENTATION OF THE JIT AND TQC SYSTEMS IN THE TWO COUNTRIES JAPAN AND THE USA

a. Implementation of the JIT system in the two countries. Chronology, industries, and penetration.

JIT is mainly used in the continuous flow industries: iron and steel, metal products, consumer electronics and electrical machinery, automobile, precision instruments, and chemical products (see for instance Kim and Takeda 1996, Billesbach 1991, Billesbach *et al* 1991, Billesbach and Schniederjans 1989, Billesbach and Hayen 1994, Meric I. *Et al* 1997). To a lesser extent JIT can also be applied in process facilities like those of a textile industry (Billesbach 1994), or to any other industry, which makes customized products such as furniture items (Golhar and Stamm, 1993).

A couple of initial experts on the Japanese innovation of JIT, Abegglen and Stalk (1985) said "…Toyota began development of the Just-In-Time system in the late 1930s and made substantial progress in its implementation in the 1950s and 1960s…" (p.93). However, some sources proposed that JIT also started with the shipbuilding industry in the early 1960s (Schonberger, 1982, p. 17). The two writers Abegglen and Stalk (1985) also talked about the crucial relation between factory and suppliers: "…In Japan, the pattern has been for the factory to implement JIT first, then for the suppliers to follow. By 1962 Toyota had instituted JIT systemwide. Only then did it approach its suppliers. Another ten years passed before the JIT system had spread to all of Toyota's suppliers…(p. 115). Overall, we can say with safety that the Japanese firms have started imitating the pioneer Toyota in the system of JIT from about the early1970s.

On the other hand, it is only in the 1980s that JIT became noticeable and applicable by American firms (see, for example the story of Oregon Cutting Systems company, one of the pioneers of JIT in the USA, as described by Bailes and Kleinsorge, 1992). In his classical book on JIT written in 1982, Schonberger said: "…In one sense it is a bit early to write about just-in-time manufacturing management in the United States. JIT has scarcely been tested here…On the other hand, the Japanese already have at least ten years' head start- and much more if one considers Japan's long history of adaptation to its environment of resource scarcities…" (p. 83).

What is the penetration of JIT usage in Japanese industries? According to Kim and Takeda (1996), a survey of 81 usable questionnaires revealed the following results.

JIT adoption	**% Of Respondents**
Partly JIT firms	11.11
Totally JIT firms	44.44 (mainly automobile and consumer electronics industries)
Non-JIT firms	41.98

Source: Kim and Takeda (1996)

As I have already mentioned, in the USA, it is only in the 1980s, that TQC and JIT started being implemented by an increasing number of firms. It is for this reason that when Billesbach and Hayen (1994) compared the effect of JIT in the long term for 28 American companies, they examined data between the last three years of the 1970s and the last three years of the 1980s. Overall, it seems that the Americans have been behind the Japanese regarding the implementation of JIT by around 10 to 15 years, though this gap is now closing more rapidly.

According to a 1993 study by Baldwin R. and Gagnon R. J., the following results (Table 2) were obtained from their survey of 200 large Ohio firms (the state of Ohio is part of the Midwest, the industrial heartland of the USA). This sample was representative of both US and Japanese owned and operated manufacturing companies (eg Honda of America). Note that 100 firms were labeled purchasers and were drawn from the SIC end product industries 35, 36, and 37. The vendors were 100 firms drawn from the raw materials and parts industries (SIC 28, 29, 33, and 34).

In this Table 2, it can be seen that the penetration of JIT in American firms by 1993 was about 35% (at least for the larger firms). This figure is confirmed by another study conducted by Stamm and Golhar in 1991, according to which 29 out of 77 respondents (that is 37.7%) identified themselves as JIT firms.

Table 2: Percent of Firms with a Modified Use of Japanese Principles

Principle	**Purchasers**	**Vendors**	**Combined**
Reduction of vendors	41	52	47
Quality certification	44	48	46
Quality circles	49	38	43
JIT	33	40	37
Ringi	33	38	36
Long-term employment	26	29	27
Firms with usage of at least one principle	77	85	81

Source: Baldwin R. and Gagnon R. J, 1993

From the above information we can form the following diagram regarding the evolution of JIT implementation in the two countries:

Japan

Toyota started Many other companies followed progressively more

1950 1960 1970 1980 1990

USA

Absent Start Spreading out

1950 1960 1970 1980 1990

b. Implementation of the Quality Control systems in the two countries. Chronology, industries, and penetration.

A recent detailed study of the evolution of "Quality Movement" in the USA, and in comparison to Japan by one of the experts in this field R. E. Cole (1998) clearly shows how the Americans have been trying to introduce and implement various quality control systems in the USA. According to Cole, "…quality means maximizing organizational behavior to enhance the satisfaction of present and potential customers" (p. 43).

There are two ideal types or paradigms of quality, as table 3 summarizes (ibid, pp. 43-44). In 1980, most large US manufacturing companies followed the old quality paradigm, whereas the leading Japanese firms had already begun to assume more of the features of the new paradigm, which was developed in Japan between 1955 and 1980 (ibid, p.45). Let the author summarize the situation in the early 1980s:

"…For a great number of large and medium size American manufacturing firms across a broad array of industries (from air-conditioning to autos, from consumer electronics to computers, from copiers to color televisions, from steel to semiconductor equipment, and from metal fabrication to machine tools),

especially those subject to international competition, the pressures to find a competitive response to the Japanese became incredibly intense. In almost all these cases, observers documented a major quality gap between US and Japanese companies in the early 1980s…" (p. 45).

Table 3: Comparison of the two quality paradigms

OLD PARADIGM	NEW PARADIGM
Internal orientation stressing conformance to requirements	Internalize external customer preferences
Just one of many functional specialties	A common corporate-wide language of problem identification and problem solving
Not seen as a competitive element as long as you match your competitors	A strong corporate competitive strategy
A specialized function carried out by a small number of experts reporting to operations	All-employee involvement in quality improvements
Emphasis on downstream fixes	An upstream prevention focus
A limited repetitive cycle of detect and repair	A well-defined problem-solving methodology
A stand-alone effort, with each functional specialty acting to maximize its own goals	Training activities tied to continuous quality improvement
Based on whether a product or service is built or delivered according to agreed-upon standards	Integration of quality into the corporate-wide control system of goals, plans and actions
	Emphasis on cross-functional cooperation to achieve quality improvement objectives
	Anticipation of customer needs sometimes even before customers are aware of them

Source: Adapted from Cole, 1998

So, how did the American business world respond? Already, in the 1970s, Japanese competition in sewing machines, cameras, watches, and colour TVs have provided the Americans with some good examples of the actual Japanese threat (for instance, the whole American industry of colour TVs was lost to the Japanese during that period. The late 1970s and early 1980s was a period of denial, a slow theoretical and ineffectual debate between the gurus of quality movement (Deming, Juran, Crosby, Feigenbaum, Ishikawa), and slow trial-and error process of tactics for quality control (ibid). However, from the late 1980s and early 1990s, more productive efforts took place, as this was testified by the proliferation of a large institutional network of users, consultants, and other non-market players. Cole analysed seven such organizations, for example, the 1987 established Malcolm Baldridge National Quality Award, the American Supplier Institute whose activities took off in the late 1980s, and the American Society for Quality (ASQ).

For the ASQ, the membership grew as follows (Cole, 1998):

YEAR	NUMBER OF MEMBERS
1979	32000
1988	57000
1997	133000
2000	187000

As Cole testifies, similar trends occurred with the other organizations (ibid). Regarding the ASQ again, the July 2000 report on the readership of their journal "Quality Progress" shows the split of readers into various manufacturing industries as follows (Table 4).

Table 4: Readers of ASQ

SIC Industry	Name of Industry	QP Readers	%
3000	Rubber and Plastic	14424	11.3
3300	Primary Metal	9616	7.5
3400	Fabricated Metal	21636	17.0
3500	Industrial Machinery	9616	7.5
3600	Electrical/ Electronic	26444	20.8
3700	Transportation	12020	9.4
3800	Measuring Instruments	14424	11.3
3900	Miscellaneous	19232	15.1
		127412	100

Source: ASQ, Quality Progress, July 2000.

At the end of this long process of the American Quality movement, what are the results? Let Cole again summarise his findings (ibid, p. 44 and 70):

"…By the mid-1990s, US firms significantly narrowed (and sometimes closed) the quality performance gap with the Japanese across a broad range of manufacturing industries, such as autos and semiconductors…By the mid- and late-1990s, quality disappeared as a major topic in the media and was less and less a focus of top management's attention. This is a natural process manifested in the growing normalization of quality improvement as a management activity…"

Another less recent article written by a well-known scholar, P. Senge in 1992 (which appeared again in part in the same Journal in 1999) has a similar view on the evolution of the Quality movement in the USA and Japan. This author distinguishes three stages in quality and learning. The primary focus of the first wave has been the front-line workers, and the aim was to champion continual improvement and remove impediments such as quality control experts. This stage has been replaced by the second wave in Japan from the 1980s. The primary focus of this latter wave has been the managers themselves and the aim was to shift the changes from improving work processes to improving how we work. Quality circles and *kaizen* are an important part of this second stage. The third wave is a blend of the previous two waves. US industry was operating primarily in the first wave by 1992, and hence the goal of continuous improvement was still an elusive target for most American corporations. To illustrate this elusive target we can use for example Shroeder and Robinson's remark (1991) that in 1986, Japanese companies received almost 48 million improvement proposals from their employees, while their counterparts in the USA received about one million (p. 74).

N. Kano, a student of Ihikawa, and an expert in quality management, has been visiting the USA since 1977. In his article of 1993 he expressed similar views to the previous two authors. Thus he wrote: "…during the past 10 years, American improvement efforts, including TQM, have gradually led to good results in some industries…" (p. 29). For example, in the steel industry, in parallel with new technologies brought into the industry in the late 1980s, TCQ and a better-qualified workforce have been introduced and extensively implemented by most American steel makers (Dinnen, 1992).

For Japan, S. Watanabe in his 1991 article wrote: "…Scientific quality control methods were introduced in pre-war Japan by the National Railway Corporation, navy arsenals and pioneering private sector companies such as Toshiba…" (p. 61). The term "quality" means anything that can be improved. In 1958, a study team brought back from the USA Feigenbaum's concept of TQC. In 1962, the JUSE (Japanese Union of Scientists and Engineers) launched its quarterly QC Circle Magazine (QCCM) and urged industries to organize workers into small study groups. Today, Watanabe remarks, "…Japanese workers often discuss subjects related to their quality circle activities during a tea break, at lunch time or at an after-work social gathering…" (p. 62).

How much did QC circles spread in the Japanese economy since 1962? Table 5 shows the trends for registrations at QC Circle Headquarters, 1962-90.

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Table 5: Growth of the numbers of QC circles and participants

Year	QC Circles	Participants
1962	23	
1965	4930	70920
1970	33499	388543
1975	72475	723201
1980	115254	1062759
1985	223762	1831299
1990	313924	2454635

Source: Watanabe (1991)

QC circles are only one side of the Qua lity movement in Japan. TQC started earlier and spread earlier. As Goldman (1993) said: "…The transported TQC philosophy radically transformed Japanese organizations (such as Toyota, Nissan, Sanyo, Matsushita, Mitsubishi) during the 1960s, 1970s, and 1980s…In sharp contrast, US and European implementation of TQC did not surface until the late 1970s and early 1980s…" (p. 32). To illustrate this contrast, a comprehensive study sponsored by Ernst Young and the American Quality Foundation in 1991 has confirmed the Japanese superiority in terms of quality control vis-à-vis the USA, Germany, and Canada (Bowles 1992, Yearout 1992).

C: ECONOMETRIC EVIDENCE

Lieberman and Demeester (1999) in their abstract said: "…The literature on JIT production suggests a ca usal link between work-in-process inventory and manufacturing productivity. Such a connection has been described in numerous case studies but never tested statistically. This paper uses historical data for 52 Japanese automotive companies to evaluate the inventory-productivity relationship…" These two authors used mainly Granger causality tests to find that a significant elasticity of about –0.1 (see below for interpretations) applies to that relationship. In my paper, I will attempt to provide a more general and comprehensive evidence of causality between economic growth (as represented by total factor productivity (TFP), production per capita and so on) and the LPS or it equivalent JIT/QC system (as represented by the inventory to shipments ratio).

1. Simple regression analysis (OLS)

i) A cross 28 sector analysis regarding TFP

I used two databases: the UNIDO ISIC 3-digit sectoral data from 1963 to 1997 (updated version 2000) and the NBER 4-digit 459 sectoral data from 1958 to 1996 (June 2000). The UNIDO data are supposedly consistent through countries and are recorded according to the ISIC 3-digit classification (28 manufacturing sectors). They include the series of employment (E), value added (VA), index of industrial production (RO), nominal output (NO), and nominal wages and salaries (W). For the calculation of TFP based on UNIDO data, I used the real capital stock (CS) from the NBER publication (2000), and the intermediate inputs or materials (M) were computed as the difference between nominal output and value added.). For the calculation of TFP based on NBER data directly, I transformed the initial 459 sector TFP series into the 85 sector and then into 28 sector TFP series.

The TFP (UNIDO-based) was calculated for each year from 1964 to 1997 according to the following formulation:

$$TFP' = RO' - w_1 E' - w_2 M' - (1 - w_1 - w_2) CS'$$

The variables $TFP', RO', E', M', CS', \ldots$ are computed as the first differences in natural logarithms of these variables, thus expressing rates of growth. The weights w_i are the averages of each pair of years for which TFP is computed. For example:

$W_{t1} = ((W/NO)_t - (W/NO)_{t-1})/2$

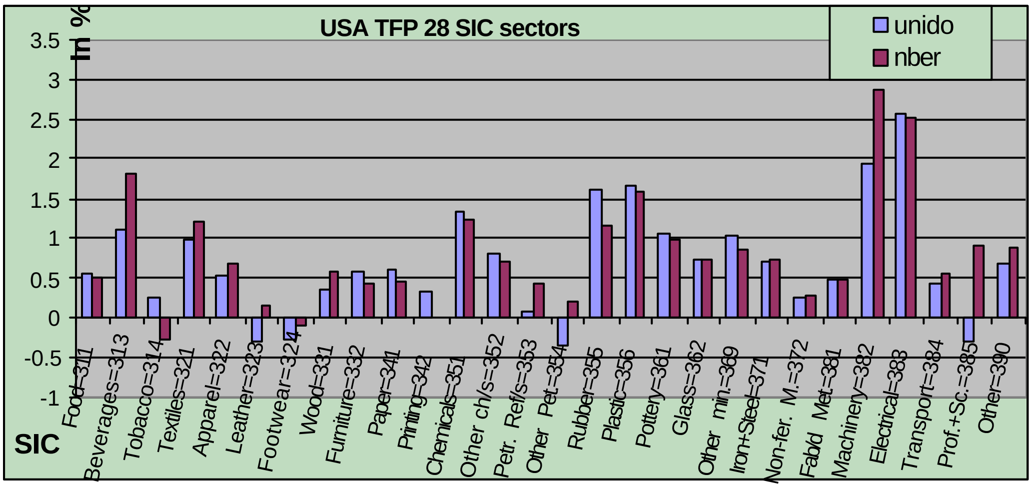
These formulae are consistent with Jorgenson's work (1990,1995, 2000). Hence, TFP is calculated according to the gross output formula so that it includes the impact of materials and not according to the value added formula that excludes the impact of materials. However, my results and conclusions would not be significantly different when using either of these formulae (the value added formula usually gives TFPs which are about double of those TFPs when using the gross output formula).

The TFP thus calculated for the UNIDO data are very similar to those I computed according to the NBER publication (2000). There are, however, some noticeable differences for a very limited number of sectors such as the "Scientific Instruments" one (ISIC 385), for which there is a definite break (perhaps error in data) in the series of employment etc. Nonetheless, the distribution of TFP across the 28 sectors remains unchanged in terms of relative magnitude (see Figure 3). It is also worth noting that Jorgenson's and Stiroh's (2000) calculated TFPs for the 2-digit SIC sectors, which are very similar to mine, at least in terms of their magnitudes' distribution.

In order to explore the relationship between TFP and JIT/QC I regressed the cross sectional data of 28 TFPs (in %) with the rate of decline or growth in the ratio of inventories to shipments (INVR) (in %), which is a good proxy for the implementation of

JIT cum TQC systems (see sections A and B). The use of this proxy follows from the extensive discussion in the previous sections where it was found that the JIT innovation could only be successful if it is implemented within a more general framework of TQC, Kaizen, and employees' active participation, in other words this proxy is an inherent and integral part of the LPS. In addition the end-of-the-day aim of JIT management is to reduce inventories as much as possible.

Figure 3



Source: My calculations based on the UNIDO (1999) and NBER (2000) data bases.

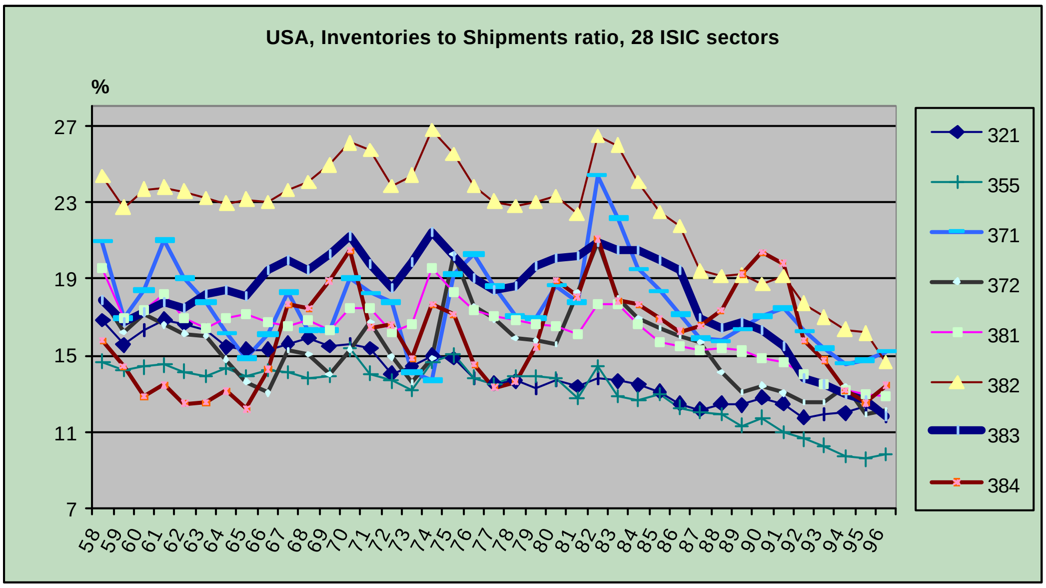
Figure 4 exhibits some selected sectors in terms of their INVR from 1958 to 1996. Although not all the sectors are shown in Figure 4, the tendency has been the same for all of them, that is, either a reduction in the ratio of inventories to shipments consistently since the middle of the 1980s or a constant ratio. In Figure 4, one can also see that the impact of the so-called business cycle on the inventories ratio was not significant in the 1990/91 recession as it was in previous recessions (e.g 1974/75 or 1981/82).

Three periods were examined, approximately around 11 years each, and each one containing a major depression (the 1974/5 one, the 1980/82 one, and the 1990/91 one). According to the evidence brought in the sections above, an increasing number of American firms started implementing TQC and JIT in a more systematic way from the second half of the 1980s. The econometric results are shown in Table 6.

As expected, during the period 1964-76, the LP (JIT/QC) system as represented by the variable INVR had no contribution at all to the growth in TFP. Also, during the period 1977 to 1986 TQC and JIT were almost absent in the American economy and hence no contribution of these systems to the TFP took place during this time, though the improvement in the regression is noticeable (the coefficient of INVR has the right sign and the t-statistic is greater than that for the period 1964-76).

On the contrary, and as expected, during the period 1987 to 1997, and according to the analysis of the previous sections, the TQC and JIT implementation in many firms and sectors of the American economy has significantly contributed in the acceleration of TFP.

Figure 4



Source: My calculations based on the NBER (2000) database.

I also used in a similar manner the TFPs for 85 sectors, which I calculated from the original NBER 459 SIC sectors (2000). The results of the regression are also shown in Table 6 (regression (6)). These findings for a much larger (N=85) sample significantly confirm the results of the regression with 28 sectors. Furthermore, note that similar results were obtained as those above when the NBER 28 ISIC 28 sector based estimated TFPs were used instead of those UNIDO based TFPs.
Furthermore, I also used the TFP calculations based on the value added (VA) formula directly:

$$TFP = VA - wE^{'} - (1-w)CS^{'}$$

I tested the regressions (1), (2) and (3) with this value added based formula. The results are once more confirming the story so far. For example, considering the 1987-96 period, the relevant results are also shown in Table 6 (regression (5). Note that the VA based TFP is much larger in magnitude than the gross output based TFP, and hence the constant as well the SEE are also accordingly much larger.

In this section, the contribution of the JIT/TQC will in addition be examined in the context of a more general model in which more variables are included in order to take into account other important influences such as competition, technology, and labor replacement. For the period 1987-1997, the results are shown in Table 6 again (regression no 4).

For this regression, the variables TFP and INVR are defined as before. The variable DEFL is the actual gross output deflator and represents two important factors: the degree of competition in the industry, and the level of technological innovations. The higher the change in producer prices (DEFL) is during the period 1987-1997, the lower the competition within the sector. For instance, some of the least competitive (in the sense of being more oligopolistic in nature or facing more substitutes) industries also exhibit some of the highest price increases; these industries are tobacco, wood, chemicals, plastics, and non-ferrous metals. On the contrary, some of the most competitive sectors show low levels of price increases; these sectors are textiles, apparel, fabricated metals, non-electrical machinery (mainly computers), and electrical machinery (mainly semiconductors). The latter two sectors also exhibited a high level of technological improvements, which, nonetheless, are not always clear as to their effects on prices (a good example is the chemicals with continuously innovating technologies either in terms of new products or in terms of new ways of manufacturing).

The variable LAB shows the changes in the labor input over the period 1987-97. It represents two tendencies; first the internal (within the firm) changes in organization of labor and capital (e.g. less labor is needed because of the implementation of the JIT system), and second the external (outside the firm but within the sector) changes in organization (e.g. less labor is needed because of fewer firms operating within the sector). A perusal of the relevant data shows that the competitive industries of all types of machinery either increased employment only marginally or even reduced employment (as in the electrical machinery sector).

The variable DUM is a dummy one to take into account the errors in the data for the sector 385 (precision instruments) as it was already mentioned above. The exclusion of this sector leaves the coefficients of the regression (4) unchanged, which further confirms the peculiar 'behavior' of this industry. Also note that both the employment data from the NBER and the UNIDO bases were used in the regression (4), in order to check the validity of the results. The latter remained unaltered despite some differences in the two series (again the sector 385 exhibited the greatest difference between the two labor series). Finally, it must be emphasized that the coefficient of the variable INVR is much more significant in this enriched regression (4) than in the previous simple regressions. This once more confirms the importance of the proxy for JIT/QC, as it was analyzed in detail above.

The comparison between the three periods in terms of average quantities (weighted averages did not alter the results) across the 28 sectors will further clarify my assertions. The following Table 7 and Figure 5 summarize the findings:

Table 7: Comparison of the 3 periods TFP and other variables

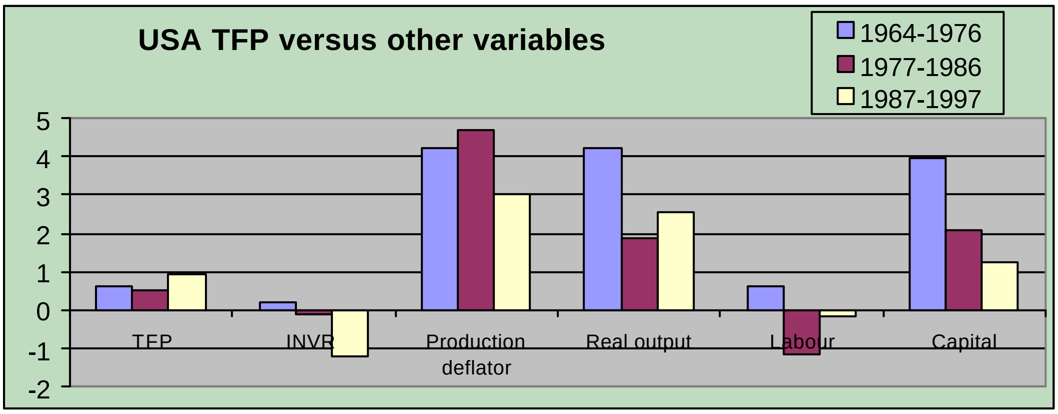
Variable	**1964-1976**	**1977-1986**	**1987-1997**
TFP	0.62	0.54	0.94
INVR	0.21	-0.12	-1.21
Production deflator	4.21	4.70	3.00
Real output	4.21	1.90	2.56
Labor	0.65	-1.15	-0.16
Capital	3.99	2.07	1.23

Source: My calculations from the primary NBER, 2000 Data Base.

Table 6 Simple cross sector OLS regression results

Dependent	TFP 64-76 (UNIDO derived TFP)	TFP 77-86	TFP 87-96	TFP 87-96	TFP 87-96 (VA based)	TFP 87-96 (NBER based)
N	28	28	28	28	28	85
Regression No	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	**0.61**	**0.53**	**0.37**	**1.84**	**1.56**	**0.27**
t-stat	4.4	2.7	1.3	8	4	1.56
INVR	**0.034**	**-0.113**	**-0.47**	**-0.39**	**-0.48**	**-0.497**
t-stat	0.31	0.84	3.4	5.1	2.4	6.58
DEFL				**-0.49**		
t-stat				9		
LAB				**-0.086**		
t-stat				1.65		
DUM				**2.49**		
t-stat				3.9		
R^2	0.004	0.027	0.3	0.86	0.19	0.34
SE	0.73	1.05	1.16	0.56	1.65	1.37
SD of dep/t	0.72	1.05	1.36	1.36	1.79	1.68
Diagnostic tests (p-values)						
Serial cor/n	0.21	0.54	0.9	0.29	0.76	0.28
Functional	0.18	0.18	0.01	0.16	0.35	0.000
Normality	0.001	0.91	0.43	0.87	0.9	0.000
Heteros/ty	0.48	0.78	0.000	0.46	0.5	0.000

Figure 5

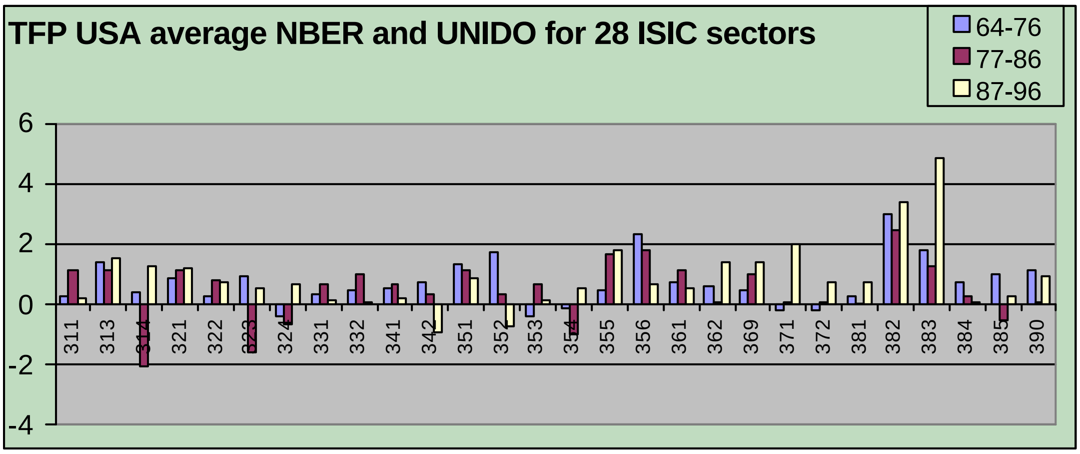


Source: My calculations are from the primary NBER, 2000 Data Base.

The above Table and Figure reveal some interesting results. The sharp increase in TFP during 1987-1997 is accompanied with a sharp increase in JIT and TQC (which in turn are represented by the inventories to shipments ratio). At the same time, competition has also increased during 1987-1997 as this shown by a significantly smaller increase in producers' prices (though there are other factors involved). In addition, capital has not increased as much as it has in the previous two periods, which suggests that TFP was mainly the outcome of JIT/QC and competition. Furthermore, labor has decreased in the same period, which indirectly indicates that again JIT/QC was the central issue at stake during the period 1987-1997. The latter point is confirmed by Brox and Fader (1997), who empirically found that JIT firms are more labor and materials saving than non-JIT firms. Finally, noting that the use of Internet became noticeable only from about 1997-8, and hence the impact of Internet on output and TFP growth can only be assessed from that year onwards further reinforces the above conclusions, as my regressions are based on the period ending in 1996.

Confirmation of these important findings can be made by looking into the evolution of TFP across the three periods and across the 28 sectors. The Figure 6 shows the relevant data. The main increases during the most recent period 1987-1996 took place in the SIC categories of 371, 372, 381, 382, 383, 362, and 314, thus confirming the leading role most of these sectors have been playing in the recent American economic revival. Also note that these key sectors 371, 372, 381, 382, and 383 experienced most of the applications and implementations of lean production processes such as JIT and QC. Furthermore, the economic revival, which took place in the last period from 1987 to 1996, despite a prolonged world recession (especially in Japan), has been coincided with a revival in all sectors (apart some exceptions). This shows that only when most or all sectors innovated in terms of JIT/QC during 1987-1996, only then overall economic growth took place again. Nonetheless, this revival was accompanied by the leading role the two sectors of 382 (mainly computers) and 383 (mainly semiconductors) played during this latter period.

Figure 6:



Source: see previous figure

ii) A pooled 28-sector analysis for TFP and JIT/QC (420 data)

Since 28 data is usually considered a small sample and hence is subject to much criticism and doubts, another way to bring valid quantitative evidence to my theses is to pool all 28 sectors together, thus forming a very large sample. The TFP of 28 sectors will now be pooled together and truncated to the period 1982 to 1996, during which the American industries have been gradually imitating the Japanese ones in terms of JIT/QC. Another reason for the choice of the 1982-year is that we have detailed census data on 3-digit establishments from 1982 to 1997 (every 4 years). The number of data is very large (420).

This TFP series will be regressed against a certain number of organizational and economic features of the 28-pooled sectors. Most of these variables are related to the number of establishments for each sector, thus taking into account the effect of small or big firms, changes in employment, industrial concentration, and so on (see also Sanidas, 2001, for the importance of the number of establishments in economic growth). One of these variables is the inventories to shipments ratio like above (INVR), which represents the lean production system (LPS). The variable SDLE is the standard deviation of the ratio employment to establishments in the period 1982 to 1997 for each sector. The variable IMEX is the ratio of imports to exports in 1992. The variable SDMEST is the average ratio of standard deviation to mean of establishments from 1982 to 1997. The variable MEANLE is the mean of the ratio employment to establishments in the period 1982 to 1997. The variable MATSHI is the annual change in the ratio of materials to shipments. Finally, the variable DUM is a dummy to take into account some outliers in the TFP series (out of 420 data, about a dozen outliers were detected).

The results of this regression are shown below.

$$TFP = \underset{6.3}{0.012} - \underset{9.0}{0.14} * INVR + \underset{6.4}{0.0022} * SDLE + \underset{2.5}{0.0014} * IMEX - \underset{5.3}{0.0018} * SDMEST -$$

$$-\underset{5.6}{0.0002} * MEANLE - \underset{4.3}{0.19} * MATSHI + \underset{16.8}{0.083} * DUM$$

$R^2 = 0.51$ SE = 0.022 SD of TFP=0.031 DW =1.84

The diagnostic tests of serial correlation, functional form, normality, and heteroscedasticity showed no reasons for concern. The figures below the coefficients are the T-ratios and show that all variables are significantly different from zero. The coefficients have the right signs. In particular the INVR variable is definitely significant, and has the negative sign as expected. If the variables MATSHI and DUM are dropped from the regression the remaining variables remain significant and their coefficients are unaffected. My aim is not to analyze here the significance and relevance of all variables in the regression but to re-enforce the results I obtained in the previous sub-section regarding the paramount role the LPS has played in the revival of the American economy in the last 15 years or so. The proxy variable INVR that is inherently linked with the LPS and the JIT/QC is once more undoubtfully significant.

iii) A pooled 28-sector analysis of JIT/QC and various variables (1008 data)

This time I will take the whole sample of the 28-pooled sectors, thus forming a very large set of 1008 data (28 times 36 years, from 1961 to 1996). The aim in this sub-section is to explore the possibility of integrating the proxy variable INVR (called IRY from now on) in the set of other important economic variables such as labor productivity etc, thus excluding TFP (this exclusion is due to the fact that TFP is a function of labor productivity and the capital to labor ratio).

The Table 8 contains the results of simple OLS regressions, for the 1008 data, relating each one of the endogenous variables YL, ML, KL, PY, and IRY to each other, and to the exogenous variables UN, PKPL, INT (all of them expressed as growth rates). The table 9 summarizes the definitions of all these variables. YL, ML, KL constitute together the classical determinants of economic growth, the PY represents the price component, and the IRY represents the mode of organizational production. Each one of these five variables is influenced by all others, but not in a simultaneous way. They are also influenced by the factors UN standing for business fluctuations or cycles, PKPL standing for the relative scarcity of capital and labor, and INT standing for the monetary policy of the American government.

The variable of immediate interest to me is the IRY one. Its coefficient is significant for all regressions and has the right sign at least for YL, and PY. Note that the YL regression is perhaps the most important to observe as it links labor productivity with the LPS proxy IRY. Also the lagged one year IRY1 and two year IRY2 seem to be significant in some regressions.

Table 9: Definitions of variables

YL	Nominal production per employee (=the classical labor productivity)
ML	Nominal materials per employee (=labor productivity for materials)
KL	Nominal capital per employee (=the classical capital labor ratio)
PY	Deflator of the shipments series
IRY	The ratio of inventories to shipments (=proxy for the JIT/QC system)
UN	Unemployment (=total number of unemployed in the economy)
PKPL	Ratio of capital to labor prices (=investment deflator over the ratio of payments to labor divided by the total number of employed people)
INT	Rate of interest

All these variables except the rate of interest (which is already given as a percentage change) are expressed as first differences in natural logs.

2. Two stages least squares regression analysis (2LS)

Still using 1008-pooled data, this time my aim is to explore the possibility of the integration of IRY into a system of simultaneous equations containing the variables used in the previous sub-section. These five variables are now simultaneously determined and also influenced by the three exogenous variables UN, PKPL, and INT. Though I do not have a set of adequate proxies for the endogenous variables I used the available UN, UN1, INT, IRY1, IRY2, PKPL, PKPL1, PKPL2, KL1, YL1, and ML1 (UN1 means UN lagged one year). Despite this inadequacy, the method of two-stage LS would still provide us with some estimates to compare with simple OLS ones. The Table 8 shows the results of these two-stage least squares regressions.

Again, the variable of immediate interest to me is the IRY one. Its coefficient is almost significant for YL, very significant for PY and has the right sign at least for YL, and PY. Note, that the magnitude of the coefficient of IRY in the YL regression is almost the same as that for the simple regression.

Note, that the coefficient of IRY for YL, in both the simple and two-stage LS regressions (around -0.13), is lower than that for the 28 data models of the period 1987-96 examined above, a result which is expected as the YL regression covers the whole period of 1958 to 1996. However, it is remarkable that the elasticity of IRY (since we have growth rates, the coefficients are also elasticities) in the YL simple and two-stage LS regressions is virtually the same as that obtained for the TFP regression of the 420 data model.

3. Vector error correction model (VECM)

In this sub-section, I will analyze the main variables YL, ML, KL, PY, IRY, UN, PKPL, INT, and RY (as defined earlier) in the context of a general vector error correction model (VECM), which underlies a vector autoregressive (VAR) model and the restrictions imposed upon it via a suitable procedure (see below). The main reasons for using such models for analyzing the impact of JIT/QC system on the American economy can be summarized as follows.

- A VECM can be interpreted as a set of simultaneous equations with endogenous and exogenous variables (see for instance section 5.6, Maddala and In-Moo Kim, 1998).
- Though the determination of the vectors (Vs) of coefficients of ECMs (via the Johansen method) is a-theoretical and a-priori void of economic interpretation, it is possible to identify the nature of each V as a correspondence between the endogenous variables and these Vs (*a-posteriori*).
- A VEC model can provide a Granger type of causality through the error correction terms (see for instance section 5.9.2, Maddala and In-Moo Kim, 1998).
- It is quite safe to use the VECM and especially Johansen's method if the number of available data is very large.
- Johansen's procedure is a reliable estimation procedure for determining the coefficients in a system of equations such as this one presented in this paper. This procedure is also related to using the full information maximum likelihood (FIML) modus operandi (Banerjee *et al*, 1993).
- Johansen's coefficients of the Vs can be used as the restrictions to estimate the ECMs (Maddala and In-Moo Kim, 1998; Enders, 1995).

In my present analysis I have used 1008 data of the pooled 28 manufacturing sectors of the American economy. The model of simultaneous equations consists of the five endogenous variables: YL, ML, KL, PY, and IRY as well as the three exogenous variables UN, PKPL, and INT. The unrestricted VAR model suggested as the optimum order a lag of 5 if the AIC is used and a lag of 1 if the SBC is used (The Microfit program is used for all the VECM analysis). Note that such discrepancy usually exists and hence one has to experiment with all lags between 1 and 5 (or even 6) in order to determine the right model. Thus, for each lag between 1 and 6, the 5 corresponding Vs were estimated (based on Johansen's method). See Table 10 for some of these results. The reason for having 5 Vs and no less for each VAR model is that the Johansen's tests strongly suggest that there are 5 Vs. This is not surprising, since all the variables used (both endogenous and exogenous) are already log differenced once and hence, as the ADF (augmented Dickey-Fuller) test confirmed, they all are integrated of order 0 (that is, I(0)), which means that they are all stationary[1].

My next aim is to determine the most representative set of 5 Vs and accordingly to estimate the ECMs (error correction models), which will ultimately provide the evidence I am seeking. In order to determine the most representative set of 5 Vs, three sets of criteria will be used. First, I already have a relatively good idea as to how each one of the Vs are looking like from the previous econometric analysis shown in previous sub-sections. Second, a priori economic reasoning can identify the expected sign of each long-term coefficient of a given V. And third, the signs, significance and magnitude of the relevant ECMs will confirm the first two criteria.

Out of all the 6 sets of Vs, those of VAR (3) and VAR (6) were discarded since some of the coefficients are extremely high. Out of the four remaining, finally the Vs of VAR (1) and VAR (2) were chosen as they satisfied to a large extent all three criteria. For instance, virtually all coefficients have the right sign; they also have approximately the right magnitude and to some degree they are similar to the regression results shown in previous sections. It would be possible to test and slightly change some of the coefficients according to the log-likelihood ratio, however this is not the purpose of this analysis. A more detailed examination of the sets of coefficients of the selected Vs is outside the scope of this report since my main purpose is to show the integrated impact of the JIT/QC variable on the economy via the ECMs, for which the results are now shown in Table 11.

Three sets of ECMs were estimated: the first is based on the VAR (1) model, the second on the VAR (2), and the third on the VAR (5) but using the restrictions (coefficients) of the VAR (1) model (noted as VAR(5)* in Table 11). The VAR (1), as expected, still has some serial correlation problems, whereas the VAR (5) does not. All three models have apparently a significant heteroscedasticity, but this as expected because the 1008 data are pooled data of 28 sectors and hence they have some pattern in terms of variance across these sectors. In addition, a few extreme values (outliers) certainly adversely affected this test. To verify the validity of these explanations, the covariance matrix was re-estimated using the White's and Newey-West's methods (see for this Pesaran and Pesaran, 1997, also Greene, 1993). The new T-ratios obtained according to the new covariance matrices were smaller as expected but still high enough and close to those shown in Table 11. Though the normality test (Bera-Jarque) rejects the assumption that the residuals are normally distributed, the very large sample used in my estimations and the plots of the histograms of residuals (which approximately show a normal distribution) suggest that the normality assumption is not a problem. Again, outliers have a negative impact on most of these diagnostic tests.

The R^2 is quite high in all regressions, which is encouraging given the nature and stationarity of data. The T-ratios of the ECM coefficients are generally high suggesting the significant impact of the dependent variables underlying the ECMs. In particular, the coefficient of the ECM corresponding to the variable IRY (inventories to shipments ratio) has a considerable impact in determining the other endogenous variables (YL, ML, KL, and PY) in a causal way. The negative coefficients of IRY in the ECM combined with the original negative coefficient of IRY in the V regarding the dependent variables YL or ML show that shocks produced by IRY have a positive short-term impact on the mean value of YL. This error seems to be cumulative in the short run, thus, perhaps showing the complexity of the situation. It is possible that this positive impact of IRY on the long trend of growth rates of productivities signifies that in a longer period of time (longer than the 40 years of the sample) the impact of the LPS becomes more permanent. In any case, all this further validates my conclusions of the significant impact of JIT/QC on economic growth. Furthermore, when IRY becomes the dependent variable, the coefficients of the ECMs of all five endogenous variables are also significant, thus re-enforcing the two-way causal and simultaneous interactions of these variables with IRY[2].

Some more remarks will justify my comments so far:

- The choice of the relevant underlying dependent variables of the ECMs is strongly confirmed by the right sign and significance of the appropriate ECM in each regression. For example, for the IRY dependent variable, the ECM1 (-1) corresponding to the IRY variable has a positive sign (hence negative if the ECM equation contained IRY with a positive sign; but it did not as it is shown in the last column of the Table), is very significant (a T-statistic ranging from 16.5 to 32.6), and its magnitude shows that its impact 'corrects' the long-term path of IRY without not too much delay.
- The coefficients of each ECM regression are relatively stable for the three VAR models used, have the right sign and agree with the previous econometric analysis carried out in sub-sections above.
- In the VAR (5) model, the exogenous variables play a significant role (for instance the variable PKPL has a strong impact on KL). This active role of the exogenous variables makes the relationships between the endogenous variables more valid and significant.
- Though the results shown and analyzed so far are based on the version of "restricted intercepts and no trends in the VAR", other versions such as the "unrestricted intercepts and restricted trends in the VAR" produced very similar results[3].
- Further examination of the ECM regressions, involving plots of actual and fitted values, plots of residuals, Wald tests of restrictions imposed on parameters, autocorrelation and spectral functions of residuals, unit root tests for residuals, CUSUM tests etc, all confirmed the validity of the present analysis.

CONCLUSIONS

The quantitative analysis presented in section 3 provides us with some important conclusions, which support the assertions of the first two sections that the LPS or its equivalent JIT/QC system is significant in increasing productivity at the sector level and hence economic growth.

In particular, the main proxy I used here to evaluate the impact of the LPS, the ratio of inventories to shipments seems to participate in shaping all other four endogenous variables in the system of equations examined, namely the output to labor ratio, the materials to labor ratio, the capital to labor ratio and the output deflator of all 28 manufacturing sectors in the USA pooled together from 1960 to 1996. Vive-versa, all these four endogenous variables have a significant impact on the JIT/QC proxy. The latter has also a significant impact on the TFPs. The elasticity between the LPS proxy and the output to labor ratio or TFP seems to be around –0.2 or even approaching –0.4 if the later period 1987 to 1996 is considered.

These results have some far-reaching implications on the theory of economic growth and policy. First, models of economic growth, whether endogenous or not, should include a new variable, namely the organizational relation between the traditional inputs of capital and labor. Second, growth policies should encourage the development of quality control, outsourcing of supplies, the lean production process in general, and the SMEs (for the link between SMEs and economic growth in this respect see Sanidas, 2001). And third, the American experience shows that it is possible to transplant with success Japanese type of organizational innovations in other countries.

NOTES

1. Usually cointegration is estimated via the estimation of the Vs of variables integrated of order 1 (I(1)). However, the Vs of variables of order 0 can also be estimated, in order to use the coefficients as restrictions on the ECMs, which is the case of my study.

2. A detailed exploration of Table 11 is outside the scope of this paper. However, some remarks are necessary here, as there are many other elements that support my main findings. First, the ECM variables corresponding to the same dependent variables (e.g. ECM(-1) (YL) of the dependent YL), have all the right sign (negative if the sign of the dependent variable is positive and vice-versa). This means that any 'error' of the variance of the dependent variable is brought back to zero (rapidly for YL and ML, slowly for KL and PY, average pace for IRY). Second, often the exogenous variables are significant, thus providing more robustness to the regressions. Third, the system of simultaneous equations of the 5 dependent variables YL, ML, KL, PY, and IRY seem to provide a good explanatory tool for the functioning of the economy from the manufacturing sub-sectors points of view. This means that organizational structures such as the JIT/QC as represented by IRY are an integral part of the economy.

3. As expected because the data are virtually stationary.

Table 8 **Results of the simple OLS and 2SLS regressions**

	SIMPLE OLS REGRESSIONS					TWO-STAGE LS REGRESSIONS				
Dependent	YL	ML	KL	PY	IRY	YL	ML	KL	PY	IRY
Intercept	**0.011**	**-0.0015**	**0.0083**	**-0.029**	**0.004**	**0.0057**	**0.002**	**-0.006**	**-0.029**	**0.03**
	6.3	0.61	2.2	9.1	0.66	1.5	0.41	0.41	4.4	2.8
YL		**1.053**	**0.187**	**0.61**	**-1.304**		**0.884**	**1.86**	**0.429**	**-0.988**
		43.5	2.8	11.3	14.6		4.5	2.6	0.62	1.2
ML	**0.62**		**-0.14**	**0.173**	**0.613**	**0.782**		**-1.76**	**0.8**	**-0.424**
	43.5		2.7	3.9	8.4	5.7		2.9	1.3	0.52
KL	**0.042**	**-0.054**		**-0.033**	**0.309**	**0.17**	**-0.217**		**0.109**	**-0.124**
	2.8	2.7		1.2	6.7	2.7	2.9		0.53	0.48
PY	**0.187**	**0.089**	**-0.045**		**0.372**	**0.078**	**0.165**	**-0.091**		**0.946**
	11.3	3.9	1.2		7	0.71	1.2	0.23		4
IRY	**-0.135**	**0.107**	**0.141**	**0.126**		**-0.122**	**-0.059**	**-0.251**	**0.64**	
	14.6	8.4	6.7	7		1.4	0.49	0.84	4.1	
UN	**0.016**	**-0.027**	**0.142**	**0.017**	**0.049**	**-0.0006**	**0.016**	**0.145**	**-0.043**	**0.08**
	3.3	4.3	15.2	1.9	3.2	0.04	0.97	5	1.3	2.2
PKPL	**-0.221**	**0.078**	**-0.129**	**0.493**	**0.042**	**-0.139**	**0.045**	**0.354**	**0.39**	**-0.309**
	8.8	2.3	2.4	11.1	0.51	2.8	0.55	1.5	3.3	1.7
INT	**0.00009**	**-0.0002**	**0.0009**	**0.0017**	**0.002**	**-0.00009**	**0.0005**	**0.003**	**-0.0007**	**0.002**
	0.47	0.96	2.4	5.1	3.6	0.25	0.98	2.8	0.71	2.1
IRY1	**-0.02**	**0.02**	**0.086**	**0.015**	**-0.102**					
	2	1.5	4.1	0.85	3.3					
IRY2	**-0.008**	**0.004**	**0.024**	**0.001**	**-0.078**					
	-0.88	0.38	1.3	0.06	2.8					
PKPL1	**0.051**	**-0.018**	**-0.066**	**-0.006**	**-0.079**			**-0.183**		
	2	0.54	1.2	0.12	1			1.8		
PKPL2	**-0.006**	**0.009**	**-0.137**	**0.0004**	**0.075**			**-0.122**		
	0.26	0.29	2.9	0.01	1.1			1.5		
UN1	**-0.0063**	**0.019**	**-0.042**	**-0.023**	**-0.013**					
	1.26	3	4	2.6	0.81					
KL1	**0.067**	**-0.057**	**0.196**	**-0.066**	**-0.028**					
	4.5	2.9	6.3	2.4	0.6					
YL1	**0.00003**	**-0.035**	**-0.0094**	**0.258**	**-0.147**					
	0	0.87	0.14	4.7	1.5					
ML1	**-0.0025**	**0.041**	**0.006**	**-0.098**	**0.078**					
	-0.1	1.3	0.1	2.2	1					
R^2 bar	0.88	0.86	0.36	0.68	0.34	0.55	0.43	0.15	0.23	0.13
SE	0.017	0.022	0.037	0.031	0.054	0.019	0.026	0.063	0.052	0.065
SD Dep/t	0.051	0.06	0.046	0.056	0.067					
DW-stat	2.02	2	1.93	1.6	1.98					
Diagnostic tests										
Ser. Cor/n	0.45	0.93	0.005	0.000	0.401					
Functional	0.4	0.1	0.132	0.011	0.000					
Normality	0.000	0.000	0.000	0.000	0.000					
Heteros/ty	0.000	0.000	0.001	0.000	0.000					

Notes:
1. The figures under the coefficients (in bold) are t-statistics
2. The figures of the diagnostic tests are the p-values

Table 10 The cointegrating vectors (CVs) of selected VAR models

VAR (1)	Part I	Initial CVs				Part II	Regression coefficients			
Dependent	IRY	YL	ML	KL	PY	IRY	YL	ML	KL	PY
YL	**-1**	**-1**	**-1**	**-1**	**-1**	**-0.538**	**1.000**	**1.053**	**0.565**	**-0.313**
ML	**1.85**	**0.45**	**0.95**	**2.81**	**0.49**	**0.995**	**0.450**	**1.000**	**-1.588**	**0.154**
KL	**-0.22**	**0.21**	**-0.37**	**1.77**	**-0.77**	**-0.118**	**0.210**	**0.389**	**1.000**	**-0.241**
PY	**-0.75**	**0.32**	**0.04**	**-1.83**	**-3.19**	**-0.403**	**0.320**	**-0.042**	**1.034**	**1.000**
IRY	**-1.86**	**-0.27**	**0.2**	**0.28**	**0.09**	**1.000**	**-0.270**	**-0.211**	**-0.158**	**0.028**
UN	**-0.203**	**0.0206**	**-0.037**	**-0.02**	**-0.162**	**-0.109**	**0.021**	**0.039**	**0.011**	**-0.051**
T-stat	-4.95	3.23	-3.36	-0.47	-1.70	**-0.2239**	**0.0392**	**0.14105**	**0.11254**	**-0.0508**
PKPL	**-0.068**	**-0.008**	**-0.097**	**0.131**	**1.361**	**-0.037**	**-0.008**	**0.102**	**-0.074**	**0.427**
T-stat	-0.38	-0.29	-1.98	0.72	3.25	**-0.4156**	**-0.1455**	**0.546**	**-0.9102**	**0.42677**
INT	**0.0091**	**0.0002**	**0.0023**	**-0.004**	**0.0039**	**0.005**	**0.0002**	**-0.002**	**0.002**	**0.001**
T-stat	6.50	0.72	5.90	-3.00	1.17	**-6E-05**	**0.00049**	**-0.0014**	**0.00028**	**0.00121**
Intercept	**-0.103**	**0.015**	**-0.006**	**-0.055**	**0.1556**	**-0.055**	**0.015**	**0.007**	**0.031**	**0.049**
T-stat	-8.05	7.58	-1.78	-4.26	5.24	**-0.0165**	**0.0103**	**0.00099**	**0.0313**	**0.04878**

Note: In Part II above , the underlined coefficients are from the VAR(5) model under the restrictions of the endogenous variables' coefficients of the VAR (1) model.

VAR (2)	Part I	Initial CVs				Part II	Regression coefficients			
Dependent	IRY	YL	ML	KL	PY	IRY	YL	ML	KL	PY
YL	**-1**	**-1**	**-1**	**-1**	**-1**	**-1.176**	**1.000**	**1.010**	**-1.695**	**0.179**
ML	**0.74**	**0.45**	**0.99**	**-0.13**	**-1.55**	**0.871**	**0.450**	**1.000**	**-0.220**	**0.278**
KL	**0.31**	**0.45**	**-0.14**	**-0.59**	**-2.44**	**0.365**	**0.450**	**0.141**	**1.000**	**0.437**
PY	**0.1**	**0.36**	**-0.06**	**0.33**	**5.58**	**0.118**	**0.360**	**0.061**	**0.559**	**1.000**
IRY	**-0.85**	**-0.11**	**0.054**	**-0.22**	**-0.49**	**1.000**	**-0.110**	**-0.055**	**-0.373**	**0.088**
UN	**0.0008**	**0.0189**	**-0.042**	**0.16**	**0.049**	**0.0009**	**0.0189**	**0.0424**	**0.2712**	**-0.009**
T-stat	0.05	1.77	-3.72	6.84	0.37					
PKPL	**-0.088**	**0.1508**	**-0.193**	**-0.371**	**-1.781**	**-0.1029**	**0.1508**	**0.1949**	**-0.629**	**0.319**
T-stat	-1.15	3.03	-3.67	-3.41	-2.87					
INT	**0.0008**	**-3E-04**	**0.0016**	**0.0005**	**0.0079**	**0.0009**	**-3E-04**	**-0.002**	**0.0009**	**-0.001**
T-stat	1.63	-0.82	4.85	0.74	1.98					
Intercept	**-0.007**	**0.0135**	**-0.007**	**0.0628**	**-0.066**	**-0.0085**	**0.0135**	**0.0073**	**0.1064**	**0.012**
T-stat	-1.71	4.82	-2.45	10.30	-1.88					

VAR (3)	Part I	Initial CVs				Part II	Regression coefficients			
Dependent	IRY	YL	ML	KL	PY	IRY	YL	ML	KL	PY
YL	**-1**	**-1**	**-1**	**-1**	**-1**	**-0.013**	**1.000**	**0.901**	**-1.898**	**0.145**
ML	**3.46**	**0.497**	**1.11**	**0.211**	**-1.568**	**0.045**	**0.497**	**1.000**	**0.400**	**0.227**
KL	**7.92**	**0.437**	**-0.004**	**-0.527**	**-1.167**	**0.104**	**0.437**	**0.004**	**1.000**	**0.169**
PY	**-10.24**	**0.272**	**-0.093**	**0.335**	**6.92**	**-0.135**	**0.272**	**0.084**	**0.636**	**1.000**
IRY	**-76.11**	**-0.261**	**-0.053**	**-0.129**	**-0.913**	**1.000**	**-0.261**	**0.048**	**-0.245**	**0.132**
UN	**1.04**	**0.026**	**-0.094**	**0.118**	**-0.383**	**0.014**	**0.026**	**0.085**	**0.224**	**0.055**
PKPL	**-8.21**	**0.159**	**-0.156**	**-0.513**	**-2.015**	**-0.108**	**0.159**	**0.141**	**-0.973**	**0.291**
INT	**-0.018**	**0.0001**	**0.0016**	**0.001**	**0.0092**	**0.000**	**0.000**	**-0.001**	**0.002**	**-0.001**
Intercept	**-0.403**	**0.0098**	**-0.017**	**0.0355**	**-0.155**	**-0.005**	**0.010**	**0.015**	**0.067**	**0.022**

Note: The VAR (3) model was discarded for the final ECM estimations.

Table 11: ECMs of the 3 VAR models

Dependent	VAR (1) dYL Coeff.	T-ratio	VAR (5)* dYL Coeff.	T-ratio	VAR (2) dYL Coeff.	T-ratio	VAR (1) dML Coeff.	T-ratio	VAR (5)* dML Coeff.	T-ratio	VAR (2) dML Coeff.	T-ratio	Sign of dep var. in the ECM
ECM1(-1)(IRY)	-0.136	13.6	-0.14	6	-0.2	4.5	-0.15	12.5	-0.13	4.8	-0.26	4.9	--
ECM2(-1)(YL)	0.896	13	1.05	6.4	0.64	9.1	0.42	5.2	0.52	2.7	0.26	3.1	--
ECM3(-1)(ML)	-0.145	3.5	-0.42	4.7	-0.31	3.9	-0.65	13.1	-0.92	8.9	-1.1	11.7	+
ECM4(-1)(KL)	-0.04	3.1	0.004	0.2	-0.54	13.2	-0.13	8.6	-0.12	4	-0.6	12.5	+
ECM5(-1)(PY)	0.131	16.8	0.15	12	0.085	10.7	0.14	15.5	0.18	12.2	0.085	9.1	--
Bar -R^2	0.39		0.49		0.41		0.4		0.51		0.42		
SE	0.048		0.044		0.048		0.057		0.052		0.055		
SD of dep/t	0.062		0.062		0.062		0.073		0.073		0.073		
DW-stat	2.05		2.02		2.04		2.07		2.02		2.06		
Ser. Corr. Test	0.012		0.107		0.001		0.001		0.128		0.000		
Funct. Form	0.000		0.09		0.001		0.037		0.313		0.019		
Normality	0.000		0.000		0.000		0.000		0.000		0.000		
Heterosc/ty	0.000		0.002		0.000		0.000		0.057		0.000		

Dependent	VAR (1) dKL Coeff.	T-ratio	VAR (5)* dKL Coeff.	T-ratio	VAR (2) dKL Coeff.	T-ratio	VAR (1) dPY Coeff.	T-ratio	VAR (5)* dPY Coeff.	T-ratio	VAR (2) dPY Coeff.	T-ratio	
ECM1(-1)(IRY)	0.067	7.8	0.039	1.9	-0.13	3.6	0.044	4.3	0.055	2.2	0.04	0.9	--
ECM2(-1)(YL)	-0.42	7.1	-0.43	3.1	-0.73	12.8	-0.41	5.8	-0.19	1.1	-0.49	6.9	--
ECM3(-1)(ML)	0.76	21.2	0.6	7.8	0.59	9.2	-0.23	5.5	-0.47	5.1	-0.21	2.7	+
ECM4(-1)(KL)	-0.21	18.5	-0.21	9.9	-0.41	12.2	0.044	3.3	-0.004	0.1	-0.3	7.2	+
ECM5(-1)(PY)	0.015	2.3	0.038	3.6	-0.049	7.5	0.15	19.3	0.16	12	0.13	16	--
Bar -R^2	0.47		0.57		0.54		0.31		0.41		0.34		
SE	0.042		0.038		0.039		0.049		0.046		0.048		
SD of dep/t	0.058		0.058		0.058		0.059		0.059		0.059		
DW-stat	1.91		2.05		2.03		2		2.04		2		
Ser. Corr. Test	0.001		0.000		0.049		0.985		0.003		0.469		
Funct. Form	0.002		0.000		0.018		0.975		0.519		1		
Normality	0.000		0.000		0.000		0.000		0.000		0.000		
Heterosc/ty	0.074		0.011		0.123		0.000		0.000		0.000		

Dependent	VAR (1) dIRY Coeff.	T-ratio	VAR (5)* dIRY Coeff.	T-ratio	VAR (2) dIRY Coeff.	T-ratio
ECM1(-1)(IRY)	0.43	32.6	0.54	16.5	1.31	22.2
ECM2(-1)(YL)	0.31	3.4	0.51	2.3	-0.92	10.1
ECM3(-1)(ML)	-0.38	6.9	-0.5	4.2	-0.32	3.2
ECM4(-1)(KL)	-0.17	9.6	-0.24	7.2	-0.15	2.7
ECM5(-1)(PY)	-0.16	1.6	0.004	0.2	-0.048	4.6
Bar -R^2	0.55		0.61		0.58	
SE	0.064		0.06		0.062	
SD of dep/t	0.095		0.095		0.095	
DW-stat	2		1.99		2.05	
Ser. Corr. Test	0.697		0.297		0.001	
Funct. Form	0.03		0.308		0.104	
Normality	0.000		0.000		0.000	
Heterosc/ty	0.107		0.004		0.006	

Significant lagged variables of VAR (5)
(at less than 5%, unless otherwise indicated)

dYL2	(dKL)	**dINT1**	(dYL,dML,dKL,dPY,dIRY)
dYL3	(dKL)	**dINT2**	(dYL,dKL,dIRY)
dYL4	(dYL,dML,dPY)	**dINT3**	(dYL,dML,dPY,dIRY)
dML1	(dKL)	**dINT4**	(dML(9.7),dKL,dPY(10.3),dIRY)
dML2	(dKL)	**dUN1**	(dYL,dML,dPY)
dML3	(dKL)	**dUN2**	(dYL,dML,dPY)
dKL1	(dYL)	**dUN3**	(dYL,dML,dPY)
dKL2	(dYL,dKL)	**dUN4**	(dYL,dML,dPY,dIRY)
dKL3	(dKL)	**dPKPL1**	(dYL(8.8),dKL,dIRY)
dKL4	(dKL)	**dPKPL2**	(dYL,dML,dKL,dPY(8.1))
dPY1	(dYL,dML,dPY(6.9),dIRY(5.2))		
dPY2	(dPY)	**dPKPL3**	(dYL,dML,dPY)
dPY3	(dPY(9.8))	**dPKPL4**	(dYL(9.7),dKL)
dPY4	(dYL,dML)		
dIRY1	(dPY(6),dIRY)		
dIRY2	(dPY(10.7),dIRY)		
dIRY4	(dPY)		

Note: the corresponding dependent variables are in brackets.

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