Technology Regimes and Growth in the Netherlands, An Empirical Record of Two Centuries

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April 2002 (second draft)

Abstract

This paper assesses the impact of general purpose technologies, such as steam, electricity and information and communication technology, on economic growth in the Netherlands. Following a review of the evidence for the UK and the USA, we make use of a macroeconomic dataset (based on historical national accounts) for the Netherlands covering two centuries. We look at aggregate productivity growth performance, adoption rates of new technologies, and contributions of industries to aggregate productivity growth for subperiods. We find that of the GPTs studied in this paper, the effects of electricity appear to be particularly largest and most widespread in the Netherlands during early 20th century, when electricity adoption rates increased most rapidly and productivity growth was most pervasive across industry. The effects of steam during the late 19th century were smaller, as it was introduced relatively late and its effects remained limited to a few (manufacturing) industries. In comparison, effects of ICT were already present during the 1980s and early 1990s, but mainly through the rationalization process in manufacturing. More recently effects of ICT are strongly impacting some service industries, but the aggregate impact is still small compared to the electricity era and looks much more like the steam case for the Netherlands.

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[1] This paper benefits from earlier work we did in particular with Herman de Jong, whom we thank for comments and suggestions. See, for example, van Ark and de Jong (1996), Smits, de Jong and van Ark (1999) and Smits and de Jong (2000).

1. Introduction

The rapid acceleration in GDP growth across the OECD since 1995 has raised expectations that a new era of technological change will lead to a recovery from the growth slowdown since the 1970s. Between 1995 and 2000, real GDP in the OECD increased at 3.3 per cent per year, up from 2.8 per cent between the previous two decades (1975-1995). Even though many factors may have contributed to this recent acceleration of growth – not in the least the fact that most OECD countries were in an upward phase of the business cycle – information and communication technology (ICT) has been singled out as one of the factors of major importance (OECD, 2001).

Much of the recent evidence on the impact of ICT on growth pertains to the United States, partly because of better data availability but also because the United States appears ahead of most other countries in generating output and productivity growth effects from both the production of ICT and its intensive use across the economy.[2] But still ICT has also impacted the acceleration of growth elsewhere though at a slower rate. For example, in the Netherlands, labour productivity growth in the business sector slightly accelerated at 0.3 %-point from 1995-2000 over 1990-1995, of which 0.1%-point was due to great use of ICT capital, 0.7%-point to faster growth of total factor productivity, and –0.4%-point due to a slowdown in use of non-ICT capital.[3]

In earlier papers we discussed the main characteristics of information and communication technology (ICT) as a potential source of uneven output and productivity growth *across countries* and *across industries* (van Ark, 2000, 2001). Differences across countries may be due to such factors as comparative advantages in ICT production, the flexibility of labour, product and capital markets to allocate ICT to its most productive uses, and the ability of firms to make complementary investments in intangible capital, such as R&D and organizational capital. The latter in turn depend on the infrastructure concerning human and organizational capital (Brynjolfsson and Hitt, 2000; OECD, 2001).

Differences in the productivity impact from ICT across industries is related to the high concentration of ICT investment in service sectors, in particular in trade and in financial and business services. On the whole these industries contribute more productivity growth than industries where ICT is used less intensively. But even within this group of intensive ICT-using industries the effects from ICT are quite different. For example, productivity responses to ICT in financial and business services have been clearly than in the trade sector, although there are important differences between countries (Pilat and Lee, 2001; Baily and Lawrence, 2001; McKinsey Global Institute, 2001).[4]

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[2] For US evidence, see, for example, Oliner and Sichel (2000), Jorgenson (2001), and Jorgenson, Ho and Stiroh (2002). For international comparisons of the impact of ICT on growth, see OECD (2000), van Ark (2001), Pilat and Lee (2001).

[3] CPB (2001). This compares an acceleration if labour productivity in the business sector of the United States at 0.6%-point, of which 0.5%-point came from ICT capital, zero from other capital and 0.1% from a combination of faster TFP growth and a decline in labour quality (Jorgenson, Ho, and Stiroh, 2002).

[4] For example, in contrast to most other countries, the trade sector in the United States has experienced a spectacular acceleration in productivity growth during the second half of the 1990s.

In this paper we switch the emphasis from analyzing the impact of ICT – as a typical example of a general purpose technology (GPT) – on growth from the short term and international comparative perspective to a more historical perspective. How does the recent upsurge in output growth and the acceleration of productivity growth in intensive ICT-using industries compare to earlier episodes of rapid technological change, such as the introduction of steam during the nineteenth century and that of electricity during the twentieth century? And is the present dispersion of ICT across the economy comparable to that of electricity and steam?

Most of the historical literature on the impact of GPTs on growth derives from experiences in the United Kingdom and the United States, largely because of the ample availability of data for these countries going back in time far enough. As both countries were typically at the frontier of the new technologocal paradigms in steam (UK) and electricity (USA), the experience of follower countries may be quite different as it is more strictly based on the effects of diffusion of the GPT rather than invention itself. The recent completion of the historical national accounts of the Netherlands for the period 1800-1913, combined with some major empirical studies on the twentieth century, provides an almost complete series of macroeconomic estimates for two centuries to analyze the questions posed above for the case of the Netherlands.

We find that of the GPTs studied in this paper, the effects of electricity appear to be particularly largest and most widespread in the Netherlands during early 20th century, when electricity adoption rates increased most rapidly and productivity growth was most pervasive across industry. The effects of steam during the late 19th century were smaller, as it was introduced relatively late and its effects remained limited to a few (manufacturing) industries. In comparison the effects of ICT have already been present during the 1980s and early 1990s, but mainly through the rationalization process in manufacturing. More recently effects of ICT are strongly impacting some service industries, but the aggregate impact is still small compared to the electricity era and looks much more like the steam case for the Netherlands.

In Section 2 we review the recent literature on historical parallels of the relation between the rise of new technological paradigms and the impact on economic growth, largely basing ourselves on the UK and US experience. In Section 3 we briefly discuss the characteristics of the new two-century data base of macroeconomic accounts, and describe the major trends in output, per capita income and productivity growth. In Section 4 we compare estimates of technology adoption rates for steam, electricity, and ICT with the macroeconomic growth performance. In Section 5 we adopt an industry perspective to look at contributions of industries to aggregate labour productivity growth, using so-called sunrise diagrams as pioneered by Harberger (1998). In this light we also use Harberger's metaphor of "mushroom" versus "yeast" growth to analyze the pervasiveness of general purpose technologies impacting economy-wide productivity growth. Section 6 concludes with some remarks on what the historical evidence indicates for the future effects of ICT.

2. Three Phases of Technological Change

Since the 1950s empirical and theoretical work on economic growth has shown that productivity is the driving force of the improvement in per capita income in the long run (Solow, 1957; Kuznets, 1966). How this increase in output per unit of labour is realized, however, has remained a matter of debate. Solow's traditional growth model states that in the short run economic growth is primarily driven by a rise in the capital-output ratio. As the returns on capital accumulation diminish, the economy will ultimately converge to the so-called steady state. However, notwithstanding phases of faster and slower productivity growth, empirical research unequivocally shows that in the long run no systematic decline in returns on capital nor a slowdown in the growth of labour productivity sets in (Abramovitz, 1986; Maddison, 1995, 2001). This has led theorists to introduce technological change in their models, either in an exogenous manner (in the guise of total factor productivity growth) or endogenously (through the introduction of product variety, quality ladders, or the creation of knowledge and ideas).[5]

Technological change has featured predominantly as the key to economic growth in the economic-historical literature for a long time, starting with the work of Schumpeter in the early 20th century and later on including the work of David, Landes, Mokyr, and Rosenberg – to name just a few.[6] Shifts in technological paradigms has become a key theme in this literature. Schumpeter (1939) spoke distinctly of three "successive industrial revolutions", i.e. (1) one starting around the 1780s (new textile machinery, Watt's steam engine and Cort's method of fabricating good iron with coke); (2) one starting modestly around the 1830s (railroads and steel production); (3) one originating at the turn of the nineteenth century (electricity, chemicals and the internal combustion engine). Whereas Schumpeter's classification was primarily based on the inventions, Freeman and Soete (1987, p. 19) put greater emphasis on the diffusion of innovations. They recognize five technology waves: (1) 1780s-1840s: factory production for textiles; (2) 1840-1890s: age of steam power and railways; (3) 1890s-1940s: age of electricity and steel; (4) 1940-1990s: age of mass production; (5) 1990s-?: age of microelectronics and computer networks.

Within each of these phases, waves or paradigms – the terminology being dependent on the degree of regularity over time –, the distinction between the major inventions and subsequent streams of innovations is of crucial importance. Mokyr (1990) makes a distinction between macro and micro inventions. Macro inventions (steam engine, electrical motor, computer chip) represent more or less exogenous technological shocks, which create new production possibilities. After the introduction of a macro invention, the new technology will be adapted by means of "small, incremental steps that improve, adapt, and streamline existing techiques already in use, reducing costs, improving form and function, increasing durability, and reducing energy and raw material requirements" (Mokyr, p. 13). According to Mokyr the process of technological adaption and diffusion is characterized by diminishing returns. Hence productivity growth in the long run will

[5] For reviews of the recent literature see, for example, Jones (1998), Aghion and Howitt (1998) and Valdés (1999).
[6] See von Tunzelmann (1995) for a review.

only be secured when from time to time new macro inventions are introduced which create new growth possibilities.

The distinction between macro and micro inventions comes close to the concept of the General Purpose Technology (GPT), which implies that, for example, steam, electricity and ICT represent broad encompassing technologies with wide applications and much scope for incremental improvement (Bresnahan and Trajtenberg, 1995). However, in contrast to Mokyr, the GPT literature emphasizes there is a case for increasing returns emerging from the new GPT. For example, Bresnahan (2000) formulates various kinds of externalities, which originate from co-invention of techniques and from netwerk externalities. He also explicitly recognizes the time lag for such externalities to occur. Even when looking at the most intensive ICT-using economy, the United States, the evidence on externalities from ICT is still slim if not absent.[7]

The first explicit and quantitative comparison of different phases of technological change originates from Paul David (1989, 1990) who drew an anology between the introduction of electricity around the turn of the 19th century and the introduction of ICT during the 1970s and 1980s. David emphasizes the time lag between invention and productivity advances, as both the United Kingdom and the United States experienced a vigorous expansion of technology during the period 1900 to 1913, but a relatively slow growth of productivity. Only after 1913 a significant acceleration in productivity could be observed for both countries.[8]

Gordon (1999, 2000) confirms the rapid acceleration in U.S. productivity after 1913 using a growth accounting methodology with refined calculations of the contributions of factor inputs and total factor productivity. Indeed TFP increased at much higher rates during the whole period 1913-1972 than either before or thereafter (Table 1).[9] In this light, Gordon speaks of “one big wave” which is strongly linked to to the major inventions of the late 19th and early 20th centuries. He identifies four main innovation clusters, namely electricity, the internal combustion engine, the “rearrangment of molecules” (petrochemicals, plastics and pharmaceuticals”, and communications/entertainment). Indeed – according to Gordon – the inventions of the ICT era, including VCR (which combines TVs and movies) and internet (which substitutes one form of entertainment for the other) are of a second order (Gordon, 1999, p. 127).

Recent work by Crafts (2001) appears to challenge Gordon’s viewpoint by measuring the combined contributions to labour productivity growth from investments in equipment which embodies the new technology, and the total factor productivity growth arising from the industry producing the new equipment. Crafts compared the US estimates for the recent ICT era from 1974 to 2000, with earlier estimates for the United States on the contributions of electricity between 1899 and 1919 and with estimates for the United Kingdom on the contributions of steam between 1760 and 1860 (Table 2).

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[7] See Stiroh (2001) for an explicit statement on the absence of externalities from ICT in the manufacturing sector.
[8] See Maddison (1995).

Table 1: Labour Productivity and Total Factor Productivity Growth in the United States, 1800-1996

	Output per Manhour	Crude Total Factor Productivity	Adjusted Total Factor Productivity
1800-1855	0.4	0.2	
1855-1890	1.1	0.4	
1870-1913	1.2	0.9	0.5
1913-1972	1.9	1.6	1.0
1972-1996	1.0	0.6	0.1

Note: "Crude total factor productivity" is labour productivity adjusted for capital per manhour. "Adjusted total factor productivity" includes adjustments for composition of labour and capital and capital quantity adjustments (notably variable retirement ages)
Source: 1855-1890 from David and Wright (1999); 1870-1996 from Gordon (2000)

Crafts' estimates show that during the 1990s ICT contributed more to US labour productivity growth than electricity between 1899 and 1929, and much more than steam in the United Kingdom even during its heydays. In the early part of the steam age the major contributions to growth came from investment in the textile industry. The rise in the contribution from steam between 1860 and 1890 mainly originated from the contribution of railway capital. During the electricity era the average contribution to labour productivity growth between 1899 and 1929 was clearly less then during the ICT era, and even did not go beyond the labour productivity contribution at the dawn of the ICT era, i.e., between 1974 and 2000. The substantial contribution of electricity during the 1920s, at 47% of labour productivity growth, is almost entirely due to an assumed TFP spillover effect from electricity use. TFP spillover effects from ICT have been virtually absent or non-existent during the 1990s and may (or may not) set in at a later stage. But even without such effects ICT has contributed significantly more to labour productivity growth in the United States than the earlier technologies.[10] Whether this evidence can be easily transferred to the experience of other countries remains to be seen, as both ICT production and ICT investment in the US seems to have been ahead of other countries during the 1990s.

[9] Gordon (1999) shows that adjustments for increased quality of labour and capital as well as for the lengthening of asset lives during the Great Depression do not alter differences in growth rates between these three periods.

[10] See Colecchia and Schreyer (2001), Daveri (2001) and ECB (2001) for a review of ICT contributions for countries other than the U.S., which in almost cases – with the exceptions of Finland and Ireland – are lower than in the United States. See Pilat and Lee (2001) or van Ark (2001) for an overview.

Table 2: Contribution of New Technology Capital and TFP to Labour Productivity Growth in the United Kingdom (1760-1860), and the United States (1899-1929 and 1974-2000)

	Capital Contribution	Total Factor Productivity Contribution	Total Contribution	Contribution as % of growth rate GDP/person employed
United Kingdom				
1760-1800 (a)	0.005	0.003	0.008	3.8
1800-1830 (a)	0.012	0.000	0.012	2.4
1830-1860 (ab)	0.200	0.060	0.260	23.6
United States				
1899-1929 (c)	0.50	0.06	0.56	28.2
1919-1929 (c)	0.93 (e)	0.05	0.98	47.0
United States				
1974-1990 (d)	0.52	0.17	0.69	30.4
1991-1995 (d)	0.57	0.24	0.81	54.6
1996-2000 (d)	1.36	0.50	1.86	56.3

(a) contribution of steam power technology
(b) contribution of steam power technology and railway technology
(c) contribution of electrical machinery and electric utilities
(d) contribution of information and communication technology, including software
(e) of which 0.7 is due to TFP spillovers from the adoption of electricity (based on David and Wright, 1999)
Source: Crafts (2001), Tables 1-3.

Although these numbers certainly help to assess the impact of GPT's on growth, it should be noted that there is also a need to clearly recognize key requirements of an organizational and institutional nature which need to be met before a GPT can lead to accelerated growth – and only with a substantial time lag.[11] As mentioned above, the "regime transition" towards electricity was a long delayed and far from automatic process. For example, David and Wright (1999) stress the importance of changes in competion policies and policies towards corporate governance to let electricity take as a leading contributor to growth. These policies included the need to increase central station generating capacity, to integrate and extend power transmission networks, to improve utilization of fixed capacity and to set up an efficient regulation system. It also required formulation of terms under which long-term monopoly franchises could be secured, and the setting up of holding companies to facilitate acquisition and investment needed to integrate the system (p. 13). Furthermore, organizational changes such as the implementation of personnel

[11] Indeed even by the 1920s only half of the manufacturing sector in the United States made use of electricity, which was four decades after the first central power station opened for business (David and Wright, 1999).

plans, legal changes concerning industrial safety and child labour use, and the continuous rise of the age of compulsory schooling have also been identified as key factors contributing to productivity growth (p. 22). These changes in policies and business strategies have been strongly complementary to or even indispensable for the success of electricity applications. In today's ICT era, issues concerning property rights of ICT products and services produced by network industries, competition policies in those industries, and changes in required skills are key issues for organizational and institutional reforms, creating large time lags between the introduction of ICT and the realization of growth effects.

3. Economic Growth and Productivity in the Netherlands from 1800 to 2000

Before going into the relationship between new technology regimes and growth in the Dutch context, a brief description of the much improved empirical evidence on economic growth in the Netherlands since 1800 is appropriate. The historiography of the Dutch economy has suffered for a long time from the weak empirical basis for analysis of the 19th century and first half of the 20th century. For example, mostly qualitative studies on the 19th century suggested that the Dutch economy during this period was stagnant and lacked the necessary conditions to benefit from the first industrial revolution (De Vries, 1968). Quantitative studies, which were mostly restricted to some industries or to rather short periods, displayed divergent results on the 19th century.[12] For the first half of the 20th century much of the long run evidence was obscured by the two world wars which created serious breaks in data collection. And even during the second half of the 20th century, major revisions in national accounts methodology have caused breaks in the series, as these were not worked back in time, in particular not to the period before 1969.

To obtain a consistent picture of the performance of the Dutch economy during these two centuries, one requires a comprehensive statistical framework, for which the official System of National Accounts (SNA), as adopted by the statistical agencies after World War II, was the obvious candidate.[13] During the 1990s a project aimed at constructing the Historical National Accounts for the Netherlands in the period 1800-1921 was initiated. The main results of the project are published in Smits, Horlings and van Zanden (2000).[14] The starting point of the project was the estimation of output by industry. This involved the estimation of value added in agriculture, industry and services and required extensive research on the movement of output,

[12] Griffiths (1979) and De Meere (1983) maintained that the 1830s and 1840s were a period of economic expansion, while Brugmans (1983) considered the 1860s as a turning point in the growth process. According to De Jonge (1976), however, the period after 1895 had been crucial for economic development. De Jonge's analysis has been influential, as it was tied to the popular Rostowian notion of 'take off', implicitly indicating that the modernisation of the Dutch economy still had been slow and lagging behind the European average.

[13] The estimates in the historical national accounts are based on the System of National Accounts (SNA) 1968. During the 1990s the System of National Accounts has been renewed, and the measures for the Netherlands since 1995 are now based on the European System of Accounts (ESA) 1995.

[14] The data book as well as the underlying historical series are from http://www.nationalaccounts.niwi.knaw.nl.

input and prices in the various sectors of the economy. Detailed research was also done on capital formation. Other categories of expenditure were estimated either directly from primary source material (e.g. government expenditure) or indirectly by combining data on output and foreign trade (private consumer expenditure). Finally, the income side of the accounting system was dealt with in two separate studies, one on wages, salaries and income inequality and one on income from capital. Since most of the work was done within a national accounting framework, it was possible to integrate the output, expenditure and income results and provide a major source for a detailed analysis of the sources of economic growth in the Netherlands in the period 1800-1921.

For the post-1921 period a number of projects were undertaken to reconstruct the quantitative growth performance, which included the reconstruction of the national accounts for the period 1921-1939 by den Bakker, van Bochove and Huitker (1987) and the reconstruction of the contemporary national accounts from 1969 onwards. Van Ark and de Jong (1996) provide a growth accounting study for the period 1913-1994 using the material from the studies mentioned, and additional statistics from Statistics Netherlands on output, employment and capital.

Table 3: Gross Domestic Product, GDP per Capita (annual compound growth rates), average GDP shares of main sector (%) and contribution of the industrial sector to GDP (%-point)

	Gross Domestic Product (annual growth)	GDP per Capita (annual growth)	Average GDP share of A-I-S (a) (%)	Contribution of I (a) to GDP Growth (%)
1807-1820	0.8	0.2	26-26-49	-21
1820-1850	2.1	1.1	23-29-48	36
1850-1870	1.6	0.9	28-24-48	29
1870-1890	2.0	0.8	24-30-46	45
1890-1913	2.4	1.0	19-31-50	33
1913-1929	3.7	2.2	15-35-60	45
1929-1947	0.5	-0.7	18-30-52	35
1947-1960	5.3	3.9	10-40-50	54
1960-1973	4.9	3.6	8-41-51	53
1973-1995	2.2	1.6	4-32-64	13
1995-2000	3.6	3.0	3-27-69	20
1820-1913	2.0	1.0	23-29-48	38
1913-2000	3.0	1.9	11-34-55	36

(a) average of shares of first and last year of each subperiod; (b) Industry (I) includes mining, manufacturing, utilities and construction

Source: 1807-1913 from Smits, Horlings and van Zanden (2000). 1913-2000 from van Ark and de Jong (1996), updated to 2000 with sources from CBS, Nationale Rekeningen, various issues.

Table 3 shows aggregate numbers on output and per capita income growth from 1807 to 2000. Between 1820 and 1913 real GDP grew at two per cent on average. Strikingly the period 1820-1850 showed faster growth than the period 1850-1870 and similar growth rates compared to the period 1870-1890. Per capita GDP grew at only one per cent on average during the 19th centry. Part of this modest income growth can be explained by high population growth which was a main characteristic of the Dutch economy until the end of the twentieth century.

The industrial structure of the Dutch economy showed little change during the 19th century. For most of the century agriculture, industry and services accounted for roughly 25, 25 and 50 per cent of total GDP respectively and did not change much before well into the twentieth century. Contrary to other countries differences in levels of productivity between the sectors were small (Crafts, 1984). Dutch labour productivity levels in the service sectors were relatively high and differences in productivity levels between industry and agriculture were small until about 1870. Only since the 1870s, when agrarian prices dropped sharply due to the Great Depression, nominal levels of labour productivity in agriculture fell and the share of agrarian employment decreased. The slow structural change during the 19th century had two implications. Firstly, incentives leading to shifts of economic activities between sectors were small. Secondly, when the shifts eventually occurred, these had only limited effects on the macro-economic growth performance. The forces of "modern economic growth" (Kuznets, 1966) were clearly not well at work, and on these grounds alone it is unlikely that steam technology would have contributed much to 19th century growth.

The absence of structural change during the nineteenth century begs the question what happened to productivity growth in this period. As the Dutch historical national accounts project also delivered estimates of physical capital, measures of labour productivity (LP) growth could be complemented with measures of total factor productivity (TFP) growth for both the total economy and for the manufacturing sector (Groote, 1995; Albers, 1998). Table 4 shows productivity growth rates for the total economy as well as for manufacturing. During the period 1820-1850 the growth rates for LP and TFP were around 1 per cent per year for the economy as whole. It then further slowed down between 1850 and 1870 but restored to above 1 per cent between 1870 and 1890. The latter period was labelled by Albers as the "transition to the first stages of modern economic growth" (Albers, 1998). During this period the growth of fixed capital increased rapidly with technical progress presumably being captured in fixed tangible capital. It is therefore all the more surprising that the original TFP growth rates for manufacturing – the main recipient of new technologies – turned negative after 1870.

One possible explanation for this negative trend in TFP during the late 19th century is that much of the new investment in machinery led to substitution of new for old capital without creating spillovers that are reflected in TFP growth. However, another explanation for the negative growth rates of manufacturing TFP between 1870 and 1913 is of a statistical nature. As the original estimates for manufacturing during the nineteenth century are based on a single deflation procedure – using gross output deflators at value added level – these may fail to take account of rapidly divergent trend in prices of output and intermediate inputs. For example, during the 1860s-1870s and during the 1890s there was a significant of monopolistic pricing in

Dutch manufacturing, leading to a faster growth in output prices compared to the prices of factor inputs (Smits, 2000). Indeed the alternative "double deflated" estimates for manufacturing in Table 4 show slower TFP growth rates for the early nineteenth century and an acceleration of these growth rates for the latter part of the century when taking account of changes in output prices relative to input prices.

Table 4: GDP per person employed or per hour worked, and total factor productivity growth, total economy and manufacturing, The Netherlands (annual compound growth rates)

	Total Economy		Manufacturing			
	GDP per per hour Worked	Total Factor Product-Ivity	GDP per hour worked: Original Estimate	GDP per hour worked: Double-Deflation Adjustment	Total factor productivity: Original Estimate	Total factor productivity: Double-deflation adjustment
1820-1850	1.1	1.1	(1.4)	-1.3a	(0.6)	-0.9a
1850-1870	0.9	0.8	(0.8)	0.5a	(0.1)	-0.1a
1870-1890	1.5	1.2	(3.9)	0.6a	(-0.7)	-0.9a
1890-1913	1.1	0.7	(0.4)	2.2a	(-0.5)	0.6a
1913-1929	3.2	2.3	(4.5)	2.3a	(2.7)	1.0a
1929-1947	(-0.6)	(-0.5)				
1947-1960	4.6	2.8	5.8b		3.0b	
1960-1973	4.5	2.8	7.8		2.8	
1973-1990	1.7	2.2	4.2cd		3.1cd	
1990-1995	1.0	0.5	3.5d		1.9d	
1995-2000	1.1	1.1de	2.9d		2.1d	
1820-1913	1.1	1.0	(1.5)	1.3*	(0.0)	0.2*
1913-2000	2.3	1.6	3.8		2.7	

Note: figures between brackets are not-preferred estimates.
a: sub-periods are 1815-1830, 1830-42, 1842-1865, 1865-1895, 1895-1913 and 1815-1913; b: 1950-1973; c: 1975-1990; d: output per full-time equivalent manyear instead of output per hour; e: market sector only
Sources: 1820-1913: Smits, Horling and van Zanden (2000) and Albers (1998); "double deflation" estimates for manufacturing from Smits (2000), Table 3; 1913-1995 (total economy) from van Ark and de Jong (1996); 1947-1973 from van Ark (1996); 1975-2000 from CPB.

Compared to the nineteenth century, the early twentieth century is characterised by major changes in structure and substantial variations in growth rates of the Dutch economy. Exceptionally rapid growth of output, income and productivity was found for the period 1913-1929. This strong performance is partly explained by the fact that the Netherlands were not directly involved in the hostilities of World War I, and were able to benefit from the increased foreign demand since the war (Van der Bie, 1995). During this period new industries developed rapidly, providing fertile ground for new technological applications (de Jong, 1999).

Just like other Northwest European countries, the Dutch economy fell behind the world technology and productivity frontiers during the Second World War, which created a huge potential for catch-up during the first two decades after the war. This potential was realized through increased savings and investment, a strong rise in international trade and major changes in demand structures all supporting rapid technological diffusion (Eichengreen, 1996). During the 1950s growth in the Netherlands was still strongly driven by low wages, but substantial intensifying of capital use took place during the 1960s (van Ark, de Haan and de Jong, 1996). Van Zanden (2000) has linked the early postwar growth episode to the relatively good performance of the Dutch economy during the 1920s. He labeled this period as a first growth spurt and a precursor of the postwar golden age (interrupted by the depression of the 1930s). This view gets close the concept of the 'one big wave' from Gordon (1999), discussed in Section 2.

Like other OECD countries, the Dutch economy experienced a slowdown since 1973 due to the breakdown of the Bretton Woods system, the two oil crises and exhaustion of the possibility for catch-up with the United States (Crafts and Toniolo, 1996). In addition the situation in the Netherlands was worsened because of a loss of competitiveness due to low-priced gas exports (the "Dutch disease") and over-expansionary policies during the 1970s. A serious economic crisis sparked off a new prolongued phase of wage moderation, with huge restructuring of the manufacturing sector, and a substantial expansion of service sector activity.[15] It is striking that growth between 1973 and 1995 has been much slower not only compared to the 'golden age' from 1947-73, but also compared to the earlier part of the century. Hence the slowdown of growth rates since 1973 cannot be seen as just a 'return to normalcy' as was observed for many other European countries (van Ark and De Jong, 1996). Only since the mid 1990s some recovery in GDP and per capita income growth has occurred but not in productivity growth.

The final column of Table 3 shows that the contribution of the industrial sector (mining, manufacturing, utilities and construction) to overall GDP growth was highest in three sub-periods during the past two centuries, i.e. 1870-1890, 1913-1929 and 1947-1973. As we will show below in Section 4 the first two sub-periods coincide with the diffusion of steam technology and electricity. This large contribution from industry between 1947 and 1973 is to some extent related to the large industry share in total GDP, but rapid productivity growth in manufacturing has contributed as well. Strikingly the diffusion of information and communication technology after 1973 has not led to a similar rise in the contribution of industry to GDP growth compared to earlier periods. Instead the services sector has continued to grow in size up to about 70 per cent of GDP. Even since 1995, productivity growth hardly improved. Solow's famous quip, "You can see the computer age everywhere but in the productivity statistics" (Solow, 1987), may there still be quite relevant for the Dutch economy even today. The relation between technology adoption and productivity will be discussed in more detail in the next two sections.

[15] See also van Ark, de Haan and de Jong (1996) and van Ark and de Haan (2000).

4. Technology Adoption and its Relation to Overall Productivity Growth

When focusing on the technology phases in the Netherlands, we divide the two centuries discussed above into three sub-periods:[16]

1) First industrial revolution: +/- 1800-1913, with technology based on steam
2) Second industrial revolution: +/- 1890-1990, with technology based on electricity
3) Third industrial revolution: +/- 1973-…. with technology based on information and communication technologies

Each of these technologies can be characterized as a typical General Purpose Technology (GPT), which represent core technologies giving rise to a wide range of application across industries and lead to a long run stream of innovations causing continuous cost reductions (Breshnahan and Trajtenberg, 1995). We deliberately let these phases overlap as there is much evidence that the stream of innovations from different GPTs can co-exist for quite some time and even strengthen each other (for example, the continuous increase in expenditure on electronic equipment benefits from a combined application of electricity and ICT). Moreover, we also note that the GPTs are not all-inclusive. For example, the recent rise of bio-technology is another key technology next to information and communication technology with great potential to support long run growth.

Table 5: Adoption Rates of New General Purpose Technologies, Netherlands, 1860-1999

	Steam			
	1860	1870	1880	1890
Steam machines as share of total machines (a)	0.13	n.a.	0.39	0.61
Steam power as share of total power (b)	0.26	n.a.	0.65	0.81
	Electricity			
	1904	1912	1920	1930
Horsepower of all electrical machinery (c)	0.08	0.25	0.59	0.72
	Information and Communication Technology			
	1977	1985	1992	1999
Share of IT in total equipment investment	0.05	0.09	0.13	0.21
Share of ICT in total equipment investment	0.25	0.22	0.23	0.36
Share of ICT, CNC & CAM in equipment investment (d)	0.33	0.36	0.45	0.68

(a) assuming equal horse power between steam machines and other machines
(b) assuming larger horse power for steam machines (1860: 2 times; 1880: 1.66 times; 1980: 1.33 times)
(c) horsepower of all electrical machinery as % of all horsepower minus that of generators
(to avoid double counting)
(d) CNC and CAM is assumed to be 10%, 18%, 29% and 50% of total equipment, excl. ICT
Sources: Steam: Lintsen (1995), deel VI, pp. 269-279; Electricity: de Jong (1999);
ICT: estimates kindly provided by Ronald Albers (ECB)

[16] We also checked whether the breaks somehow represented structural breaks in the annual growth rates for GDP, labour productivity, capital intensity and total factor productivity using Chow-tests. The clearest structural break was found around 1916, demarcating the steam and electricity eras. Another break for GDP and labour productivity (but not for TFP as capital intensity declined with labour productivity) was found around 1975. Strikingly no structural breaks could be found in the data for the 19th century. See Smits, de Jong, and van Ark (1999).

Table 5 compares adoption rates of the steam, electricity and ICT in terms of the share of production capacity related to each technology compared to the total production capacity. As fully adequate data for this purpose are lacking we present alternative estimates for steam and ICT, representing lower and upper bounds of adoption rates. For example, the share of machines that are steam driven shows an increase from 13 per cent of the total number of machines in 1860 to 39 per cent in 1880 and then a rapid acceleration to 61 percent of total machinery in 1890. However, as adoption of steam has been faster for bigger machines than for smaller machines, we provide an upper bound estimate assuming that machines that are steam driven generated two times as much power as the average machine in 1860, 1.66 times the power of average machines in 1880 and 1.33 times the average machine's power in 1890. The latter estimate suggests that steam power accounted for as much of 81 per cent of total power by 1890. In any case it is clear that a wide application of steam power came relatively late to the Netherlands compared not only to the United Kingdom but also compared to other continental European countries. Steam has also likely affected manufacturing more than the rest of the economy. Only after 1890 growth in manufacturing labour productivity became substantially higher than during the rest of the 19th century, and total factor productivity growth turned positive for the first time only then (compare Table 4).

The adoption of electrical power seems to have proceeded somewhat faster than that of steam power. In 1904 only 8 per cent of all generated horse power came from electrical driven machinery, but during the 1910's it more than doubled in less than 10 years, and by 1930 it was in between the upper and lower bounds for steam in 1890. During the early 20th century productivity growth further improved compared to the 19th century, in particular during the period 1913-1929 when electricity adoption rates increased most rapidly (compare Tables 4 and 5). Moreover we also find that the productivity acceleration during the electricity age appeared to take place outside the manufacturing sector as well, suggesting a greater pervasiveness of electricity. Finally, the strong and sustained acceleration in productivity growth after World War II until the mid 1970s implies that electricity (and other major inventions such as the combustion engine) provided a source of continuous new innovations and diffusion of technology.

Compared to electricity and steam, the adoption rates for ICT look relatively slow but it should be mentioned that an exact estimate of computer power to total power is very difficult to make. A direct physical comparison between computer power and total power is not possible as computer power is ideally expressed in terms of the number of MIPS (millons of instructions per second), whereas other power is expressed as horsepower.[17] We therefore made use of monetary estimates, expressed as investment, for which we developed three alternatives: a lower bound estimate that represent the share of IT equipment (mainly computer equipment) in total investment in constant prices, a middle estimate that takes into account investment in communication equipment, and an upper bound estimate that incorporates an increasing share of other equipment repesenting computer controlled machinery.[18] Even when assuming that apart

[17] See Nordhaus (2001)

[18] These estimates suffer from two additional shortcomings. Firstly, as prices of ICT equipment have probably declined more rapidly then what is registered in the Dutch statistics (in contrast to the United

from ICT equipment, 50 per cent of investment of other machinery was computer controlled in 1999, less than 70 per cent of total investment in 1999 could be marked as “ICT power”.

Comparing these ICT adoption rates with the productivity growth since 1973, the link seems much weaker than for the previous technology phases. In fact productivity growth slowed down very substantially after 1973 and even since 1995, when ICT rapidly diffused across the economy, hardly any acceleration in productivity growth was observed. A possible resolution to this puzzle, is that the impact of ICT on productivity so far is strongly concentrated in a limited numbers of industries, i.e., largely industries that produce ICT or that use it very intensively. This hypothesis requires an disaggregated industry approach, which is pursued in the next section.

5. Mushroom-like or Yeast-like Productivity Growth?

A key issue in the debate on the impact of ICT on growth is whether its “general purpose technology” characteristics are effectuated in terms of widespread applications throughout the economy. At first sight this seems clearly the case as ICT investments are widely spread across the economy. Virtually no industry is the economy has been unaffected by ICT. However, as mentioned above, the distributions of ICT investments and their impact on productivity have been very uneven and even among heavy investors the productivity effects have been very different.

To analyze the dispersion of ICT and previous general purpose technologies across industries one can employ the metaphors of “mushroom” and “yeast” to characterize productivity growth, which was introduced by Harberger (1998). “Yeast-like” productivity growth represents broad advances in technology applications across the economy impacting productivity growth in many industries. “Mushroom-like” productivity growth emphasizes a more unequal distribution of productivity growth across industries. David and Wright (1999) stress that yeast-like growth best fits the conventional neoclassical production function, although it should also explicitly allow for the existence of externalities due to the aggregate growth of capital and knowledge and scale economies. Mushroom-like growth is more easily associated with the evolutionary school of economics, as it stresses the myriad and idiosyncratic sources of cost savings and the stochastic nature of the selection process.

Harberger provides a very powerful tool to analyse the “yeast” vs. “mushroom” nature of growth by looking at the industry distribution of the contributions to aggregate productivity growth. By drawing “Lorenz-type” diagrams of cumulative productivity contributions versus cumulative value added shares, one can picture whether only a small number of industries or a large range of industries together contribute to productivity growth. For example, Harberger (1998) himself, who focussed on the US experience during the 1970s and 1980s, found more of a mushroom-type growth process, which in his view resulted from real cost reductions (which is

States, the Netherlands makes no use of hedonic price indexes for computers) the rise in investment share may have been somewhat understated. But, secondly (and offsetting the bias created by the first point) we look at investment rather than capital stock, which may imply that we overstate the share of ICT, as ICT has equipment has much shorter lives than other equipment and therefore a lower share in the ICT capital stock.

one possibile interpretation of TFP) which stemmed "from 1001 different causes" (Harberger, 1998, p. 4-5). In contrast, David and Wright (1999) find a fairly equal contribution of industries to manufacturing productivity growth in the United States for the period 1919-1929, which confirms a yeast-type of growth. Comparing the two studies might indicate the strong early impact of electricity across the economy related to a productivity surge, which was followed by a more ad-hoc process of different inventions and innovations during the period of slower growth.[19] The growth experience during the latter period may also represent the petering out of the economy-wide diffusion process with some industries realizing growth effects through a continuous stream of new innovations, whereas in many other industries the new technology has only created a once-for-all level effect.

In a recent study by the McKinsey Global Institute, the contribution of only six industries (out of 50-odd industries, and representing 31 per cent of non-farm sector GDP) with the fastest acceleration in productivity growth in the United States accounted for the aggregate productivity acceleration of 1.3 percentage points from 1995-1999 compared to 1989-1995 (McKinsey Global Institute, 2001).[20] According to the McKinsey study, the small based acceleration suggested that ICT had not (yet) achieved a widespread impact on productivity growth across the economy. Other studies have suggested, however, that ICT has impacted productivity growth in a wider range of ICT-producing and ICT-using industries which also showed positive productivity growth ("overshooting" the aggregate productivity growth rate) but which was offset by other industries showing negative growth rates (Stiroh, 2001; Jorgenson, Ho and Stiroh, 2002; van Ark, Inklaar and McGuckin, 2002).

In this section we develop a range of Harberger diagrams (or "sunrise diagrams") to compare the distribution of industry contributions to labour productivity and total factor productivity growth for four sub-periods, i.e. 1860-1890 (when steam use seriously took off in the Netherlands), 1900-1938 (the period of strong increases in electricity application), 1977-1995 (the period during which the first shift towards an ICT technology paradigm occurred) and 1995-2000 (when ICT began to show its first economy-wide effects on growth). For each industry we develop diagrams for the total economy as well as for industry (or manufacturing), as we expect GPTs to affect goods production (and in particular manufacturing goods) more than service production, at least in first instance.

The Harberger disaggregation in the diagrams below is based on a computation of labour productivity growth by industry and subperiod. We first computed the industry productivity contributions on the basis of a shift-share methodology using labour weights for the first and last year of each subperiod. We then weighted the industry contribution at the value added shares in the first year of each subperiod, ranked the industries from their largest positive contribution to

[19] The comparison between the David/Wright and Harberger studies here is affected by the fact that former focuses on the manufacturing sector. The impact of electricity in other sectors of the economy, such as agriculture and services, might have been much more limited.

[20] These industries (in order of GDP share in 1995) were wholesale trade, retail trade, securities, electronics, industrial machinery and telecom services. Another 19 industries accounted for an additional 0.5 percentage point acceleration in productivity growth, which was offset by a productivity deceleration in the remaining 15 industries.

their largest negative contributions, and then cumulated the productivity contributions and value added shares to develop the sunrise diagrams.[21]

Figure 1 shows industry contributions during the period 1860 to1890. It shows that the growth contribution for the economy as a whole is fairly narrowly based on five industries covering about 35% of value added; four of which (except the trade sector) are in manufacturing. In 1860 these four manufacturing industries (metals and engineering, food processing, textiles and wearing apparel) accounted for 70% of all steam power, even though only 13% of machinery installed in the food manufacturing industry was steam driven. By 1890, steam power accounted for 85% or more in three of the four manufacturing industries, and in food processing it had gone up to 65%.[22] The positive growth performance of those industries which benefitted from steam, however, was offset by a negative growth performance of some other large industries, in particular agriculture and shipping.

Figure 2 shows that productivity growth was more pervasive during the first few decades of the 20th century compared to the late 19th century. It should be noted that productivity growth rates during this period were also substantially higher than during the period 1860-1890. Strikingly some of the smaller manufacturing industries (paper and printing) were among the fastest growing industries, but non-manufacturing industries such transport and trade contributed as well.[23] There was hardly any "overshooting" of the aggregate productivity growth rates, and only two industries (textiles and domestic services) showed slightly negative productivity contributions during this period. In this respect productivity growth was clear more "yeast-like" than during the late late 19th century. The rapid rise of electricity has probably been an important factor contributing to the improved productivity performance. Its application was widespread and went well beyond the manufacturing sector. The institutional and organizational changes required for rapid diffusion of electricity, as described above for the United States, were also largely realized during the 1910s and 1920s in the Netherlands (Schot, 2000).

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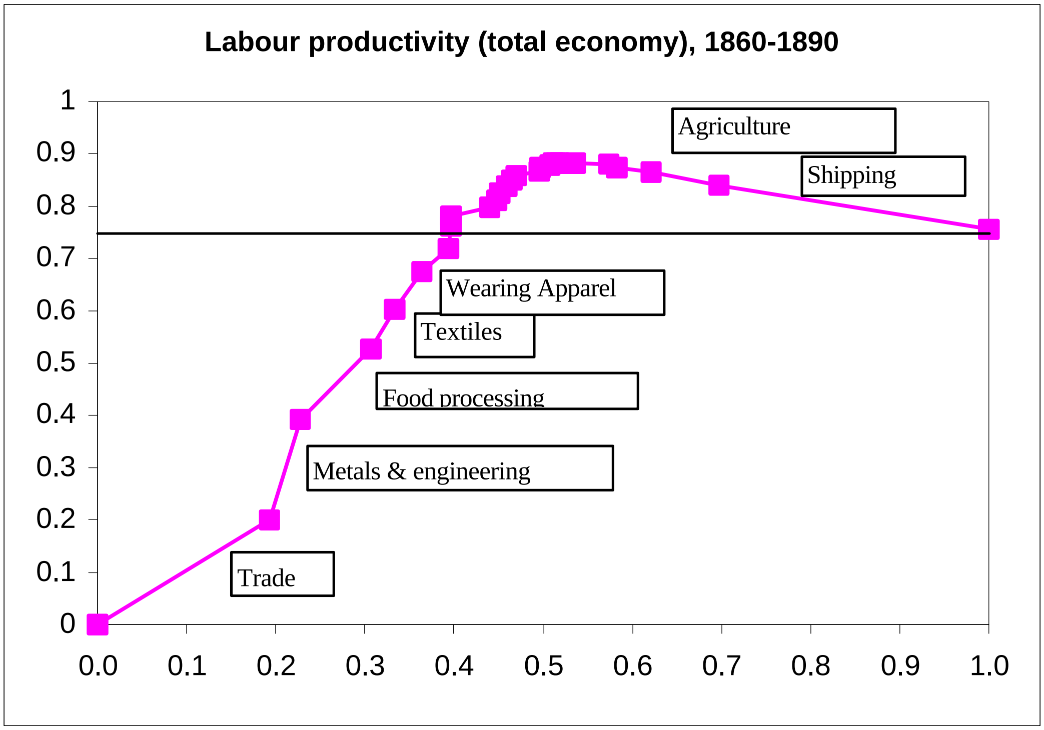
[21] See Timmer (2000) and van Ark and Timmer (2002) for an exact description of the shift-share methodology. Here we use the combined intra-industry effect and each industry's shift effect to compute industry contributions. Alternatively one might also look at the intra-industry effect only to identify the impact of technologies on productivity growth within each industry.

[22] See *Techniekgeschiedenis*, deel VI, pp. 269-279

[23] Comparisons for subperiods, not shown in the present paper, show that much of the acceleration was concentrated in the periods 1900-1913 and 1921-1929. During the period 1929-1938 steep positive contributions came from paper and printing, but otherwise productivity contributions were small, and in some of the largest industries (food processing, textiles, construction and metal engineering) zero or negative.



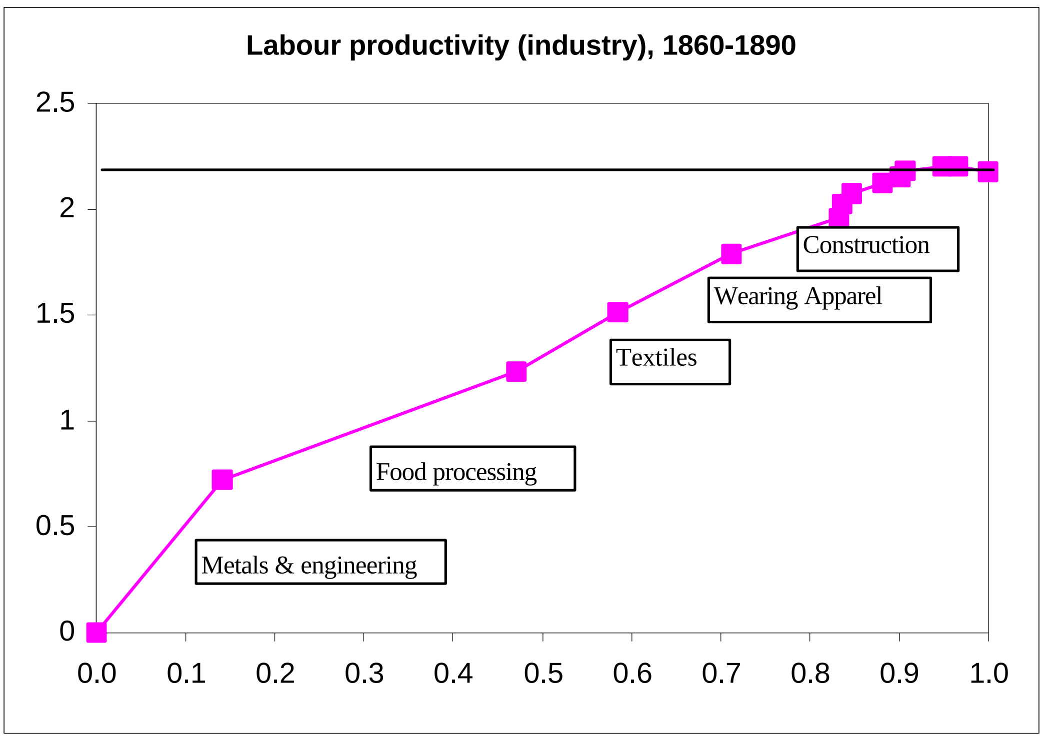
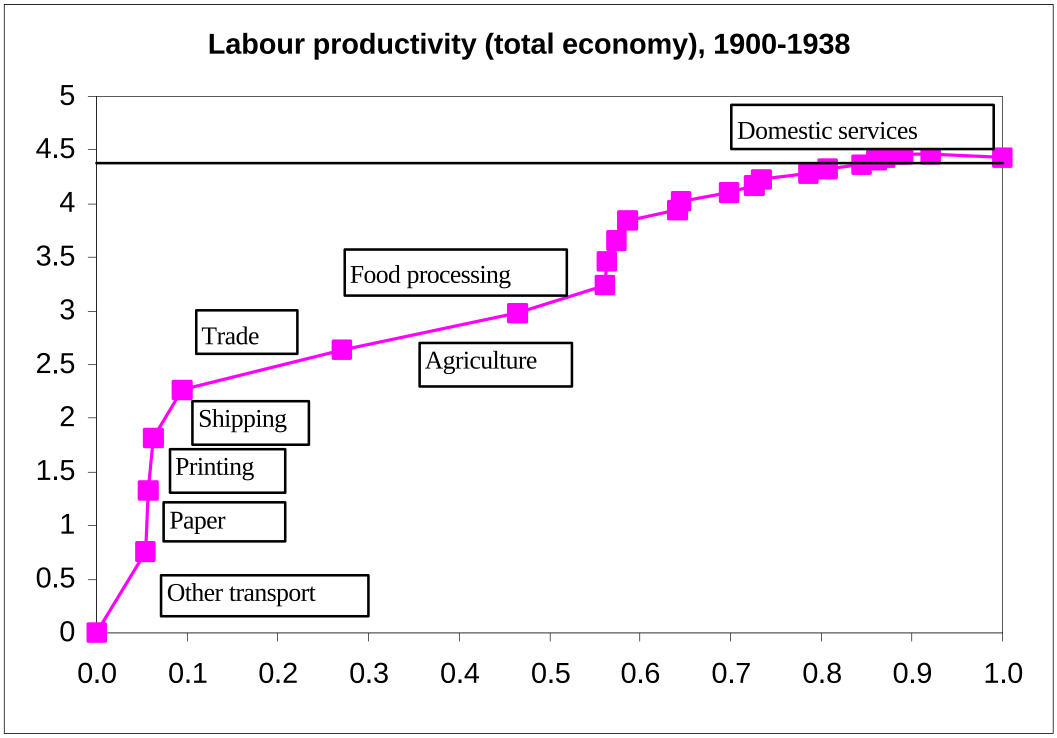


Figure 1: Industry contribution to labour productivity growth, total economy and industry, 1860-1890



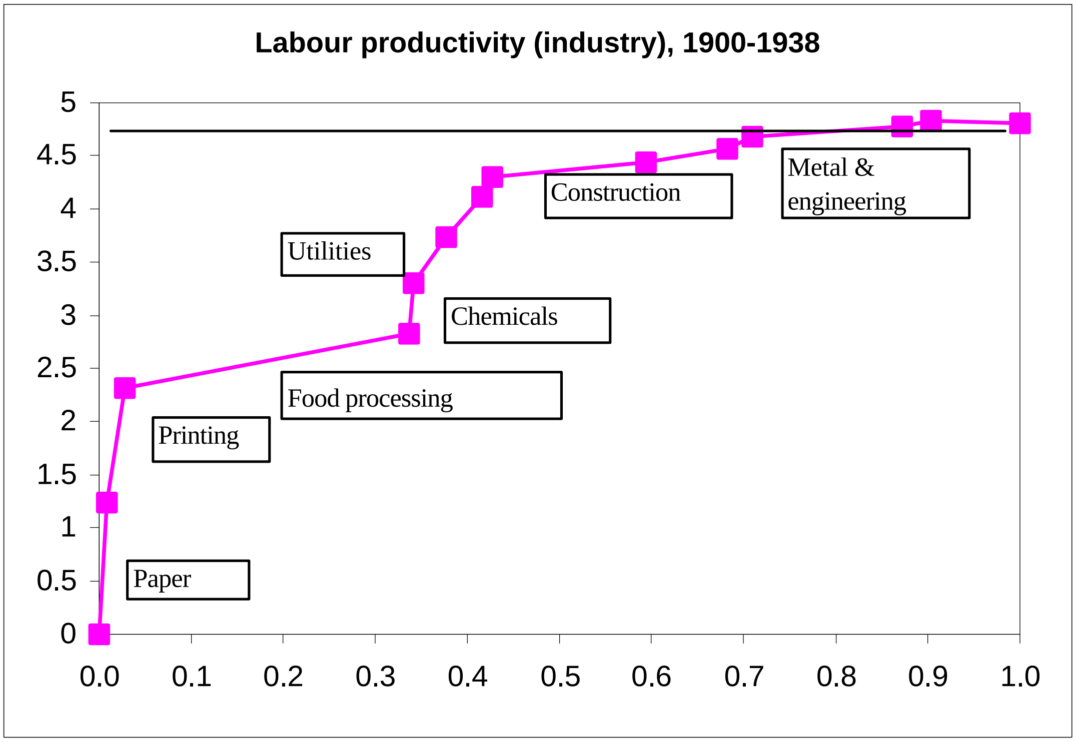
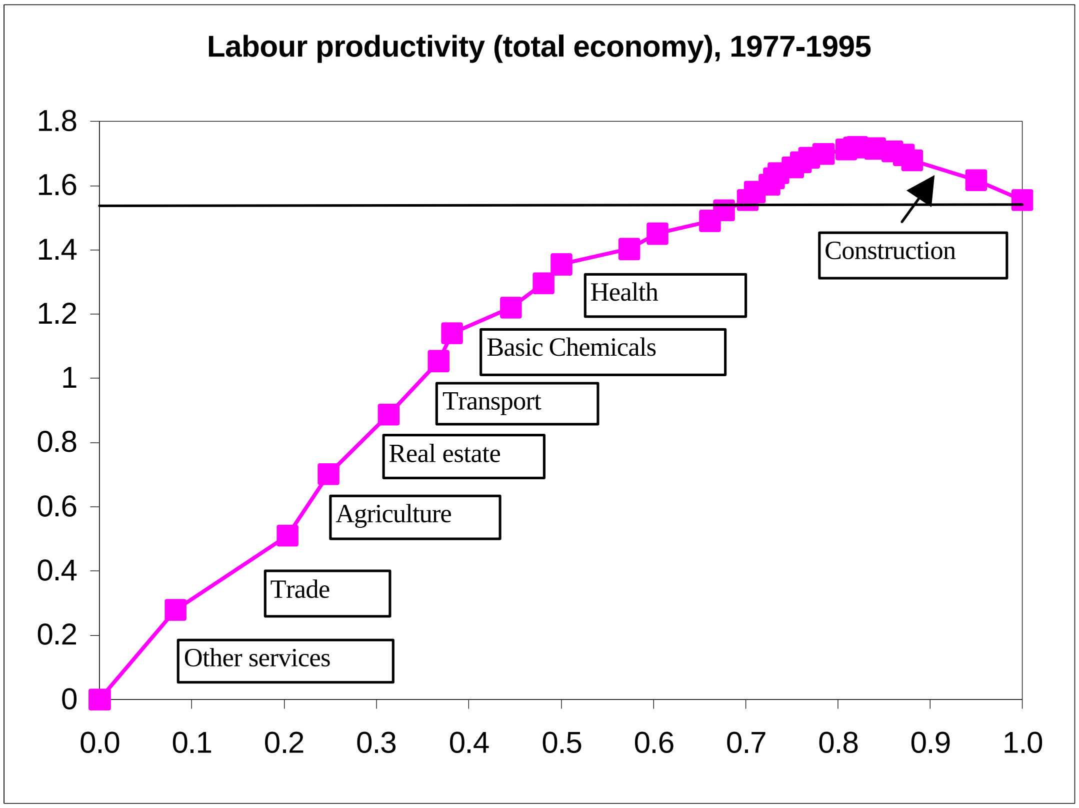


Figure 2: Industry contribution to labour productivity growth, total economy and industry, 1900-1938



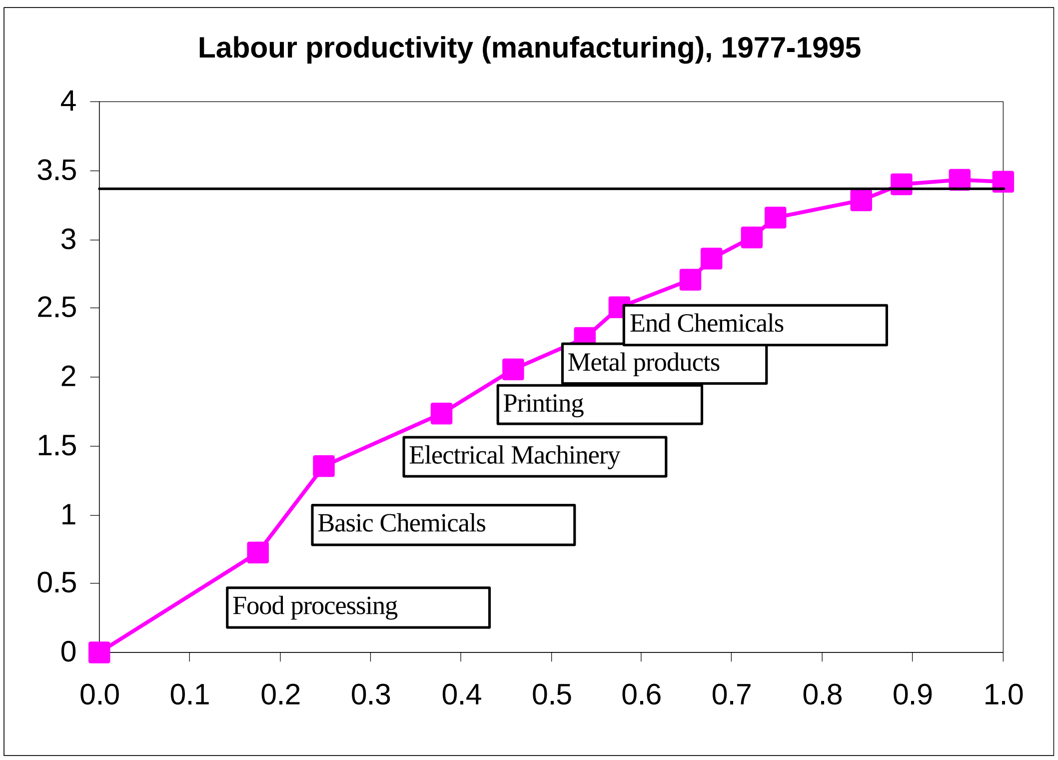
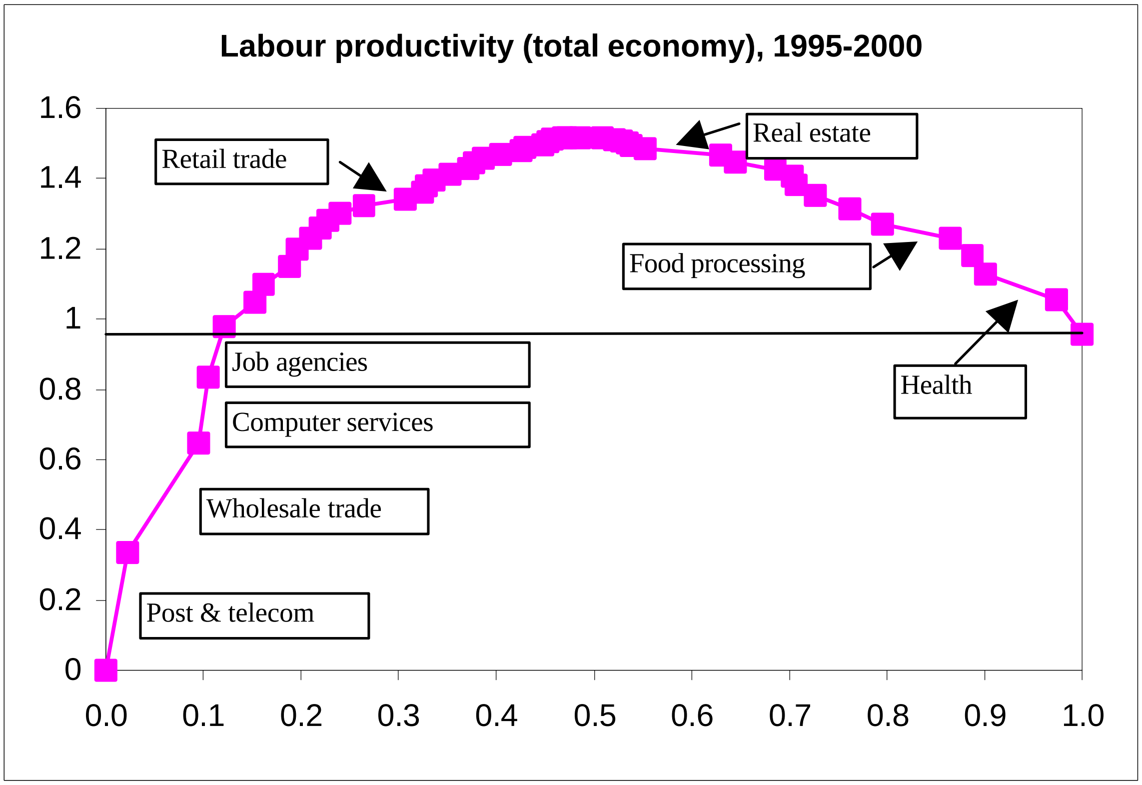


Figure 3: Industry contribution to labour productivity growth, total economy and manufacturing, 1977-1995



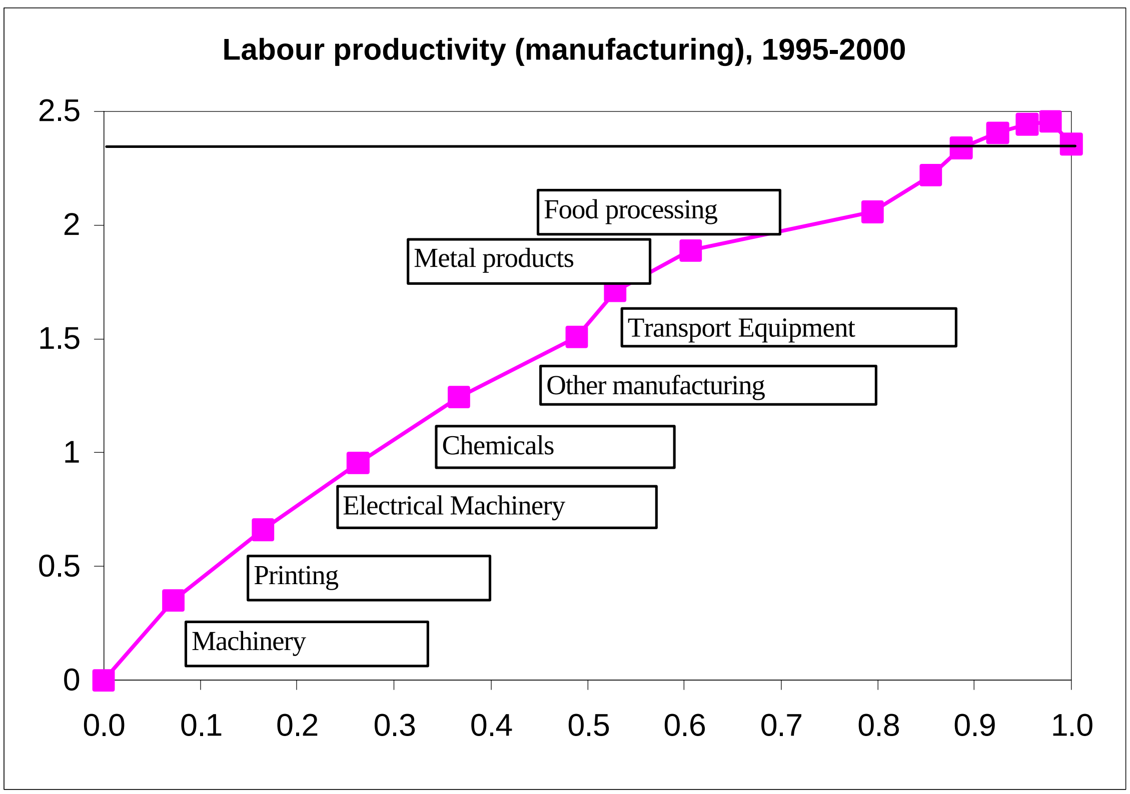


Figure 4: Industry contribution to labour productivity growth, total economy and manufacturing, 1995-2000

Figure 3 concentrates on the more recent period, 1977-1995.[24] During this period productivity growth was substantially lower than during the early post World War II period, but also well below that of the first decades of the 20th century. About twelve out of 30 industries, which represented about 65% of value added, accounted for the overall labour productivity growth of 1.6 per cent, and there was only a limited overshooting of less than 0.2 per cent. Strikingly there are no manufacturing industries among the five largest contributors to productivity growth during this period. This reflects the rapid rise of the service sector during this period. But despite its smaller size, it can be seen from the lower panel in Figure 3 that – compared to the earlier subperiods – manufacturing productivity growth rates were substantially higher than in the rest of the economy. This partly reflects rationalization and downsizing of the manufacturing sector. But at the same time, relatively high wage levels have led to further intensification of capital use in the manufacturing sector, which in turn increased opportunities for new technological applications such as the introduction of CNC and CAM machinery in the manufacturing sector. Indeed within manufacturing, productivity improvements during this period were largest in industries with traditional comparative advantages, such as food processing and basic chemicals and electrical machinery. But at the total economy level the effect of these productivity improvement were limited given the small size of these manufacturing industries. On the whole, productivity growth during this period was more “mushroom”-like and fairly typical of Harberger’s “1001 different causes” for productivity growth, of which ICT was an important one but with a relatively small contribution.

Finally, Figure 4 focuses on the most recent period. Productivity growth is substantially lower than in any of the earlier periods (around 1 per cent for the aggregate economy) and there are large differences across sectors. Four service industries (post and telecommunications, wholesale trade, computer services and job agencies) show the largest productivity increases, but account for only 10 per cent of value added. These industries are strongly ICT related, and ICT has probably contributed importantly to their productivity performance. But there is also substantial “overshooting” in productivity growth of more than 0.5 per cent as well as a large number of industries (including real estate, food processing and health) with negative offsetting productivity growth rates. In manufacturing the productivity lead is also taken by industries that are typically ICT intensive (machinery, printing, electrical), and comparison with the period 1977-1995 suggest some important structural changes. As a whole the process looks much more “mushroom” than yeast, with ICT significantly impacting some industries but not as widespread as in the case of electricity.

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[24] Unfortunately we lack good industry data for the period 1950-1973.

6. Conclusion

In this paper we have investigated the impact of ICT – representing a general purpose technology – on productivity growth in a historical perspective for the Netherlands. We find that of the GPTs (steam, electricity and ICT) studied in this paper, the effects of electricity appear to be particularly largest and most widespread in the Netherlands during early 20th century, when electricity adoption rates increased most rapidly and productivity growth was most pervasive across industry. The effects of steam during the late 19th century were smaller, as it was introduced relatively late and its effects remained limited to a few (manufacturing) industries. In comparison the effects of ICT have already been present during the 1980s and early 1990s, but mainly through the rationalization process in manufacturing. More recently effects of ICT are strongly impacting some service industries, but the aggregate impact is still small compared to the electricity era and looks much more like the steam case for the Netherlands.

There are various explanations for the hirtherto more "mushroom-like" growth effects of ICT compared to the electricity paradigm. Firstly, one obvious explanation may be the time lag hypothesis as advanced by Paul David. However, the first commercial application of ICT occurred in the 1970s, and therefore more widespread impact may be expected in due course. In particular potential applications is services are likely to generate more yeast like growth in the longer run.[25] Secondly, the complexity of ICT applications may go beyond that of electricity. Even though electricity has strongly affected the production process economy wide, new product applications were mainly concentrated in manufacturing. In contrast, whereas the potential for process-type application of ICT in manufacturing may already have been largely realized, the real challenge for ICT is in changing production processes in services and the production of new services (den Hertog, 2000). Finally, as in the case of electricity, important organizational and institutional reforms are needed to facilitate ICT applications. These include arrangements concerning of property rights (domestic and internationally) of products and services produced by network industries, the reorganization of their product markets, and changes in capital markets to provide venture capital. Moreover ICT appears to be strongly biased towards high skilled labour, putting considerable pressure on the education system to increase the nature and quality of education, to improve trajectories for lifelong learning, and strengthen the involvement of the business sector in training trajectories (OECD, 2001).

[25] See also Jorgenson, Ho and Stiroh (2002) for recent US acceleration in services productivity growth.

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