Innovation, Diffusion and Schumpeter’s Business Cycles Today

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Abstract:

In this paper, we pose (but do not attempt to answer) a number of questions about changes in the economic environment and ask whether earlier cyclical analyses are still adequate. Although there are many similarities in patterns observed in earlier cycles and those that are found at present, there have also been significant deviations since the 1970s. We ask, for example, whether the multiplication in the number of economic nodes to include increasing numbers of Asian and Latin American nations will lead to a greater diversity of growth patterns that could dampen cyclical activities when viewed from a global perspective. A second issue that we address is the increasing dominance of service activities and the corresponding diminution in the role of manufacturing in modern economies. Will this lead to changes in the timing of cyclical events both within national economies and internationally and, if so, what form will the changes take? Finally, we raise the issue of the rate and extent of the spread of scientific and technological knowledge in recent decades and ask if the increasing diffusion that we detect will lead to a proliferation in the number of national economies that can exert important influence on cycles.

Key Words: Schumpeter, economic evolution, knowledge diffusion, business cycles, technological revolutions, ICT revolution, service sector.
1. Introduction

The central issue we address is how the current technology cycle differs from previous cycles. How may the spread of industrialisation to Asia and Brazil have affected the course of cycles? Does the faster transmission of scientific and technical information and knowledge mean that the length and nature of Kondratieff long-cycles will change as the diffusion of information accelerates, or will tacitness of other types of knowledge become an insurmountable obstacle to the diffusion process? Has the shift from a manufacturing-based to a service-based economy changed the relationship between innovation and cycles? All of these factors point to a need to reconsider the Schumpeterian theory of long-cycles both in theoretical terms and through the inclusion of another 75 years of history.

While the underlying principles of Schumpeter’s theory of business cycles are grounded in the theories of Walras, Marx and Schumpeter’s own Viennese mentors, they also depend on his interpretation of history from the Industrial Revolution up to the late 1930s. As his vision of the future was based on the extrapolation of existing trends, its validity depends on a high degree of stability in the process of change. This suggests a probable need for periodic adjustments.

What Schumpeter did not envisage was that both information and knowledge would begin to spread further and at a much faster pace than in the early period of industrialization, resulting in a multiplication in the foci for innovation and a reduction in the synchronous movement of economies. Incremental but significant technological changes can now originate from many locations that were previously excluded from having a significant role in interrupting the circular flow, and there is no good reason to believe that radical change will
not eventually derive from these regions. Because these economies have their own patterns of economic growth and contraction, and because the rate of technological diffusion in general appears to have accelerated in recent decades, these developments may change the very character of the cyclical patterns of change described by Schumpeter. Significant innovations, rather than being clustered, could become more evenly spaced, lessening the tendency for the overall benefits of technological change to become dampened as was common in previous Kondratieff long-cycles or technological revolutions.

This paper explores some of these issues in the context of Schumpeter’s *Theory of Economic Development* and *Business Cycles*. The two books are very different. The first outlines the concept of innovation in the context of economic theory, while the second considers the impact that a new innovation could have on the economy as cycles proceed, or what could be called the diffusion process. Schumpeter introduces three different types of cycles, of which the Kondratieff long-cycles relate directly to the diffusion process and the Juglar medium-cycles relate to credit and how innovation is financed. Our discussion also builds on the theory of the technology long-cycle developed by Chris Freeman and Carlota Perez. Both consider the cycle as a way to measure how technology is generated, used and diffused throughout the economy and both recognize that each cycle has its own characteristics. The Juglar cycle may also play an important role, which was underestimated by Schumpeter partly because he had left the endogenous credit-driven theory of finance developed in his *Theory of Economic Development* out of *Business Cycles*. Financial crises may have an important impact on the way technology is generated, used and diffused, especially between the more developed countries of Europe and the United States and East and South Asia.

2. The Evolving Context of Economic Development
Although there was geographical diffusion of innovation following the Industrial Revolution in Great Britain, it remained confined. Throughout the period for which Schumpeter provided empirical evidence in Business Cycles, modern industrialization was confined to North America and Western Europe with some peripheral growth in Japan, the USSR and the so-called ‘regions of recent settlement’ of the British Empire. In this setting, business cycles were not synchronised, but they were systematically related through flows of capital and migration, while Kondratiev cycles across industrialised economies were more closely (although not completely) synchronized. Because of the high degree of interrelationship of cycles generated in only a few nodal economies, it was possible for cycles to play themselves out relatively free of exogenous influences that could disrupt patterns of expansion and contraction and increase the degree of seeming randomness in both supply and demand. There is reason to think that this behavior may have changed since Schumpeter’s death as the number and character of nodal economies have evolved.

Despite considerable continuity in patterns of economic development since the early nineteenth century, there have also been important changes that have affected the relationships between national economies both temporally and geographically. The initiation of new players into the world of innovation and sophisticated technologies has occurred periodically since the Industrial Revolution in Britain in the eighteenth century. Belgium, France, various German states and ultimately Imperial Germany, Austria, Bohemia, Italy, Japan and Russia were all able to establish up-to-date industrialization in at least some sectors by 1914 (Landes, 2003). In addition, members or former members of the British Empire achieved high standards of living and, in the case of the United States, industrial leadership in important sectors. However, with the exception of Japan and Russia, at the time of their initial industrialization most of these countries were not too far from the world’s leaders in terms of per capita output (Table 1). Similarly, in 1870, GDP per person employed in the
United States was nearly 90 per cent that in the United Kingdom, the world’s leader. Among the pre-1940 industrializers, only Japan, with a GDP per person employed that was barely one sixth of that in the UK, lagged substantially (Maddison, 2006, 349).

This pattern of industrialization in nations or regions that were within reasonable proximity of the leaders (that had, say, 30 per cent or more the leaders’ per capita GDP when they began their ‘take-offs’ (Rostow, 1960) or ‘great spurs’ (Gerschenkron, 1962)) has been altered in recent decades as much poorer countries have been able to achieve rapid growth and structural change. As Table 2 shows, in the final decades of the last century the economic weights of countries such as South Korea, the People’s Republic of China, Taiwan, India, and Brazil were much smaller than those of the leading industrial nations of Western Europe, Russia, North America and Japan.¹ Moreover, with the exception of Japan, most of the earlier industrializers shared a common European background that extended to some familiarity with

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>1820</th>
<th>1870</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>100</td>
<td>187</td>
</tr>
<tr>
<td>Netherlands</td>
<td>107</td>
<td>162</td>
</tr>
<tr>
<td>Belgium</td>
<td>77</td>
<td>158</td>
</tr>
<tr>
<td>France</td>
<td>72</td>
<td>110</td>
</tr>
<tr>
<td>Sweden</td>
<td>70</td>
<td>97</td>
</tr>
<tr>
<td>Italy</td>
<td>65</td>
<td>88</td>
</tr>
<tr>
<td>Spain</td>
<td>62</td>
<td>71</td>
</tr>
<tr>
<td>Russia</td>
<td>40</td>
<td>55</td>
</tr>
</tbody>
</table>


Index of Comparative Levels of GDP Per Capita of European Nations, 1820 and 1870 (UK 1820 = 100)

Table 1

¹ Given the very high populations in China, India and Brazil, their relative levels of GDP would be even more unpromising if expressed in per capita terms, as in Table 1.
<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
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<tr>
<td>1 USA</td>
<td>27.10</td>
<td>26.70</td>
<td>26.46</td>
<td>26.87</td>
<td>26.87</td>
<td>27.90</td>
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<td>26.47</td>
</tr>
<tr>
<td>2 EU15</td>
<td>35.14</td>
<td>34.05</td>
<td>32.65</td>
<td>31.53</td>
<td>31.16</td>
<td>30.13</td>
<td>29.26</td>
<td>27.29</td>
</tr>
<tr>
<td>3 Former Soviet Union</td>
<td>4.16</td>
<td>4.07</td>
<td>4.17</td>
<td>4.00</td>
<td>2.63</td>
<td>1.79</td>
<td>2.05</td>
<td>2.40</td>
</tr>
<tr>
<td>4 Japan</td>
<td>10.43</td>
<td>10.64</td>
<td>11.43</td>
<td>12.06</td>
<td>12.51</td>
<td>11.39</td>
<td>10.30</td>
<td>9.40</td>
</tr>
<tr>
<td>5 Total 1-4</td>
<td>76.83</td>
<td>75.46</td>
<td>74.71</td>
<td>74.46</td>
<td>73.17</td>
<td>71.21</td>
<td>69.59</td>
<td>65.56</td>
</tr>
<tr>
<td>6 China</td>
<td>0.80</td>
<td>0.88</td>
<td>1.20</td>
<td>1.66</td>
<td>2.35</td>
<td>3.29</td>
<td>4.36</td>
<td>6.46</td>
</tr>
<tr>
<td>7 South Korea</td>
<td>0.58</td>
<td>0.72</td>
<td>0.86</td>
<td>1.13</td>
<td>1.48</td>
<td>1.67</td>
<td>1.83</td>
<td>1.93</td>
</tr>
<tr>
<td>8 Taiwan</td>
<td>0.24</td>
<td>0.32</td>
<td>0.40</td>
<td>0.50</td>
<td>0.64</td>
<td>0.73</td>
<td>0.76</td>
<td>0.82</td>
</tr>
<tr>
<td>9 India</td>
<td>0.90</td>
<td>0.91</td>
<td>0.99</td>
<td>1.09</td>
<td>1.23</td>
<td>1.43</td>
<td>1.65</td>
<td>2.15</td>
</tr>
<tr>
<td>10 Brazil</td>
<td>1.80</td>
<td>2.16</td>
<td>2.11</td>
<td>2.14</td>
<td>2.01</td>
<td>2.00</td>
<td>1.94</td>
<td>2.04</td>
</tr>
<tr>
<td>11 Total 6-9</td>
<td>4.32</td>
<td>4.99</td>
<td>5.56</td>
<td>6.52</td>
<td>7.71</td>
<td>9.12</td>
<td>10.54</td>
<td>13.40</td>
</tr>
<tr>
<td>12 10/5</td>
<td>0.056</td>
<td>0.061</td>
<td>0.074</td>
<td>0.088</td>
<td>0.105</td>
<td>0.128</td>
<td>0.151</td>
<td>0.204</td>
</tr>
</tbody>
</table>

Note: Totals in lines 5 and 10 may be slightly inaccurate due to rounding. Figures are based on 2005 US dollars.


Real 2005 GDP Shares (5-year averages in per cent), Selected Countries, 1971-2010

Table 2
each other’s languages and similarities in their education systems. By contrast, most of the new industrializers have been drawn from different cultural heritages and have had quite different cultural and societal institutions, which may have made it harder for them to acquire information and knowledge.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>3.21</td>
<td>3.27</td>
<td>3.41</td>
<td>1.58</td>
</tr>
<tr>
<td>EU15</td>
<td>3.14</td>
<td>2.45</td>
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<td>1.21</td>
</tr>
<tr>
<td>Former Soviet Union</td>
<td>3.12</td>
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<td>-3.99</td>
<td>5.42</td>
</tr>
<tr>
<td>Japan</td>
<td>4.50</td>
<td>4.64</td>
<td>1.19</td>
<td>0.86</td>
</tr>
<tr>
<td>China</td>
<td>6.28</td>
<td>9.35</td>
<td>10.45</td>
<td>10.48</td>
</tr>
<tr>
<td>South Korea</td>
<td>7.30</td>
<td>8.74</td>
<td>6.19</td>
<td>4.16</td>
</tr>
<tr>
<td>Taiwan</td>
<td>9.77</td>
<td>7.65</td>
<td>6.24</td>
<td>3.94</td>
</tr>
<tr>
<td>India</td>
<td>3.09</td>
<td>5.57</td>
<td>5.48</td>
<td>7.78</td>
</tr>
</tbody>
</table>


Average Annual Growth Rates of Real GDP (10-year periods), Selected Countries, 1971-2010

Table 3

As late as the 1970s, the GDP of late industrializers such as the PRC, India, South Korea, Taiwan and Brazil,\(^2\) all of which have since performed well in one or more modern manufacturing sectors, comprised in total less than six per cent of the total GDP of the nodal economies of the early Post World War II period – the USA, Western Europe, the Soviet Union and Japan (Table 2). By 2010, the total GDP of the newer nodes exceeded 20 per cent of that in the older ones and was greater than the total weight of Japan and the territory of the former USSR. Although, with the exception of Taiwan and South Korea, per capita GDP remains substantially below that in the older nodal nations (Table 4), it has increased greatly

\(^2\) Other countries and regions such as Singapore and Hong Kong, could be added, but this would not affect the general picture we are presenting.
in comparative terms since 1950, because of the high GDP growth rates, especially since the 1970s (Table 3).

Our contention is not that the new nodal economies have as a group achieved anything like parity with the older ones, or even that they will in the foreseeable future. They are likely to be subject to fluctuations just as Western and Japanese economies have been since the nineteenth century (Table 3; Denison, 1967). Nevertheless, their robust performance in recent decades does raise some questions in relation to Schumpeterian formulation. Firstly, has the appearance of new nodal economies affected the patterns of global business cycles?

Table 4. Western Europe, United States, China India, Brazil and South Africa in the world economy – Share in world population and world GDP, and per capita GDP, 1820-2010

<table>
<thead>
<tr>
<th></th>
<th>1820</th>
<th>1870</th>
<th>1913</th>
<th>1950</th>
<th>1973</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Percentage share of world population</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Europe</td>
<td>11.0</td>
<td>12.8</td>
<td>12.7</td>
<td>10.5</td>
<td>8.0</td>
<td>5.1</td>
</tr>
<tr>
<td>United States</td>
<td>1.0</td>
<td>3.2</td>
<td>5.4</td>
<td>6.2</td>
<td>5.6</td>
<td>4.7</td>
</tr>
<tr>
<td>China</td>
<td>36.6</td>
<td>28.1</td>
<td>24.4</td>
<td>22.3</td>
<td>23.3</td>
<td>20.3</td>
</tr>
<tr>
<td>India</td>
<td>19.9</td>
<td>17.0</td>
<td>14.2</td>
<td>14.7</td>
<td>15.3</td>
<td>17.9</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.4</td>
<td>0.8</td>
<td>1.3</td>
<td>2.2</td>
<td>2.7</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Percentage share of world income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Europe</td>
<td>20.5</td>
<td>30.5</td>
<td>30.8</td>
<td>24.4</td>
<td>23.3</td>
<td>13.9</td>
</tr>
<tr>
<td>United States</td>
<td>1.8</td>
<td>8.8</td>
<td>18.9</td>
<td>28.1</td>
<td>22.7</td>
<td>18.2</td>
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<tr>
<td>China</td>
<td>32.9</td>
<td>17.1</td>
<td>8.8</td>
<td>3.7</td>
<td>3.7</td>
<td>18.7</td>
</tr>
<tr>
<td>India</td>
<td>16.1</td>
<td>12.1</td>
<td>7.5</td>
<td>4.3</td>
<td>3.2</td>
<td>7.5</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.4</td>
<td>0.6</td>
<td>0.7</td>
<td>1.7</td>
<td>2.6</td>
<td>2.6</td>
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<tr>
<td><strong>Per Capita GDP (Geary-Khamis dollars)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Western Europe</td>
<td>1,245</td>
<td>2,088</td>
<td>3,688</td>
<td>4,906</td>
<td>12,014</td>
<td>21,774</td>
</tr>
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<td>United States</td>
<td>1,257</td>
<td>2,445</td>
<td>5,301</td>
<td>9,561</td>
<td>16,689</td>
<td>30,834</td>
</tr>
<tr>
<td>China</td>
<td>600</td>
<td>530</td>
<td>552</td>
<td>347</td>
<td>649</td>
<td>7,371</td>
</tr>
<tr>
<td>South Korea</td>
<td>893</td>
<td>770</td>
<td>2,841</td>
<td>30,000*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>533</td>
<td>533</td>
<td>673</td>
<td>619</td>
<td>853</td>
<td>3,331</td>
</tr>
<tr>
<td>Taiwan</td>
<td>936</td>
<td>4117</td>
<td>35,700*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>646</td>
<td>713</td>
<td>811</td>
<td>1,672</td>
<td>3,880</td>
<td>6,789</td>
</tr>
</tbody>
</table>

*Note: Percentages were calculated from estimates of total world population and GDP. The Geary-Khamis dollar, is a hypothetical unit of currency that has the same purchasing power parity (PPPs) that the U.S. dollar had in the United States in 1990. Western Europe includes the 12 most advanced economies: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.

* 2010 US dollars, PPP.

Secondly, how have changing patterns in the diffusion of knowledge contributed to the relative growth of East Asian and Brazilian economies? And finally, do the sectoral patterns of growth of these new nodes indicate that Schumpeter’s growth model and the role that innovation plays have changed since the end of the Second World War. The latter question is particular relevant in view of two factors that are discussed later in our paper: The increasing contribution of the newer nodal economies to innovation, and the effects of innovation on cycles and on growth in a world economy that is increasingly oriented towards services rather than manufacturing as in the first half of the twentieth century.

3. Schumpeter on innovation and diffusion

Schumpeter (1912) began his Theory of Economic Development by describing production as a circular flow of income between producers and consumers. The first chapter essentially develops a Walrasian pure exchange economy, in which production and consumption are in equilibrium through the exchange process and, in the absence of exogenous change, the economy will neither grow nor contract significantly. In this economy people are endowed with goods and have preferences over bundles of goods and so may desire to exchange the goods they are endowed with for other goods. He then describes the data or independent variables from which Walras (1873) started with: (1) the initial endowments; (2) the preferences of consumers; and (3) the technical alternatives from which cost-minimizing producers can choose. In equilibrium, prices of all factors of production and their distribution across different industries are determined simultaneously and symmetrically when marginal revenue equals marginal costs when there is free competition. Profits are maximized since there would be no economic profits remaining in the economic system. In a production-based economy, Schumpeter (1912: 62) upheld the long held belief that equilibrium prices, including uniform rates of remuneration for each particular kind of input (including labour
and other material inputs), result from the actions of competitive profit-seeking producers concerned with minimizing production costs. This process of search and selection by profit-seeking producers explains how capital and labour move between enterprises in the absence of significant barriers to entry and exit.

To explain economic development and the business cycle, Schumpeter (1912, 1939) assumed that the technical alternatives available to the enterprise could change, while the initial endowments and the preferences of consumers remained constant. He also assigned the Walrasian entrepreneur with a new function; one that is to carry out ‘new combinations’ of resources available to the enterprise, or what is more aptly called innovation. Schumpeter does not consider the entrepreneur as an individual person, but as an agent or instrument of change assigned with the function of carrying out new combinations of resources available to the enterprise. These agents of change can earn “entrepreneurial” profits above the normal rate of return for bringing novelty to the market. Schumpeter considered innovation to be part of the economic process itself with the actions of cost-minimizing capitalists generating a tendency toward equilibrium through the search for ‘global’ investment opportunities, and the actions of profit-seeking entrepreneurs engendering disequilibrium behavior through the introduction of new products, markets, methods of products, and new organizational forms.

Innovation is an endogenous process in Schumpeter’s vision that makes it possible for economic agents to obtain a surplus over costs, or entrepreneurial profit. Schumpeter (1934: 59) notes how his views on economic theory differs from his predecessors, namely Walras, and then adds that his view of economic dynamics “nearly parallels that of Marx.” In his theory, enterprises compete with one another to gain market share and improve their ability to increase profit through the use of new methods of production. The result was that competition for capital across industries created a tendency toward equilibrium, whereas competition for
capital within an industry created a tendency toward disequilibrium. Nevertheless, Schumpeter adopts the Walrasian theory of capital formation under free competition to explain the tendency toward equilibrium, and then introduces the entrepreneur as innovator to explain the tendency toward disequilibrium.

Diffusion does not play a prominent role in Schumpeter’s *Theory of Economic Development* and only appears as a process by which firms copy, imitate and gradually improve on the original innovation, or what he described as ‘induced innovations’. In this book, Schumpeter reasoned that new combinations of technical alternatives should be large enough to disrupt the existing set of technical alternatives. Diffusion becomes more important in his *Business Cycles*, where he emphasized the temporal nature of entrepreneurial profit and the importance of competition in spreading technology over the course of the cycle. Schumpeter appears to be more interested in innovation clusters and swarms of innovative activity, and less interested on the issue of whether enterprises below the technology frontier can also search for and learn to combine available resources in similar ways. The diffusion process is implicit in Schumpeter’s vision by way of reinforcing the tendency toward equilibrium as enterprises learn to imitate the leader (Schultz, 1975).

The disequilibrating behavior of the entrepreneur is the main cause of economic development in Schumpeter, but he also believed that it proceeds in cyclical way along several time lines. In his *Business Cycles*, Schumpeter (1939) introduces three synchronized cycles, a short-term “Kitchin” inventory cycle of about 40 months duration that are also related to information asymmetries, a medium-term investment or “Juglar” cycle involving both the monetary or financial markets, and a long-term “Kondratiev” cycle capturing the rise and decline of the use of major technological innovations. Schumpeter (1939: 177) considered the three-cycle schema as a “convenient descriptive device,” with its main
purpose to explain cyclical behavior over time. Still, the Juglar cycles and Kondratiev cycles were essentially investment and innovation-driven, but the former was related to the idea that the demand for capital and credit, and hence endogenous money, would generate cyclical fluctuations. Juglar (1862) understood them to be a consequence of excessive speculative behavior rather than of innovative behavior.

Schumpeter’s idea that major or radical innovations initiate a fundamental change in the way things are produced, the types of products being produced, how a firm is organized, and the way people transport things and communicate suggest that long waves are caused by the clustering of innovations. Using statistics on price behavior, including wages, interest rates, raw material prices, foreign trade, and bank deposits, Kondratiev (1928) identified two full cycles of expansion, stagnation, and recession that took place from 1790 to 1849 and from 1850 to 1896. In contrast to Kondratiev, Schumpeter (1939: 178) described long waves in terms of production and dated them according to the broadly defined technology that characterized the period: the industrial revolution for the period between 1780s and 1842; the age of steam and steel for the period between 1842 and 1897; and era of electricity, chemistry, and motors, which began in 1898. He observed that innovations tend to appear in bunches and often depend on clusters of entrepreneurs located in the same general location. Schumpeter also noted that even given the extensive statistical analysis, there is considerable doubt as to the dating of each cycle. An extensive literature developed out of Schumpeter’s interpretation of the Kondratiev wave, some of it questioning the validity of long wave theory and Kondratiev’s own description of long waves as sinusoidal-like cycles, and others developing the idea that technological revolutions are essential to each long wave cycle.

4. Long-wave Theory from a Freeman and Perez perspective.
Freeman and Perez (1988), Freeman and Louçã (2001) and Perez (2002) provide the basis for much of the recent discussion on the existence and theory of long waves. These authors consider each cycle or long wave to represent not only a technological revolution but also a change in the techno-economic paradigm. Each technological revolution represents a kind of Kuhnian paradigm shift (Kuhn 1962) and is based on Schumpeter’s (1939) idea that major or radical innovations initiate a fundamental change in the way things are produced, the types of products being produced, how a firm is organized, how networks are formed, and the way people transport things and communicate. Perhaps the most important reason to describe Freeman and Perez as Schumpeterian might be because of their development of Schumpeter’s interpretation of the Kondratieff wave.

Perez (2002: 8) defined a technological revolution as a “powerful and highly visible cluster of new and dynamic technologies, products and industries, capable of bringing about an upheaval in the whole fabric of the economy” which lies at the center of each technological revolution. This cluster contains several interrelated radical breakthroughs that form a major constellation of interdependent technologies. One or more general-purpose technologies (GPT) (Helpman, 1998; Lipsey et al., 2005) are found at the center of the cluster, which will affect the entire global economy by gradually being used either directly or indirectly in the production of virtually every other commodity and by the tendency to drive down the cost of production over time. Following Schumpeter, the radical innovations underlying a technological revolution will spread far beyond the sector and geographic location where it was first developed, creating the potential for long-term productivity growth in the global economy as a whole over the cycle.

Each technological revolution or techno-economic paradigm appears as a cycle, lasting from 50 to 75 years. The cycle does not appear smooth and continuous, but contains many
upheavals as new enterprises, industries, and technologies displace the old and mature ones, much in the same way as Schumpeter (1942) described the process of creative destruction. Figure 1 illustrates the four distinct phases in the techno-economic paradigm identified by Perez (2002): (1) irruption, when the new technology is introduced; (2) frenzy, or the period of intense exploration; (3) synergy, when the technology is diffused throughout the economy; and (4) maturity, as the diffusion process becomes complete. Both stagnation and dynamic growth appear in the irruption stage, as old technologies mature and new technologies have not diffused through the economy. During the frenzy stage, many new opportunities to apply the new technology open up, leading to the creation of new markets and the revival of old industries. Dynamic expansion, economies of scale, and diffusion are most common during the synergy phase, when producers tend to dominate. Perez (2002, 53) describes this phase as the “golden age” when economic growth is harmonious and social cohesiveness becomes an imperative. In the last phase complacency appears as the technology reaches maturity and diffuses through the economy.

Figure 1: The phases of the technology cycle.

Source: Based on Perez (2002)
Freeman and Louçã (2001, 146) used the term technology system to describe how the Schumpeterian clusters are formed and the dynamic interrelatedness that develops within them. Their long-wave contains six phases, of which phases two to five roughly correspond to the technology cycle described by Perez (2002). The first and last phases overlap in the sense that both the new and old technology systems coexist around the time of the big-bang. A new technology system will begin a laboratory-invention phase, with prototypes, patents, and early applications. This phase could be seen as the gestation period of the new technology and may present a challenge to the dominant technology system. Establishing the feasibility of the new technology by demonstrating its potential application to products and processes roughly corresponds to the first part of the irruption phase. This phase is followed by the explosive take off, which is also marked by significant and sometimes turbulent changes to industrial structure and the regulatory regime. In the fourth phase, stable long-term growth occurs as the new technology system asserts itself as the dominant system in the countries on the technological frontier. This period corresponds to the steep upward slope of the technology life cycle in Figure 1. The technology system then enters a period of maturity, when it first experiences a slowdown and erosion of profitability and then becomes increasingly challenged by the new technologies that will drive the next technology system.

A novel feature of Perez’s (2002) technological revolutions is that each long wave is marked by a turning point when financial capital is supplanted by production capital. This idea follows from Schumpeter’s recognition of the entrepreneur and financier as two independent agents that drive the innovation process. The financier dominates in the first two phases of the cycle and the entrepreneur dominates in the second two phases. Financial bubbles are also common in the second phase as confidence in the financial system to support the new technology gains momentum. There is also a tendency for free market policies to
dominate in the first two phases and a re-evaluation of the governance systems and institutional arrangements of the economy in the second half of the cycle.

5. Five successive technological revolutions since the 1770s

There have been five successive technological revolutions since the 1770s. All three authors date the start of the industrial revolution around 1771 when the first water-powered cotton mill was opened in Cromford, England. This event marked the beginning of large-scale factory manufacturing with mechanized production, and entrepreneurship. Water became the main source of power as well as a way to transport goods over long distances, together with roads and turnpikes. Iron, raw cotton, and coal became the key inputs (GPTs) into the production system, with iron being applied in virtually every industry through the development of new machinery and equipment that replaced wooden ones, and as various inputs in the production process. Innovations in the machine tool industry and in precision engineering from during this period made it possible to design and construct high-pressure engines, which triggered the second technological revolution that began in 1831 with the Liverpool-Manchester railway (Freeman and Louçã 2001). Agglomeration, standard parts, construction and steam engines and specialized machinery emerged as key inputs during this period as did the appearance of large joint stock companies. The railway, telegraph, and steamship became central to the transport and communications infrastructure.

The discovery of electricity, inexpensive steel and heavy chemical and civil engineering, led to the third technological revolution, which began around 1875. These industries together led to the development of an electrical equipment industry, and new ways of packaging things, especially foods, as well as to the appearance of the research and development (R&D) laboratory. They also led to the further development of a global infrastructure, which not only included the creation of a world wide telegraph and telephone
network, but also the further development of shipping (steamships), railways, and great
bridges and tunnels. Motorized vehicles and oil appeared in the second half of this revolution,
but became core inputs in the fourth technological revolution, which was triggered by Henry
Ford when he introduced the moving assembly line in 1913 to build the Model T. This
application of mass production techniques, including making use of machines and presses to
stamp out parts and insure interchangeability that led to the relative cheapness of large-scale
production and the emergence of mass consumption (Hounshell 1984). Many other industries
emerged using mass production techniques, including automotive components, tractors,
aircraft, consumer durables, and synthetic materials, and to insure that mass consumption
continued, consumer credit innovations were essential (Freeman and Louçã 2001).

All three revolutions were characterized by increasing returns to scale. Labor
productivity growth began to take off during the first revolution, much of which was
attributed to timesaving management and specialization in tasks within the enterprise (von
Tunzelmann 1995). The expansion of markets, both local and global, saw international trade
rise in the second revolution, further encouraging productivity growth. Further development
of a global infrastructure continued to encourage international trade during the third industrial
revolution, but economies of scale tended to be located mainly within the plant, as enterprises
became larger. At the same time science became a productive force through the creation of
industrial research laboratories. Edison's Menlo Park (New Jersey) laboratory was set up in
1876 with the specific purpose of producing a steady stream of new products for the market,
including the phonograph, microphones, electric lighting, and a system for electrical
distribution, as well as other goods. The rapid growth of the consumer markets generated
large economies of scale in the fourth technological revolution, but it also created large
corporations that required new ways of managing diverse operations, including several
different brand names, consumer credit operations and an internal research laboratory (Chandler 1977).

After World War II, mass production fuelled the economy, resulting in high growth for long periods of time and a vast array of new product innovations. But by the end of the 1960s, the U.S. economy entered a period of stagnation that lasted through the 1970s. During this time, however, the ICT technological revolution gained momentum, culminating in the introduction of the first commercially viable microprocessor by Intel in 1971, which made it possible to incorporate all of the functions of a central processing unit (CPU) onto a single integrated circuit. This technology led to the development of personal computers, digital control instruments, software, and application of integrated circuits in a wide variety of products and services. Semiconductors also made it possible to develop a global digital telecommunications network and the Internet, making it easier to communicate and network the economy. Apple, Cisco Systems, and Microsoft are three examples of small entrepreneurial enterprises that emerged during the early part of this period that became large corporations in a relatively short period of time. Computing performance per unit cost has roughly doubled every two years since their introduction (Brock, 2006).

6. What, if anything, is so different about the information and telecommunications revolution?

As we discussed in Section 2, the rapid growth and increase in relative importance of our five new nodal countries have led to changes in the center of gravity of the world economy in recent decades. We feel that this trend is unlikely to be reversed even if the rate of change slows somewhat. Our question is whether this represents a major discontinuity in the way in which innovation affects business cycles.
The first thing to point out is that there are substantial areas of continuity between earlier cycles and the current one. The ICT revolution has resulted in advances that are in many respects intensifications of the developments of earlier cycles. Many of the most important innovations of the nineteenth and twentieth centuries were in communications, including the related transport sector. For example, the introduction of telegraphy, telephony, and radio communications all generated enormous changes in business efficiency, changes that in terms of their influence on relative prices and their impact on production may have, in their own historical contexts, been as great as (or even greater than) the consequences of innovations such as the internet and mobile telephony have been more recently. Parallel with these earlier innovations and closely connected to them were improvements in land and sea transport, that largely expressed themselves through widespread linkages to other aspects of local, national, and international economic activity.

As an example, in The Visible Hand (1977) Alfred D. Chandler, Jr. shows how railroadization in the United States led to a thorough transformation of the economy from 1850 onwards. In Chandler’s story, which is compatible with Schumpeter’s in most respects, the United States had enormous resources that could not be exploited profitably as long as internal and external transport and communications were slow and expensive. The problem was not that demand did not exist but that it could not be met adequately while transport and communication costs remained at the levels of the early nineteenth century. As a result, markets were fragmented, which in turn (in Smithian fashion) reduced to incentive to adopt manufacturing technologies that were only profitable when production runs were long. Between them, the coming of railways and improved ocean shipping made it possible not only to integrate different American regions more effectively than in earlier periods, but for the US to better serve a growing demand for foodstuffs as population increases outstripped the ability of the Western Europe to supply its own food. The telegraph was, in turn, a
necessary adjunct of improved transportation because it enabled The Managerial Revolution in American Business (the subtitle of Chandler’s book). Faster and cheaper communications reduced risks associated with business and generated reduced operating and transaction costs. The telegraph was also responsible for direct improvements in the efficiency and safety of railways, further reducing transport cost. The upshot was manifold advances in economic performance in the US and in its trading partners. Railways, better ocean shipping, and the telegraph made it profitable to develop the interior of the US by drastically reducing the transport component in the total cost of providing foodstuffs from the Midwest and the Great Plains to Europe. Of equal importance was the effect of improved transportation and communications on the use of better manufacturing equipment and the creation of economies of scale in the domestic economy of the US as fragmented local markets were replaced by much larger regional and national ones, resulting in the creation of the giant firms discussed by Schumpeter in *Capitalism, Socialism and Democracy* (1942).

When used to analyze medium- and long-run developments, the framework provided by both Schumpeter and Chandler reveals the signal importance of two phenomena: linkages and diffusion. As Rostow (1960) points out, the unifying factor behind the stimulus provided by most important sectors is that their impact is very widespread. Iron and later steel, for instance, had important backward linkages into mining that created incentives to improve transportation and drainage in mine shafts. The former translated into canal building and railways and the latter into better steam engines. But, as canals and railways could be used to transport all kinds of physical goods, and as steam engines found additional uses in powering factories, ships, and locomotives, the forward linkages from iron and steel were enormous even without considering their huge direct value as inputs into machinery and construction materials. Similarly, the diffusion of the internal combustion engine led to massive backward linkages (for example to steel) and forward linkages (to concrete production and road
building) in addition to the direct economic importance of automobile production and road transport.

From this point of view, many of the effects of the current ICT revolution may be viewed as improvements in developments in earlier periods rather than as ways of answering problems that have remained unsolvable until now. For the most part, even faster communications and improved business practices are merely new examples of diffusion and linkages. The importance of microprocessors, for example, is largely realized through their use in a wide range of equipment, just as the telegraph, telephone, railways and automobiles have been inputs into the products of other industries. This, however, brings us to a possible discontinuity with effects that are so far difficult to judge.

Implicitly, and often explicitly, the stories provided by writers such as Schumpeter, Chandler, and Lazonick (1990, 1991) revolve around economies that are dominated by developing manufacturing sectors. In this nineteenth and twentieth century world, advances in communications, transportation, and organization (all service activities) did generally translate into improvements in manufacturing, which was the main engine of growth. But we no longer live in this world. Not only did the share of manufacturing in American GDP fall from nearly 25% in 1970 to 12.9% in 2009, but the share of manufacturing globally declined nearly in parallel, from just over 27% to 16.6%. In Germany and Japan, which are still reckoned to be manufacturing powerhouses, the fall was from 35% to 19% and 20%, respectively. Even in Brazil, one of the new nodes that we cite, the figures were 24.6% and 13.3% (Perry, 2011). Most of the slack has been taken up by substantial increases in the shares of various service industries with intangible outputs. The question that we pose, although cannot answer, is whether innovations of the sorts that are cited by Freeman and Perez, as underpinning the ICT long cycle will interact with services in the 21st century in the
same way as seminal innovations have with manufacturing in the past. Even if there is reason to suppose that improved ICT will make manufacturing more efficient by reversing some of the advantages provided by economies of scale and allowing greater interaction with external suppliers and other market activities (Langlois, 2003), it is legitimate to ask if growing service sectors such as education and health will exhibit cyclical behavior of the sort that manufacturing has produced.

Another consideration is the role of the new nodes as generators of innovations, and not just users or adaptors. In electrical products and electronics, for example, China has moved quite quickly from being a producer of simple electrical products such as fans to a country that is making important breakthroughs in cellular phone technology (Guo, 2011; Long and Laestadius, 2011). The growing importance of generating scientific and technological advances is also supported by US patent data (Table 5). The raw figures, of course, say nothing about the level of significance of the discoveries that have been patented. Nevertheless, as patenting is a reasonably costly activity, especially for small or poor firms, the data demonstrate that the organizations that filed were convinced that their discoveries were of potential use to others if not to themselves directly. As Table 5 illustrates, the number of patents granted to some of our new nodes is considerable. In particular, Taiwan is in third place among foreign nations, behind only Japan and Germany, in terms of US patents granted and South Korea ranks sixth. Of the others, the PRC (16th place) and India (21st) have shown rapid increases in patenting activity since 2000.

The ability of firms in nations such as Taiwan and South Korea to engage in wide-spread scientific and technological activity is again nothing new. Advances made by Germany and the USA in chemicals, electrical products and steel were of great importance in the technological wave that began around 1875 (Landes, 2003) even though these countries
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U.S. Patents Granted Annually, 1998-2011

Table 5
were still well behind the United Kingdom in terms of per capita GDP at that time. As we argue in Section 2, however, they were much closer to the leader than several of our five nodal countries were in the 1970s. This raises the issues of whether learning has spread faster in recent years and of whether the connection between levels of scientific knowledge and per capital incomes is perhaps weakening.

At the onset of the ICT revolution, the five developing countries had little hope of “catching-up”. At the time, all five had low levels of per capita income, China and India were mired by famines and bad economic policies, and Brazil was caught in long-term stagnation. Catching-up (Abramovitz, 1986), however, is a process that depends largely on a capacity to adapt. As Malerba and Nelson (2012) note, “Catch-up does not mean cloning. What actually is achieved invariably diverges in certain ways from practice in the countries serving as the model.” Firms and nations that wish to catch-up therefore need not only basic scientific knowledge to understand what others have done and are continuing to do, but also an ability to change (and if possible improve on) existing knowledge and practices in order to adjust them to meet the capabilities and requirements of the borrower.

In part, this need for knowledge can be met by cross-border shifts of people with advanced knowledge. This has resulted from the return to their homelands of people who have studied and/or worked abroad and also from movements of citizens of advanced countries who migrate, often temporarily and for ad hoc reasons, to serve as advisors or employees of foreign companies in developing economies. Together, these groups have helped to establish bases of indigenous technological capabilities, but these need to be complemented by the growth of local institutions for training and research (Mazzoleni and Nelson 2007)

There is, in fact, solid evidence that this challenge is being met, at least in scientific and engineering fields in which codification and publication are reasonably common. Reverse
engineering and industrial espionage are still common, as is the voluntary but informal exchange of information from advanced to less advanced producers (Chen, 2009), a form of what might be termed, “learning-by-snooping-around”. But while these activities may provide insights, recipients generally need additional knowledge and skills to make advances (Mazzoleni and Nelson, 2007).

There are at least two types of evidence to show that, since the 1950s, knowledge has spread and become indigenized in many countries that are now catching-up and that the trend to faster and broader diffusion of knowledge is accelerating. Firstly, it is clear that certain types of highly technical knowledge can be mastered even by countries with very low levels of GDP per capita. The best example is perhaps North Korea, which has managed to grasp important aspects of nuclear and guided missile technology despite being unable to meet the basic economic needs of its population, an experience that follows on similar achievements in Pakistan. Even though these countries, or even our generally richer new nodal countries, do not have the resources to achieve modernization across the board, they are able to concentrate the resources needed to meet designated priorities.

Another important indicator of the growth of indigenous knowledge is the increase in the number of important universities and research institutions in all of our new nodal countries. University rankings are contentious, but it is clear that there are now excellent universities in China, Taiwan, South Korea, and India, as well as in Hong Kong and Singapore (Times Higher Education Supplement, 2012). Investment in education in Brazil grew faster in 2000-2008 than in any other OECD country and Brazilian universities now rank among the very strongest in Latin America (QS, 2012).

Naturally, the spread of codified knowledge and of universities and research institutes (Mazzoleni and Nelson, 2007) does not solve all problems. As in advanced nations, firms in the newer nodes need experiential and tacit knowledge, which may be harder to acquire
because it requires more than access to books or the internet. For this reason, business skills are arguably in shorter supply than technical knowledge in developing countries (Malerba and Nelson, 2012). To a degree, movements of workers from existing firms to new ones can help to provide a solution (Rasiah, et al., 2012), as has happened in Korea in recent years (and in early industrializers such as Belgium nearly 200 years ago (Landes, 2003)). But there is also much learning-by-doing and learning-by-using as experienced workers may be too scarce and too expensive for many firms. Lack of prior experience may even be an advantage as it prevents problem-solvers from falling back on well-known but possibly sub-optimal formulae and to rethink questions from the beginning (Radjou et. al., 2012).

The importance for business cycles of these broad geographical movements of knowledge and of the creation of additional sources of new knowledge deserves further attention. If the number of nodes multiplies and a wider variety of loosely connected or disconnect influences comes into play, it is reasonable to ask how this may influence the timing of innovation movements on a global scale and therefore the nature of cyclical activity. Is it possible, for example, that innovations that initially appear in the same general time period will draw on forces that are not subject to the same synchronizing influences as have operated in earlier cycles, leading to a dampening of upswings and downswings because fluctuations in a wide range of industries at different stages in their particular technological or product life cycles will cancel each other out to an significant extent when viewed from a macroeconomic standpoint?

7. Conclusion

Each cycle starts with a different structure and this structure evolves throughout the cycle itself. Nevertheless, since the eighteenth century there have been many underlying similarities in cycles that make it possible to place them all in a single category. In particular, throughout the first four or five cycles there was a slow expansion in the number of countries
that had achieved high degrees of industrialization. In addition, the cycles have been built on general purpose technologies that have been important in building infrastructure through improvements in communication, transportation, or construction materials. Finally, in each cycle, important new GPTs have been most vigorously developed in countries of relatively recent development. This has led to changes in economic leadership, but the overall result among developed nations has been convergence rather than wholesale replacement of one group of nations by another at the top of the table of standards of living. Although recent trends during the current ICT-based cycle have confirmed these patterns to a degree, there have also been important differences. Whereas, with the exception of Japan, economically-advanced nations before 1970 were all essentially European in background if not in actual location, in recent decades economic development has begun to spread through East and South Asia and Latin America. Secondly, the new nodal countries have in many cases started from lower bases as measured by their relative levels of per capita GDP, but they have also been able to make up ground in relation the leaders more quickly than occurred in earlier cycles. Thirdly, there have been changes in structure within individual economies and between nations that raise questions about whether the mechanisms for the transmission of growth that have been identified in the past have now been substantially altered or even displaced. Among these are changes that seem to have taken place in the transmission of scientific and technological knowledge and changes in the drivers within economies as the role of services has increased and that of manufacturing as an engine of growth has diminished considerably since Schumpeter’s time.

If business cycle analysis is to have predictive value, economists must be able to work out what is likely to transpire in the early stages of a cycle, rather than treating cycles as a way of organizing historical events. It is vital that we achieve a good appreciation of the likely effects of the changes in patterns rather than concentrating excessively on continuities,
real as they are. We therefore need to learn whether a service-based economy will respond differently to innovation than one that depends heavily on manufacturing to propel growth. We also need to learn how a much greater degree of codification of knowledge will affect the spread of knowledge and increase the ability of people in economies that are still relatively poor to generate important innovations. Finally, we need to learn how changes such as these will affect cyclical patterns and whether they will reinforce or undermine the analyses of Schumpeter and of more recent economists such as Freeman and Perez.

In this paper, we have freed a number of theoretical hares to roam freely, but have made no attempt to chase or capture them. Considering the magnitude of the problems, this is fair enough since it is unlikely that anyone, even someone with the skills and knowledge of Schumpeter, can find solutions to all of the issues. Instead, teams of people need to be inspired, a purpose that we hope to have achieved even if on a modest scale.
Bibliography


