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ECONOMIC THEORY, APPLICATIONS AND ISSUES

Working Paper No. 70

Information Technology's Impacts on Productivity, Welfare and Social Change: Second Version

by

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Information Technology's Impacts on Productivity, Welfare and Social Change: Second Version[1]

by

Clem Tisdell[2]

December 2014

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INFORMATION TECHNOLOGY'S IMPACTS ON PRODUCTIVITY, WELFARE AND SOCIAL CHANGE: SECOND VERSION

Abstract

There has been a rapid increase in global expenditure on information technology and there is still much to learn about its effects on productivity, welfare and social change. At the macro-level, it has been estimated that Internet-related value accounts for as much as 7% of GDP of some OECD economies. As discussed, two basic methods have been used to estimate the contribution of ICT to the growth in GDP and labour productivity. Estimates of these vary considerably but it seems that the consensus is that ICT's contribution is positive. However, whether it is increasing is disputed. Currently, GDP is expected by some economists to increase by about 1% for a 10% rise in ICT-capital. All industries have had added value as a result of the introduction of ICT but the overall aggregate effect is largest for the tertiary (service) sector. It is shown how the Internet can increase economic productivity (1) by reducing input costs and (2) raising allocative efficiency within enterprises. Other ways in which Internet access can increase economic welfare are via reduced market transaction costs and a decline in material and transport costs as well as by increasing the variety of available commodities. These aspects are analyzed and discussed critically. Attention is also given to the employment consequences of the use of ICT, associated health issues, and the impacts of ICT on social interaction and the environment. It is suggested that the use of the Internet for consumption may exceed it use for production. Additional matters touched on are the consequences for economic performance of ICT in education and research and in the health industry, as well as the comparative benefit of ICT to rural residents compared to city-dwellers. In conclusion, it is noted that not all IT depends on the Internet and that non-Internet IT has had little economic attention.

Keywords: economic welfare, education and ICT, ICT, information technology, Internet, market transaction costs, productivity, social change.

JEL classifications: O3, D2, D6

INFORMATION TECHNOLOGY'S IMPACTS ON PRODUCTIVITY, WELFARE AND SOCIAL CHANGE: SECOND VERSION

1. Introduction

Within a relatively short period of time, use of modern information and communication technology (ICT) has become widespread and its use is continuing to grow at a rapid rate. According to one account, total global expenditure on IT is increasing at 5% per year and consequently, is doubling every 15 years (Anon, 2014). It accounts for large and growing proportion of the budget of companies and other organizations such as government bodies (Anon, 2014) and educational institutions as well as that of many consumers.

Despite the pervasiveness of ICT, its impacts on productivity are imperfectly known and views differ about its effects on human welfare and social change. The purpose of this article is to outline and discuss broad views about these subjects. First, macro-level impacts of ICT on economic activity and productivity will be considered and then these effects at the micro-level and industry-level will be discussed. In doing so, attention is given to the economic efficiency consequences of the adoption of ICT. Consideration is subsequently given to additional welfare consequences of the diffusion of ICT and its genesis of social changes.

Measuring the magnitude of ICT as an input in any economy is very challenging. Many studies measure this input focusing on the level of ICT-capital, as proxied by accumulated investment in Internet-related commodities. This is difficult to measure accurately. Furthermore, not all ICT is Internet-related. Both capital costs and operating costs are involved in the use of ICT within organizations and both need to be taken into account in considering its contribution to productivity. Sometimes, only estimates of ICT-capital are taken into account in macroeconomic studies of this subject. Additional quantitative measures (indices) of the Internet as an input to economic activity continue to be developed based on the degree of access to the Internet (OECD, 2013).

2. Macro-level Impacts of ICT on Economic Activity and Productivity

Estimates are available of Internet-related value added for several economies but as pointed out by the OECD (2013), the 'results should be treated cautiously' because the methodologies used are often unclear, may differ between studies and the input data are usually not made available. Nevertheless, these results may be of some comparative value. Estimates are not available for all countries but the largest proportionate contribution to GDP of Internet-related value added appears to be for the United States and the United Kingdom at around 7.2%. The estimate for Australia is 3.6%, slightly higher than for Germany but lower than for several European countries and for Hong Kong (see Table 1). The Australian estimate is based on a similar approach to that of the Boston Consulting Group (OECD, 2013, p. 21).

Table 1: Estimates of the percentages added to GDP by Internet-related value for various economies

Original source	Economy	% of GDP
Koutroumpis (2009)	USA	$\leq$ 7.2
Boston Consulting Group (2010)	UK	7.2
Boston Consulting Group (2011)	Sweden	6.6
As above	Hong Kong	5.9
As above	Denmark	5.8
As above	Netherlands	5.8
Deloitte Access Economics (2011)	Australia	3.6
Boston Consulting Group (2011)	Germany	3.4
As above	Italy	1.9
As above	Turkey	1.4

Source: Based on OECD (2013, Table 2, p. 20 and p. 39)

While the estimates in Table 1 indicate the importance of Internet-related activities as a contributor to aggregate economic activity, they do not provide a measure of the contribution of ICT to productivity. At the macro-level, two different types of approaches have been used to estimate the contribution of ICT to productivity. These

are non-parametric approaches and parametric ones. The former is based on extensions of Solow's modelling of the impact on aggregate production of technical change (Solow, 1957). Assuming the existence of a Cobb-Douglas aggregate production function, this method divides increases in aggregate production per hour worked into that associated with rises in ICT capital and non-ICT capital, labour quality change and a remainder or a residual. The residual identifies growth in productivity which is faster than the growth rate of all combined inputs in the economy. It is identified as Total Factor Productivity, and its increased value represents the increase in productivity that cannot be assigned to a change in specific factors of production.

Venturini (2009) uses this method to estimate production functions for the US and 15 EU nations based on data for the period 1980-2004. He concludes that ICT technology was a significant driver of economic growth and increased productivity in this period. He finds that in the overall sample, increased ICT capital contributed a slightly larger amount to economic growth in GDP and productivity than rises in non-ICT capital. ICT's contribution to economic growth was larger in the US than for any of the other countries in Venturini's sample. Nevertheless, the growth-enhancing role of human capital was also found to be important. Contrary to Venturini's findings (ibid.) (which also include a significant contribution of ICT to GDP growth in the UK), Marrano et al. (2009) argue that the 'information economy' has made little difference to the UK's macroeconomic performance.

Venturini (2009) does not include in his sample Australian estimates of the impact of IT on productivity and GDP growth. Recently, Shahiduzzaman and Alam (2014b) using the same type of analysis as Venturini (ibid.) found that in the long-period (1965-2008) increased ICT capital made a noticeable contribution to growth in Australian GDP (exceeding its proportionate share of capital formation) and that it was a Granger-causal factor in this increase. However, they also found in an earlier article (Shahiduzzaman and Alam, 2014a) that the elasticity of this contribution was 0.001 in the period 1975-90, reached a peak of 0.08 in the period 1991-99 and fell back to 0.07 in 2001-11. Neither the first nor the last mentioned result were however found to be statistically significant. When they examined labour productivity they found a similar pattern. The estimated elasticities were 0.004 for 1975-90, 0.11 for 1991-99 and 0.04 for 2001-11.

The first figure is statistically insignificant but the last two estimates were found to be statistically significant at the 5% level. Why there has been an apparent fall in the elasticity of the contribution of increases in ICT capital to GDP and labour productivity growth in Australia since 2000 has yet to be explained.

The non-parametric approach is subject to several limitations. For example, the aggregate production of an economy may not be of a Cobb-Douglas type and, therefore, may not exhibit constant returns to scale. The assumption of perfect competition (which is an integral assumption when this method is adopted) may be violated. Furthermore, aggregate values for the inputs in the production function must be constructed using indices or proxies, and given the heterogeneity of these inputs, doubts can arise about the adequacies of these estimates.

Parametric approaches to estimating the impacts of ICT on aggregate production are more direct in their approach than are non-parametric ones because they make fewer economic assumptions. For example, they do not suppose that economies are perfectly competitive. Nevertheless, they also rely on theoretical assumptions, for example, about the mathematical form of the aggregate production function, and indices of aggregate values of inputs must still be constructed. Frequently, but not always, a Cobb-Douglas function in log linear form is used for estimation purposes. In this macroeconomic function, gross output measured by the level of GDP is the dependent variable and the independent variables are the stock of ICT capital, the stock of non-ICT capital and L is the labour input variable. The log linear functional form has the advantage that the elasticities of responses of production to increases in value of the independent variables are easily identified.[1]

Kretschmer (2012, p. 15) summarises available estimates of elasticities of production increases in relation to rises in ICT capital for the period 1980-2005. The majority of the estimates are for the US economy. Their modal value is 0.05 – 0.06 but actual estimates range from around –0.08 to almost 0.3. Kretschmer (2012, p. 15) points out that these estimated values have been increasing with the passage of time and by 2005 were approaching on average, 0.1. The latter implies that for every 10% increase in ICT capital, GDP increases by almost 1%. Furthermore, examination of the scatter of values graphed by Kretschmer in his Figure 2 (ibid.) reveals that no negative estimates of this

elasticity value occur after 1990; all the negative values are for the period 1980-1990.

These trends suggest that with the passage of time, the proportionate increase in production as a result a proportionate increase in ICT capital is rising. This may be due to several factors. For example, with the passage of time,

- the size of networks (e.g. the number of persons and organizations connected to the web) has grown;
- the amount of information on the web has expanded;
- more individuals have become computer proficient; and
- new vintages of ICT capital have been adopted which embody more efficient technologies than their predecessors.

However, this type of inference is not supported by the econometric estimates of Shahiduzzaman and Alam (2014a) for Australia. They find that since 2000, the production-enhancing effects of increased ITC capital have waned. The reasons for this result are not yet known. Nevertheless, it may be partly a result of deficiencies in the measurement of variables utilized in the economic relationships. For example, Shahiduzzaman and Alam (2014a, p. 129) point out that they use Australian Bureau of Statistics data to measure IT capital stock. This consists of data on stocks of computers and peripherals, computer software and electrical and electronic equipment. This data needs to be scrutinized to decide how accurately it measures the stock of ITC capital. For example, to what extent is electrical equipment a form of IT capital?

A possible problem in measuring the macro-contribution of ICT capital to GDP is that a considerable amount of ICT capital is used by households for personal consumption. It is not easy to disentangle consumption and production uses of ICT. If estimates of the magnitude of IT capital include stocks of household of ICT capital, this will undoubtedly impact on estimates of the productivity-enhancing consequences of increases in this stock. For example, in the period 2001-11, there appears to have been an upsurge in expenditure by Australian households on IT capital and this probably was more for the purposes of increased consumption rather than for adding to production. This effect might have influenced the productivity results obtained by Shahiduzzaman

and Alam (2014a). However, other hypotheses should also be explored.

Using data from 25 OECD countries, including Australia, Czernich et al. (2011) conclude that increased broadband diffusion raises GDP per capita by 0.9 to 1.5 percentage points for each 10 percent rise in broadband point section. This, however, does not distinguish between the increased consumption component of the rise and its productivity-enhancing effect.

3. Industry-level and Firm-level Effects of ICT on Economic Activity, Economic Efficiency and Productivity: Microeconomics

In some ways, it is easier to grasp the impacts of ICT on economic activity and productivity at the level of industries and firms than at the macro-level. Furthermore, the actual processes that can help to raise economic efficiency (or reduce it) are more easily identified by using disaggregated analysis. Unfortunately, there is a shortage of up-to-date studies of this kind for Australia.

Value added in different industries by ICT

Data from the USA indicate that in 2011, Internet-related activities added considerable value to all US industries (OECD, 2013, Table 3, p.24). Table 2 lists the top industries or sectors by decreasing rank according to the estimated total amount of value added to them by Internet-related activities in 2011. Government heads the list. Among other things, the Internet facilitates transactions, particularly market transactions, in all industries by reducing transaction costs and bounded rationality.

Table 2: The top eight US industries ranked in decreasing order by the estimated size of the contribution of Internet-related activities to their value added in 2011

Rank	Industry or Sector
1.	Government
2.	Manufacturing
3.	Real estate
4.	Finance and insurance
5.	Educational services, health care and social assistance
6.	Retail trade
7.	Wholesale trade
8.	Information sector

Source: Based on information in OECD (2013, Table 3, p. 24)

Increased economic efficiency due to ICT

ICT has the potential to increase economic efficiency by (1) reducing input costs (input use) in relation to output (that is by increasing technical efficiency) and (2) by enabling greater allocative efficiency to be achieved. In addition, it can elevate economic welfare by reducing market transaction costs. Consider each of these aspects in turn.

Technical efficiency

One of the economic advantages of the Internet and computers is that they save storage space because information does not need to be retained in hard copies. Consequently, many offices can be virtually 'paperless'. Printed material (such as forms) can be downloaded as required. Given the availability of e-books and so on, less physical material needs to be housed in libraries and on shelves. Consequently, staff in many industries (particularly service industries) can be fitted into a smaller space reducing overhead costs, for example, rents for office space. Open-plan work areas appear to become more common in many service industries with the diffusion of ICT and these reduce the amount of space needed per employee and the costs of partitioning areas of work-space.

As well, information technologies are often labour saving. For example, fewer staff are required (in many businesses) to supply information to customers or potential customers because much of this information can be accessed via the Internet. As an example

consider the widespread availability now of information about real estate on the Internet. There is also greater scope for buyers to engage in self-service, for instance, at retail outlets and this reduces the number of check-out staff required. This is not only true of supermarkets and similar outlets but also is important in finance and insurance.

Increased allocative efficiency

Apart from the role of increased technical efficiency in adding to economic welfare, improvements in allocative efficiency also add to economic welfare. Information obtained via the Internet can improve the knowledge of buyers about price offers and it may promote greater competition between suppliers. Both these factors can contribute to an increase in allocative efficiency.

However, information obtained via the Internet is not perfect. It may, for example, be difficult to judge the quality of the product or resource being offered on the Internet and the reliability of the supplier. Consequently, asymmetry of information between buyers and sellers can be marked (even greater than in the absence of the Internet) resulting in the type of economic failures originally identified by Akerlof (1970). If fraud is prevalent in offers made via the Internet, marketing via the Internet could collapse because 'the bad drives out the good'. Therefore, safeguards need to be built in to protect those trading via the Internet from fraud. This protection, of course, usually involves a cost.

Reduced market transaction costs and economic efficiency

Now consider possible increases in economic welfare as a result of IT reducing market transaction costs. ICT can potentially reduce the market transaction costs of both buyers and sellers. It is easy to show by using partial equilibrium analysis that if market demand and supply curves have a normal slope (and other things, remain constant), a reduction in the market transaction cost increases consumer surplus. This is so if either the market transaction costs of consumers or that of sellers is reduced or both.

This is illustrated in Figure 1. In this figure, line D_1D_1 represents the demand for a product, X, given the market transaction costs prevailing prior to the introduction of ICT. D_2D_2 is that after ICT is introduced and lowers the market transaction costs for

consumers. The reduction in costs to consumers of each transaction is assumed (for convenience) to be a constant. S_1S_1 is the assumed supply curve for the product. Therefore, prior to the introduction of ICT the equilibrium of the market corresponds to E_1. If only consumers have a reduction in their market transaction costs after ICT is introduced, market equilibrium becomes E_2. Consumer surplus rises by an amount equal to the dotted area and producer surplus increases by an amount equal to the hatched area. Both parties gain.

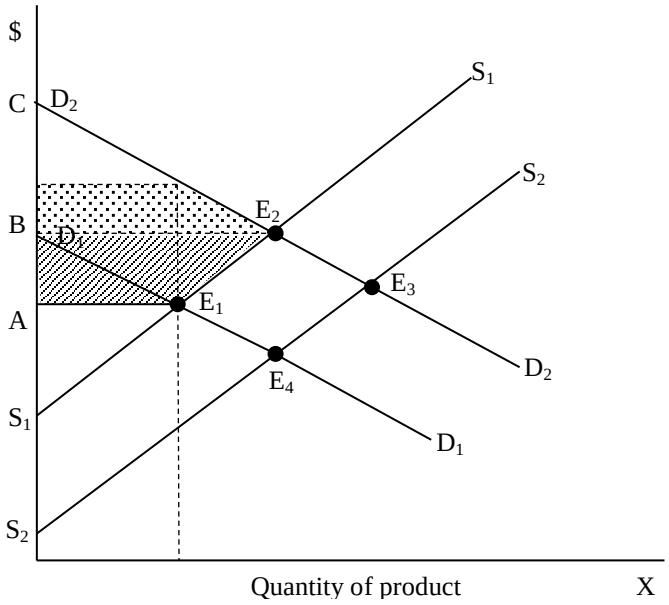

Figure 1: An illustration of how a reduction in market transaction costs made possible by ICT can increase both consumers' and producers' surplus.

In addition, if after the introduction of ICT, the market transaction costs of producers declines resulting in an effective decline in the industry supply curve from S_1S_1 to S_2S_2, market equilibrium shifts to E_3. Consequently, there is an additional rise in consumer surplus because the price of the product declines. Also given a parallel shift in the supply curve, producer surplus increases. However, if instead of shifting by a constant, the supply curve pivots so that its slope is reduced, producer surplus could fall (see Duncan and Tisdell, 1971). Nevertheless, consumer surplus still rises.

Furthermore, it can be observed from Figure 1 that (given normal supply and demand relationships) a reduction in the market transaction costs of suppliers, generates a rise in consumer surplus, other things held constant (see also, Tisdell, 1996, Ch. 16). For example, if the market is originally in equilibrium at E_1 and the market transaction costs of suppliers declines and results in a shift in the supply curve from S_1S_1 to S_2S_2, the equilibrium of the market alters to E_4. The price of the product declines and consumer surplus rises. Moreover, in the case illustrated, producer surplus rises but it would not do so if the slope of line S_2S_2 is sufficiently small compared to that of S_1S_1. Despite the possibility of an eventual fall in aggregate producer surplus, market competition could still result in suppliers adopting ICT which lowers their market transaction costs. This is because early adopters will increase their income until laggards catch up in the adoption process.

While reduced market transaction costs increase total economic welfare in a static setting, they may not do so in a dynamic setting. Lack of market frictions can in some circumstances make markets prone to destabilization as has been pointed out by Tobin (1978) and by Tisdell (2013, Ch. 8). Financial markets (including markets for securities) may become victims of such destabilization. Therefore, a reduction in market transaction costs does not always add to economic welfare.

4. Additional Welfare Consequences of ICT and Observations on its Social Impacts

Reduced prices for e-commodities

Apart from potentially lowering market transaction costs[2], ICT enables the price of some types of commodities to be reduced because fewer physical resources are used in their supply to consumers. Furthermore, in many cases, delivery costs and storage costs of stocks (inventories) decline when commodities can be electronically delivered. These commodities include e-books, e-music, e-movies, and so on. This increases the economic surplus of those consumers who consider these electronically delivered commodities to be close substitutes for hard copies. The lower cost of electronically delivered commodities is likely to result in a greater variety of these commodities becoming available to consumers. Brynjolfsson et al. (2003) have argued that the

development of online bookstores (such as Amazon) has added much more to consumers' surplus by increasing available product variety than by increasing competition and lowering prices. It is also apparent that the appearance of e-books has resulted in it being economic to publish more books and re-issue previously published books in e-form in cases where this would be uneconomic for hard copies.

On the other hand, not all consumers find electronic commodities to be suitable substitutes for hard commodities. Some individuals prefer hard copies of books to e-books and printed newspapers to e-newspapers. The advent of e-commodities can result in these consumers paying more than otherwise for hard copies if the availability of e-versions reduces sales of hard copies and the supply of hard copies is subject to economies of scale. In some cases, the production of hard copies may no longer be economic thereby reducing the available variety of this material. The consumer surplus of this set of consumers is reduced. Similarly, there may be a tendency for electronic transfers for payment of accounts to crowd out payment by alternative means, for example, by cheque. There is also the possibility that the supply of some commodities will be reduced due to internet pirating for example, of movies, books and music. This could reduce consumer welfare in the long-run.

Need for an holistic approach

In assessing the welfare effects of ICT, it is important to take a holistic approach because human beings are not only consumers. Their welfare also depends on their scope for earning a living, their conditions of work, and the type of the society they live in. ICT has impacts on all these aspects of human existence. One must go beyond a narrow economic approach in industry, the consequences of technological change.

The impact of ICT on employment and income distribution

The impact of ICT on aggregate employment and the distribution of income is not well known. It has, added to the demand for ICT specialists but on the other hand, it has and continues to displace labour in many occupations, as was mentioned above. In particular, lower level clerical and similar staff in service industries have been reduced in number by labour-saving ICT. Furthermore, in many cases, ICT has made it more economical to shift some of the work involved in service industries offshore thereby

placing greater pressure on the domestic labour market. Moreover, as considered below, the scope for shifting work offshore is not confined to lower skilled tertiary workers but occurs for more highly-skilled tertiary workers, for example in education, including university education.

It has been observed both in Australia, in the United States and in the UK (Marrano et al., 2009) that the share of profits relative to wages in national income has risen in recent years. Real wage levels have tended to stagnate. There may be many reasons for this. They could include more competitive labour markets and increased economic globalization but greater use of labour-saving technology (including ICT) may also have had an impact on this trend. While labour-saving technology and technology which enables foreign labour to be substituted for domestic labour (both attributes of ICT) need not result in greater general unemployment, it can reduce the aggregate demand for labour and restrict growth in the level of wages.

Health concerns and ICT

The increased adoption of ICT raises several health issues and other social concerns. As a result of increased use of ICT, work in several occupations has become more sedentary. In some occupations, employees now sit for long-periods of time using computers and have little exercise on the job. They also work in relatively cramped spaces in open-areas sometimes in long rows as for example, in the Australian Broadcasting Corporation's (ABC) studios in Brisbane where a 100 or so operators continually monitor different web-sites searching for material that may be newsworthy. Increased lack of exercise by members of the workforce due to technical change is considered to be a growing problem both in rural and urban areas.

This problem is made worse if outside of work hours, individuals spend a considerable amount of time engaging in sedentary activities made possible by ICT. The extent to which individuals do this varies but in some cases, individuals are addicted to these activities and this results in health problems and can have negative effects on social activities.

The Internet as a consumptive good

It is apparent from American data on the use of the Internet that probably a half or more of the time spent on the Internet is (on average) for consumptive purposes rather than productive purposes. This does not seem to be well accounted for in economic studies of the impact of ICT on productivity. According to an American study quoted in OECD (2013, p.49), in June 2010, social networks accounted for 22.7% the time Americans spent on the Internet, followed by online games at 10.2%. Videos/movies plus multi-category entertainment accounted for a further 6.7%. Emails and instant messaging took up 12.3% of the time but it is difficult to know the extent to which these messages were for consumptive or productive purposes. However, overall it seems highly probable that more time is spent on the Internet for consumptive than productive purposes. The situation in Australia is probably similar to that in the USA.

Social interaction and ICT

Advances in ICT have had both positive and negative effects on the nature of social interaction. This makes the overall assessment of its social effects difficult. The following are some of the observed positive effects:

- Individuals may extend their social contacts by using ICT.
- 'Shy' individuals may be more willing to make social contacts via ICT than directly.
- ICT makes it easier to extend the duration of social contacts.

Negative effects can include:

- Reduced direct social contacts due to electronic communications being substituted for direct interaction.
- Reduced direct social contact as a result of extra time being spent on the Internet. This may, for example, adversely affect family cohesiveness and the well-being of children.[3]
- Increased risk of injury to users and others of the use of electronic devices (such as mobile phones) in public spaces, for example, 'texting' while driving a motor vehicle.

- Addiction to e-games and other forms of Internet activity can result in individuals failing to cope adequately with life's challenges.
- The Internet may be used for cyber-bullying, for libel and 'smear' campaigns.
- Fraud and cyber-crime occur on the Internet with adverse social and economic consequences.
- A reduction in privacy as a result of information posted on the Internet is another concern.

Environmental effects of ICT

The net effect of the Internet on the natural environment is unclear (OECD, 2012, p. 15). However, ICT enables some solutions to be obtained to resource-use which save resources and which are environmentally friendly. In principle, the Internet should also reduce the amount of paper used thereby sparing many trees and similar material used for paper-making and reducing carbon dioxide emissions. The extent to which this has happened is not known. In any case, global forest cover continues to decline as economic growth continues. Furthermore, OECD (2012, p. 15) states that 'even though the Internet has traditionally been viewed as a low-carbon impact alternative to traditional activities, some studies point at the potently high carbon footprint of the Internet itself, by growing greenhouse gas emissions per hour of electricity use'. The safe disposal of ICT equipment can also be challenging and the production of rare earths for use in some electronic equipment is hazardous.

ICT in education and research

Advances in ICT have created new opportunities for education and research, including scope for reducing the costs associated with these activities. The following economic and related benefits are possible in education:

- Reduced space is needed for storing copies of books, research papers, correspondence and so on. 'Paperless' offices are possible. Libraries have less physical material to store, to catalogue, need less labour to stack books and so on.

- The scope for on-line learning increases. This reduces the need for teaching or lecturing to large classes. This also reduces space requirements. Advantage can be taken of experts outside of individual educational institutions to contribute to lectures or teaching thereby economizing on staff who would otherwise be involved in these activities. At an aggregate level, fewer lectures need to be prepared and economies of scale in teaching become possible. Individuals in remote locations can benefit from teaching by experts without these being physically present.
- The reduction in lecturers or teaching material prepared in-house decreases the number of staff needed for this purpose. They can be re-deployed to provide more tutorials, demonstrations, and to assist students with practical work. In some cases, staff would also have more time for research instead of teaching.

At the same time, there are some possible negative effects of increased use of ICT in educational institutions. Reliance on a few 'experts' to provide most lecture material online could globally reduce the diversity of ideas to which students are introduced. It is also possible, in some cases that such material will not transmit relevant cultural values and appropriate institutional material. For example, reliance on lectures by experts from a foreign country may result in students not being aware of the relevant social contexts in their own country, for example, Australian and American social contexts are different. These differences are important for many subject but not for all. There is also the danger of excessive reliance on computer-based marking of examinations. As a result, there is likely to be less testing than otherwise of the ability of students to explain, analyse and assess phenomena. Those who display original thinking may not be identified. This is a serious drawback of this approach.

As far as research is concerned, advances in ICT also have advantages and drawbacks. A major advantage is that the research results of others can be assessed more quickly and at lower cost than in the absence of ICT. On the other hand, while online publishing increases the number of research articles and other material able to be published, many may not be subject to adequate screening or peer review. Articles of dubious value and which make little or no contribution to knowledge may be published. This can result in researchers experiencing an information-overload and add to their search costs, even

though the latter can be partly mitigated by the use of search engines. This explosion in the volume of online publications results in demands for accreditation of publications, for example, by university authorities. However, these schemes can disadvantage the production of new journals, and those scholars who expound values differing from mainstream ones.

ICT in the health industry

Advances in ICT have resulted in economic benefits in the health industry. They have facilitated the operation of medical practices involving multiple doctors or medical staff because patient records can be shared online. Moreover, physical records can be replaced by electronic records thereby saving space and time. Furthermore, medical practitioners can access up-to-date information that can assist them in treating their patients. Some patients may also use the Internet to diagnose and treat their own ailments. However, there are also dangers in this because medical information on the Internet is not always reliable and individuals can be mistaken in their diagnosis.

Comparative benefits of ICT to rural residents

Access to the Internet is probably of greater advantage to rural residents than to those in large cities. Compared to city-dwellers, rural residents appear to have a greater reduction in their cost of accessing material (such as information services and entertainment material) for which the Internet provides an alternative source of supply. Rural residents have greater access to educational services of higher quality than in the absence of ICT. They also have a significant expansion in the variety of goods they can purchase as a result of the availability of online purchasing.

Despite these benefits the use of Internet services can have negative effects on rural communities and towns. Local employment in some service industries, for example, banks and other financial institutions and retail outlets may disappear or be reduced. This reduces the scope for direct social contacts in rural towns and can hasten their decline. Many local rural towns may become less sustainable as a result of the widespread use of the Internet. On the whole, increased use of the Internet makes economic exchange more impersonal. For some, this involves negative social psychological consequences.

5. Conclusions

According to a review of macroeconomic studies by Kretschmer (2012), the introduction of ICT has had a substantial effect in raising GDP and that this effect is increasing. However, estimates of the elasticity of these productivity-enhancing impacts vary considerably. In Australia's case, Shahiduzzaman and Alam (2014a) provide evidence that the elasticity of GDP growth in relation to ICT capital has always been below 0.1 and has declined in recent times. Nevertheless, it has been as high as 0.8 and their most recent estimate of it is 0.7. Moreover, the long-term contribution to growth of Australia's GDP of ICT capital relative to non-ICT capital based on the estimates of Shahiduzzaman and Alam (2014b, Table 6) are much lower than those for the United States and for EU–15 based on the estimates of Venturini (2009, p. 504, Table 1).

The adoption of ICT differs between industries or sectors of the economy but is important in all industries. Overall, the greatest value added by ICT is in the tertiary or service sector, even though in the USA it is also high in manufacturing. There is a need for more Australian studies of the impacts of IT on particular sectors and industries in the economy, as well as case studies at the level of the firm.

ICT reduces market transaction costs and the amount of resources required to deliver many commodities. As a result effective prices of many commodities are reduced, consumer surplus rises in most cases, and producer surplus may also rise. However, those who prefer hard copies of commodities to e-copies (where these are alternatives) may be disadvantaged.

The advent of ICT has resulted in significant restructuring of labour markets. It may have contributed to sluggish real wage growth in Australia, the USA and the UK and the fall in wages as a proportion of national income. Although the Internet has had some positive social consequences, it has also had negative social impacts which were identified and which call for public intervention. In addition, the environmental consequences of ICT technology appear to be mixed.

Considerable benefits from the use of ICT in the education, research and health sectors were identified. Nevertheless, the increased use of ICT in education and research can

have negative consequences, some of which were discussed. Furthermore, as pointed out, increased use of ICT and the Internet has both positive and negative consequences for the welfare of rural commodities.

While most economic studies of the value of ICT concentrate on the use of the Internet, it should also be realized that there are many modern information technologies that do not depend on the Internet, or do so only to a limited extent. They include the use of robots and drones to provide information as well as satellite communications (for instance Global Positioning Systems, GPS) and other techniques, such as CT scans. Some of these techniques are of considerable value in agriculture and other industries but their economics has not received much attention yet.[4]

In conclusion, it might be noted that historically major innovations in information and communication technology have been significant influences on economic growth and social change. The development of writing and its transmission on clay tablets in Sumeria some 5500 years ago was one such early innovation. For example, it facilitated the development of state administration and enabled written agreements to be made, including written contracts. Many other important innovations in ICT occurred in subsequent millennia but most relied on hard copies for communication of information. The development of computer technology and the communication of information electronically (for example, via broadband) has in many (or most) cases made communication by hard copy obsolete, and has already begun to act as a catalyst for major economic and social changes, several of which have been identified in this discussion.[5]

6. Notes

1. Apart from the adequacy of the economic modelling of production functions and labour productivity, the accuracy of ‘observed’ values of variables relevant to the econometric estimation of these relationships requires special attention (for example, Dolman, 2009; Quiggin, 2006). Differences in the way in which these variables are measured in different countries also complicates international comparisons.

2. Note also that ICT by lowering market transaction costs (i) extends the geographical range of markets and (ii) can make some commodities marketable which otherwise would not be economic to market, for instance, some second-hand goods. These attributes also have economic benefits.
3. It is claimed (Gambotto-Burke, 2014) that in many cases, use of the Internet is causing disconnection in families and failure in parenting.
4. A matter which has not been discussed in this paper in the optimal economic rate of obsolescence in ICT. The rate of obsolescence in ICT is determined to a large extent by those who control IT networks. This rate may be too rapid or too slow from a social economic welfare point of view.
5. I would like to thank Khorshed Alam for his useful feedback on an earlier version of this article. The usual *caveat* applies.

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APPENDIX

ACCOMPANYING POWERPOINT SLIDES

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Information Technology's Impacts on Productivity, Welfare and Social Change: General Observations

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COVERAGE

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1. Introduction
2. Macro-level Impacts of ICT on Economic Activity and Productivity
3. Industry and Firm-level Effects of ICT on Economic Activity, Efficiency and Productivity: Microeconomics
4. Additional Welfare Consequences of ICT and Observations on its Social Impacts
5. Concluding Comments

2

TOPICS TOUCHED ON IN SECTION 4

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- Lower prices for e-commodities compared to hard commodities as a two-edged sword.
- Employment effects of ICT.
- Health concerns about use of ICT.
- Use of the Internet as a consumptive good.
- Consequences of ICT for social interaction.
- Environmental effects of ICT.
- ICT in education and research.
- ICT in the health industry.
- Comparative benefits of ICT to rural residents.

3

1. INTRODUCTION

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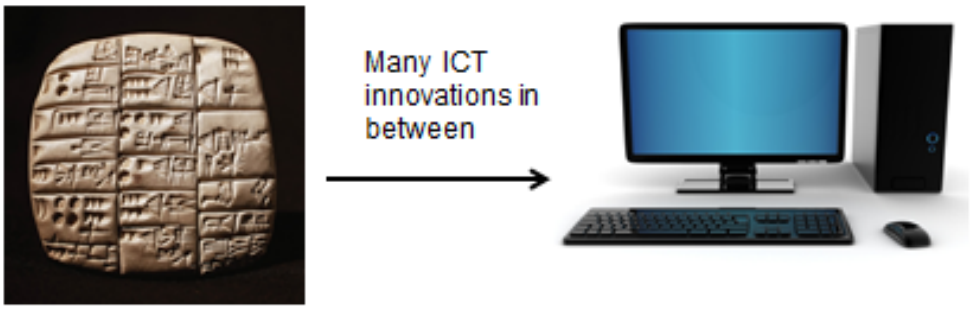
- First, I want to put the development of modern ICT in its evolutionary historical context because it is a part of continuing connected human development.
- Without the much earlier development of languages and writing, the development of modern ICT would have been impossible.
- In fact, it is not too far-fetched to claim, as Renfrew (2007, p. 203) does, that "The societies of prehistoric times are the foundations on which modern states and economies rest."
- Modern ICT represents a major step forward in information technology and communication just as the development of writing in Ancient Sumeria involving the use of clay tablets did about 5,500 years ago.

4

Figure 1: ICT technologies have transformed economies and societies



FROM HARD COPY TO ELECTRONIC COPY

5

1. INTRODUCTION (Cont.)

- Like the latter development in Sumeria (and those ICT innovations in between), modern ICT is bound to have major impacts in economic development and cultural change.
- Nevertheless, the precise economic and social impacts of the use of modern ICT are still unclear.
- The purpose of this paper is to present selected findings about its impact on economic activity, increased productivity, economic welfare as well as views about some of its social consequences.

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2. MACRO-LEVEL IMPACTS OF ICT ON ECONOMIC ACTIVITY AND PRODUCTIVITY

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VALUE ADDED

- Various consulting companies have estimated how much Internet-related activities have added to the value of the GDP of selected countries.
- These are summarised in Table 1 but should be treated cautiously.
- The value added contribution for Australia is about half of that estimated for the USA and the UK.

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Table 1: Estimates of the percentages added to GDP by Internet-related value for various economies

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Original source	Economy	% of GDP
Koutroumpis (2009)	USA	≤ 7.2
Boston Consulting Group (2010)	UK	7.2
Boston Consulting Group (2011)	Sweden	6.6
As above	Hong Kong	5.9
As above	Denmark	5.8
As above	Netherlands	5.8
Deloitte Access Economics (2011)	**Australia**	**3.6**
Boston Consulting Group (2011)	Germany	3.4
As above	Italy	1.9
As above	Turkey	1.4

Source: Based on OECD (2013, Table 2, p. 20 and p. 39)

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2. MACRO-LEVEL IMPACTS OF ICT ON ECONOMIC ACTIVITY AND PRODUCTIVITY(Cont.)

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IMPACTS OF ICT ON PRODUCTIVITY AT THE MACRO-LEVEL

- While estimates differ, most macroeconomic studies have concluded that investment in ICT capital has resulted in a significant and sizeable increase in GDP and labour productivity.
- Venturini found that investment in ICT capital contributed more to the economic growth of the US and 15 EU nations compared to investment in non-ICT capital in the period 1980-2004.
- Shahiduzzaman and Alam came to similar conclusions for the Australian economy based on data for 1965-2008.

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2. MACRO-LEVEL IMPACTS OF ICT ON ECONOMIC ACTIVITY AND PRODUCTIVITY (Cont.)

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- However, in a later article covering the period 1975-2011, they found that this elasticity at first increased but declined to some extent after 2001. They found a similar pattern for changes in labour productivity.
- While this decline in elasticity was not marked for GDP, it was considerable for labour productivity.
- Why this pattern has emerged is unclear but it indicates that the productivity enhancing effects of ICT may be tapering off.
- Shahiduzzman and Alam found that in 2001-11, GDP in Australia rose by 0.7% for every 10% increase in ICT investment.

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VALUE ADDED IN DIFFERENT INDUSTRIES BY INTERNET RELATED ACTIVITIES

- No data seems to be available for Australia. Table 2 ranks US sectors by amount of value added. The distribution is likely to be different for Australia to some extent e.g. manufacturing lower.

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Table 2: The top eight US industries ranked in decreasing order by the estimated size of the contribution of Internet-related activities to their value added in 2011

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Rank	Industry or Sector
1.	Government
2.	Manufacturing
3.	Real estate
4.	Finance and insurance
5.	Educational services, health care and social assistance
6.	Retail trade
7.	Wholesale trade
8.	Information sector

Source: Based on information in OECD (2013, Table 3, p. 24)

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INCREASED ECONOMIC EFFICIENCY DUE TO ICT

- There are two ways in which ICT can increase economic efficiency. It can do so by
  - Reducing input cost in relation to output (increased technical efficiency).
  - Increasing allocative efficiency because of greater knowledge.
- In addition, use of the Internet reduces market transaction costs which also results in an economic efficiency gain.
- It may also result in faster diffusion of knowledge (including that of new techniques) which improves technical choices by both producers and consumers.

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3. INDUSTRY AND FIRM-LEVEL EFFECTS OF ICT ON ECONOMIC ACTIVITY: MICROECONOMICS (Cont.)

EXAMPLES OF INPUT SAVINGS DUE TO ICT

- Less storage space is needed for information storage e.g. keeping of records, books etc.
- Rapid retrieval of information.
- Less office space needed resulting in increased use of open-plan work areas.
- Increased savings in labour due to information availability via the Internet and other forms of ICT.
- Labour savings due to increased use of ICT to complete market transactions.

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INCREASED ALLOCATIVE EFFICIENCY DUE TO ICT

- It is believed that the Internet may result in greater allocative efficiency (and increased competition among suppliers) by making buyers more aware of different price offers.
- It can also extend the size of the market via online purchasing and thereby increase competition.
- However, if a monopoly exists or collusion occurs among suppliers, ICT will not help.
- Furthermore, access to the Internet probably, increases the scope for false and misleading information. This can result in market collapse.

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REDUCED MARKET TRANSACTION COSTS DUE TO ICT

- An appealing economic benefit of ICT is its ability to reduce market transaction costs, and transaction costs generally.
- It may reduce market transaction costs for buyers, sellers or both.
- However, in some cases, ICT also results in a shift in the burden of transaction costs e.g. some (all?) customers may experience increased transaction costs when suppliers transaction costs fall.

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ECONOMIC WELFARE EFFECTS OF REDUCED MARKET TRANSACTION COSTS DUE TO ICT

- In most cases (but not all) comparative economic analysis indicates that both consumers' surplus and producers' surplus rises as a result of a reduction in market transaction costs, for example, due to the use of ICT.
- Even if there is some loss in economic surplus by some market participants as a result of reduced market transactions, a Kaldor-Hicks gain can be expected, assuming comparative analysis.
- However, in dynamic circumstances, a reduction in market transaction costs can destabilize markets and thereby result in a negative economic outcome.

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REDUCED PRICES FOR E-COMMODITIES AND GREATER CHOICE

- When e-copies of commodities are considered to be (almost) perfect substitutes for hard copies, Internet delivery reduces their cost and adds to consumers' surplus.
- Brynjolfsson et al. (2003) claim that the largest gain to consumers comes via their access to increased variety of e-commodities compared to comparable non-e ones.
- But there is also a downside: the cost of substitute hard copies tends to rise if economies of scale are important. Those who prefer hard copies/physical delivery have reduced consumers' surplus.
- Also difficulties in enforcing property rights in e-commodities could reduce the supply of some commodities.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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A HOLISTIC APPROACH TO EVALUATING ICT IS NEEDED

- The well-being of human beings does not only depend on their consumption of commodities.
- It depends, amongst other things:
  - On their scope for earning a living.
  - On their working conditions, and
  - On the type of society they live in.
- One must go beyond a narrow economic approach in evaluating the consequences of technological change.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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THE IMPACT OF ICT ON EMPLOYMENT AND INCOME DISTRIBUTION

- The impact of ICT on the aggregate level of employment and income distribution is not well known.
- It appears to displace lower level clerical staff and lower level service providers in many tertiary industries and facilitates the shifting of some types of work offshore.
- While correlation does not imply causation, the rise in profit relative to wages in most advanced economies is positively associated with the increased penetration of ICT.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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HEALTH CONCERNS AND ICT

- ICT has resulted in work becoming more sedentary in many occupations.
- Employers often sit for long periods in crowded conditions.
- Outside work some individuals may engage for long periods in sedentary activities made possible by ICT.

Chinese IT workers

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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THE INTERNET AS A CONSUMPTIVE COMMODITY

- US data indicates that the majority of time of Internet users is spent in leisure activities.
- Social networking tops the list followed by online games.
- In some work situations, employers may spend time when using the Internet on consumptive rather than productive activities.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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SOCIAL INTERACTION AND ICT

- Both positive and negative effects on social interaction are made possible by the Internet.
- On the one hand, the Internet may:
  - Extend the range of contacts of individuals.
  - Make it easier for 'shy' individuals to establish social contacts.
- On the other hand, it may
  - Reduce direct social contact.
  - Can create problems in families due to family members spending excessive time on the Internet.
  - Addiction to e-games etc. can create problems.
  - Cyber-bullying, libel, etc. is an increased problem.
  - Reduced privacy.
  - Risks to users and others in public spaces from using electronic devices.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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ENVIRONMENTAL EFFECTS OF ICT

- At first glance, ICT seems to be environmentally friendly because it appears to save paper and trees.
- However, it is unclear how much paper is really saved.
- The OECD points out that some studies find that the Internet has a high carbon footprint.
- Problems also arise in the safe disposal of ICT equipment.
- The production and preparation of rare earth for use in electronic equipment is hazardous.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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ICT IN EDUCATION AND RESEARCH

- ICT has and will continue to bring about major changes in education and research.
- It reduces the space and amount of labour required to perform these activities.
- There is increased scope for universities to contract out the provision of teaching material to be provided online.
- However, there are also dangers which I mention in my draft paper.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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ICT IN THE HEALTH INDUSTRY

- ICT has brought about and will continue to bring about major changes in the health industry.
- For example, medical records can now be shared by medical practitioners online. This saves space and time and has facilitated the development of medical centres relying on multiple practitioners.
- ICT has resulted in substantial advances in diagnosis and monitoring of illnesses.

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4. ADDITIONAL WELFARE CONSEQUENCES OF ICT AND ITS SOCIAL IMPACTS (Cont.)

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COMPARATIVE BENEFITS OF ICT TO RURAL RESIDENTS

- Possibly the Internet is of greater relative advantage to rural residents compared to city dwellers.
- This is because the transaction costs (in the absence of the Internet) or rural dwellers in accessing many commodities (education, purchase of a range of commodities, accessing leisure products) is higher than that of city-dwellers.
- However, there are downsides:
  - Local employment in some service industries and retail outlets may disappear or be reduced e.g. in financial institutions.
  - The scope for direct social contact in rural towns is reduced.
  - Local communities (rural towns) may become less sustainable as a result of the widespread use of the Internet.

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5. CONCLUDING COMMENTS

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- The computer and Internet revolution is probably as important an event in the evolution of human civilization as the beginning of writing itself and its transmission via hard copies.
- It has resulted in substantial increases in productivity, even though the magnitude of these increases are not known precisely.
- Its effect on economic welfare are mixed but overall, by reducing market transaction costs, increasing access to information and replacing physical forms of information provision by electronic forms it seems to have added to economic welfare, at least given the Kaldor-Hicks criterion.
- For rural residents, the Internet is a two-edged sword: it has advantages but may threaten the survival of some rural towns.

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5. CONCLUDING COMMENTS (Cont.)

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WHERE TO NOW?

- I would like to see more research done in Australia on the economic and other consequences of ICT for different industries and at the level of the firm.
- It would be very interesting to see more research on ICT and the economics of precision agriculture for example, how valuable is extra information in agriculture for precision agriculture, for instance information obtained by using drones, robots and so on. How economically valuable is this information likely to be? Are enthusiasts (hobbyists) pioneering the use of such techniques in agriculture justified in their explorations?

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A drone being used in agriculture to gather information

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A COUPLE OF FINAL THOUGHTS (QUOTES) ON COMPUTERS AND THE INTERNET

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- "A computer lets you make more mistakes faster than any invention in human history, with the possible exception of handguns and tequila".
- "Computers make it easier to do a lot of things, but most of the things they make it easier to do don't need to be done".
- "You can't retrieve your life (unless you're on Wikipedia in which case you can retrieve an inaccurate version of it)."

Thank you

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