OECDpublishing

Please cite this paper as:

Cooper, R. (2012-04-17), "Measuring the Impact of Innovations in Public IT Infrastructure on the Standard of Living in OECD Economies", *OECD Digital Economy Papers*, No. 196, OECD Publishing, Paris.
http://dx.doi.org/10.1787/5k9bf8ktf4kc-en

OECD Digital Economy Papers No. 196

Measuring the Impact of Innovations in Public IT Infrastructure on the Standard of Living in OECD Economies

Russel J. Cooper

OECD

OECD DIGITAL ECONOMY PAPERS

The OECD's Directorate for Science, Technology and Industry (STI) undertakes a wide range of activities to better understand how information and communication technologies (ICTs) contribute to sustainable economic growth, social well-being and the overall shift toward knowledge-based societies.

The OECD Digital Economy Papers series covers a broad range of ICT-related issues, both technical and analytical in nature, and makes selected studies available to a wider readership. It includes *policy reports*, which are officially declassified by an OECD committee, and occasionally *working papers*, which are meant to share early knowledge and elicit feedback. This document is a working paper. The opinions expressed in this paper are the sole responsibility of the author(s) and do not necessarily reflect those of the OECD or of the governments of its member countries.

STI also publishes the OECD Science, Technology and Industry Working Paper series, which covers a broad range of themes related to OECD's research and policy work on knowledge-based sources of economic and social growth and, more specifically, on the translation of science and technology into innovation.

OECD Digital Economy Papers and
STI Working Papers are available at:
www.oecd.org/sti/working-papers

MEASURING THE IMPACT OF INNOVATIONS IN PUBLIC IT INFRASTRUCTURE ON THE STANDARD OF LIVING IN OECD ECONOMIES

Russel J. Cooper[1]

ABSTRACT

Advances in information technology (IT) in the first decade of the 21st century have highlighted the role of IT as an *enabling technology* throughout an economy. But although the influence of IT in transforming the way in which business and consumer transactions are done is clear to all participants in the production-consumption process, it is difficult to attribute a specific value to and precisely measure the importance of the role of IT in improving consumer welfare.

The measurement of the economic value of public infrastructure has traditionally been problematic because of its ‘public good’ nature, which means that many users can benefit from use of public infrastructure at the very same time. This is especially true of ‘New Economy’ infrastructure such as IT, which links so naturally with developments in telecommunications so that the existence of many users, far from creating congestion in use, actually enhances the value of the infrastructure through network effects.

In response to the measurement problem, the approach of the current paper is to utilise an economic model that looks at the end result – observations on changes in the pattern of consumer spending behaviour – and econometrically estimates the extent of the link between these behavioural changes and their drivers: traditional economic stimuli as well as changes in the economic environment due to advances in technology and improved provision of public sector IT infrastructure. Counterfactual simulations with the estimated model provide money-metric measures of the welfare benefits of innovations in Internet-based public sector IT infrastructure in a variety of OECD economies.

1 Visiting Professor, The University of New South Wales at the Australian Defence Force Academy (email: *r.cooper@adfa.edu.au*) and Director and CEO, CHI-Research Pty Ltd, ABN 47 118 428 014 (email: *russel.cooper@chi-research.com.au*). This paper utilizes a model, CHI-MAIDS, developed under a previous research consultancy by CHI-Research Pty Ltd, studying ICT in Asian economies. The views expressed in this paper are those of the author and should not be attributed to the OECD or its member countries.

TABLE OF CONTENTS

MEASURING THE IMPACT OF INNOVATIONS IN PUBLIC IT INFRASTRUCTURE ON THE STANDARD OF LIVING IN OECD ECONOMIES

Introduction

Advances in information technology (IT) in the first decade of the 21st century have highlighted the role of IT as an *enabling technology* throughout an economy. But although the influence of IT in transforming the way in which business and consumer transactions are done is clear to all participants in the production-consumption process, it is difficult to attribute a specific value to and precisely measure the importance of the role of IT in improving consumer welfare.

The measurement of the economic value of public infrastructure has traditionally been problematic because of its 'public good' nature, which means that many users can benefit from use of public infrastructure at the very same time. This is especially true of 'New Economy' infrastructure such as IT, which links so naturally with developments in telecommunications so that the existence of many users, far from creating congestion in use, actually enhances the value of the infrastructure through network effects.

In the New Economy it is arguably becoming increasingly difficult to track the detailed price plans that are available to consumers for custom applications of IT-enhanced products and services as the range of options expands seemingly without end. The pace of innovation in IT and the complementary field of telecommunications (together information and communications technology – ICT) has meant that official price statistics, especially aggregate price indexes, lag behind the innovations, with quality-adjusted prices only following after the event, if they are computed at all.

Endorsing the view that the influence of these events is evident in changed consumer expenditure patterns, Huttner (2007) noted the ubiquitous increase in final demand for what is arguably the most prominent product born of the complementarity between IT and telecommunications – the Internet: 'Millions of people now use the Internet for everything from doing homework to buying books, or playing or downloading games, music and movies'. But the importance of the Internet cannot be grasped simply by alluding to consumer examples. Huttner also gives a counterfactual description of the importance of the Internet economy in business terms: 'Nowadays, without the Internet, planes would not fly, financial markets would not operate, supermarkets would not restock, taxes would not get paid and the power grid would not balance the supply and demand for electricity.' Although there are, on the surface, differences between the consumer and the business experience of the Internet economy, at a more fundamental and long-term level the quality of life for consumers is deeply linked to the strength of the business economy. The increasing reliance on the Internet would make it now challenging to live without it. There is an understanding that the productivity advances in ICT have led to improved living standards which could not be easily replicated without those advances. These are the elusive benefits that remain to be measured.

Arguably it is the very success of the Internet in permeating all aspects of the economy that has rendered the overall contribution of IT advances that utilise this facility difficult to measure. In response to the measurement problem, the approach of the current paper is to utilise a specially developed economic model, termed here CHI-MAIDS, that looks at the end result – observations on changes in the pattern of consumer spending behaviour – and econometrically estimates the extent of the link between these behavioural changes and some of their drivers: traditional economic stimuli as well as changes in the economic environment due to advances in technology and improved provision of Internet-based public sector IT infrastructure. Counterfactual simulations with the estimated model provide money-metric measures of the welfare benefits of innovations in Internet-based public sector IT infrastructure in a variety of OECD economies.

The plan of this paper is as follows. Section 2 presents the core features of a model of consumer behaviour which is designed to uncover the parameters required to link ICT advances to consumer welfare. Section 3 sets out the data requirements for a model of consumer behaviour in this context. It describes and presents a specialised dataset developed to represent the increased reliance on the Internet for provision of public sector infrastructure intended to enhance business and consumer experience. Section 4 provides econometric estimates of model parameters. In Section 5 the paper turns to outlining a model-consistent approach to consumer welfare evaluation. Then in Section 6 the consumer welfare implications of an experiment are examined. This section shows how much consumers would have to be compensated if typical historical Internet-based public sector infrastructure innovations had not occurred. The results are limited to measuring the size of this effect in 2008 for a variety of OECD economies. Although the interpretation of the results must be limited by the nature of the experiment, this research suggests an indirect means of measuring the impact of the Internet economy. Section 7 sets out conclusions, caveats and suggestions for further research.

Model description

An ICT-enhanced stylized consumer demand model

Many modern approaches to estimation of consumer demand systems make use of flexible function forms in some aspect of the price index specification. For example, the Almost Ideal Demand System (AIDS) popularized by Deaton and Muellbauer (1980) contains, in its specification of the indirect utility function (IUF), two price indexes, one of which is Cobb-Douglas and the other of which is Translog. The Translog price index is a flexible functional form in the sense of Diewert (1971), in that it allows at least one free parameter for each separate own and cross price effect after allowing for relationships implied by optimisation, such as homogeneity and symmetry, but it requires data on individual prices for implementation.

With lack of full information on quality-adjusted prices following as a natural consequence of fast paced ICT innovation, specification of a Translog price index is not fully viable and another approach to ensuring commodity share equation flexibility will be important. This paper begins with a stylized version of the Modified Almost Ideal Demand System (MAIDS) model to ensure Engel Curve regularity and flexibility. This is a modification of AIDS initially introduced by Cooper and McLaren (1992) to correct an inherent irregularity in AIDS associated with the zero-degree homogeneity of the Cobb-Douglas price index. MAIDS was further extended in Cooper and McLaren (1996) to allow more flexibility in the specification of the degree of non-homotheticity of preferences. It provides a consumer demand system in fractional form, so that budget share equations (Engel Curves) are modeled in a non-linear fractional specification that is fully consistent with a consumer utility maximising paradigm.

For the purposes of handling the inadequate price issue that is a major problem for ICT-related research, the consumer demand model CHI-MAIDS that is the focus of this paper is further enhanced by a hedonic-type approach to prices. However, in CHI-MAIDS, rather than being constructed beforehand, the appropriate price adjustments are built directly into the consumer demand estimation process. This procedure introduces sufficient additional parameters to allow the consumer demand system to be flexible in the sense of Diewert, even though a Translog price index is not employed and the price component of the IUF specification is based on two Cobb-Douglas price index pairs.

In a two-commodity stylized representation of MAIDS where the first commodity q_1 is the most basic necessity (here, food) and the second commodity is a composite good representing all the remaining products, say Q_R, the IUF is:

$$V(c,p) = \left(\frac{c}{P_B}\right)^{\eta} \ln\left(\frac{c}{P_A}\right) \qquad (1)$$

where

$c = p_1 q_1 + P_R Q_R$, $\ln P_A = \alpha \ln p_1 + (1-\alpha)\ln P_R$ and $\ln P_B = \beta \ln p_1 + (1-\beta)\ln P_R$.

Applying Roy's Identity to (1), the commodity share equations corresponding to the stylized MAIDS preferences can be seen to take the fractional form:

$$s_1 = \frac{\alpha + \beta\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)}$$
$$s_R = \frac{(1-\alpha) + (1-\beta)\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} \qquad (2)$$

where $s_1 = p_1 q_1 / c$ and $s_R = P_R Q_R / c$. It is important to note that this specification is really reasonably general. In particular, the price index parameters α and β may be time varying as long as they are not functions of (current levels of) p_1, p_R and c. There is, however, a preference separability assumption implicit in the specification employed for stylized MAIDS. In particular, the 'rest of expenditure' price and quantity aggregators P_R and Q_R, while not needing to be precisely specified, are understood not to depend on p_1 and q_1. It is also useful to assume that the consumer optimisation that is represented in this way mimics a situation in which consumers act as if they do not believe that their individual decisions affect aggregate outcomes. This being so, the α and β parameters can be modeled as functions of past consumer decisions without requiring a full intertemporal optimisation model. This variable parameter specification is helpful for generating the required flexibility as well as mopping up autocorrelation in the estimation routine. As is reasonably standard, two stage budgeting allows atemporal and intertemporal decisions to be considered in tandem and the research for this paper concentrates on the atemporal stage, *viz.* allocation of predetermined c between s_1 and $s_R \equiv 1 - s_1$.

Interpretation and issues for empirical implementation

A further interpretation of MAIDS shares needs to be noted. Suppose c / P_A is a low value for the first period in the sample (say unity, as could be imposed by scaling the data and treating the first period as the base period). Then $\ln\left(c / P_A\right)$ is zero in this base period and the implied shares at that point in time, from (2), are $s_1 = \alpha$ and $s_R = 1 - \alpha$. Over time of course one might hope that real incomes rise and c / P_A trends upwards. Another implication of (2) is that as $c / P_A \to \infty$, $s_1 \to \beta$ and $s_R \to 1 - \beta$.

From the definitions of P_A and P_B (given following (1)) this means that, as a cost of living indicator, emphasis changes from P_A in the base period to P_B asymptotically. Preferences are not homothetic (unless $\alpha = \beta$). This of course is what gives rise to non-constant Engle Curves.

If data were to be available on total expenditure c, on the disaggregated expenditure component $p_1 q_1$ and on the aggregate price index P_A, then using the identity $s_1 + s_R = 1$ and appending disturbance terms to the deterministic specification (2), one could write a stochastic version for estimation as:

$$\begin{aligned} s_1 &= \frac{\alpha + \beta\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} + \varepsilon_1 \\ 1 - s_1 &= \frac{(1-\alpha) + (1-\beta)\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} + \varepsilon_2 \end{aligned} \qquad (3)$$

However, adding up the two equations in (3) clearly shows that the disturbances are linearly dependent and one equation is redundant. Without loss of generality, parameter estimation can proceed on the single equation (for current purposes, the MAIDS Engel Curve for food):

$$s_1 = \frac{\alpha + \beta\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} + \varepsilon_1 \qquad (4)$$

It should be noted that, although the MAIDS IUF (1) is a function of two aggregate price indexes, P_A and P_B, only one of these, P_A, features as an aggregate price index in the estimating form (4). Thus, of the two price indexes P_A and P_B, it is P_A that has claim to being the key cost of living indicator in this model. It follows that a variable parameter specification for the key food price elasticity α, which allows α to be updated regularly based on the most recent consumer behaviour, will be an important component of the empirical specification.

To proceed, it is necessary to recognise that, with innovations in ICT, official price indexes do not adequately represent the theoretical aggregate price index P_A. On the other hand appropriate quality-adjusted variants of the individual prices p_1 and the sub-index P_R, or its component prices, are not readily available. This introduces the reason for the point of departure from MAIDS to CHI-MAIDS: to handle lack of appropriately defined official data for ICT-enhanced products. In the research reported here, to address this issue it is specified in CHI-MAIDS that

$$P_A = \theta P_{GDP} \qquad (5)$$

where P_{GDP} is an available official price index (typically, the GDP deflator). The variable parameter θ is defined to equal unity in the base period (chosen here as the initial sample point) so that all price indexes are normalised at unity at that time. However, θ needs to be specified in such a way as to allow it to fall over time if innovations in ICT occur that add to the quality of products consumed (or, equivalently, reduce the quality-adjusted price) before this information becomes available to be incorporated into the official GDP deflator.

One interpretation of (5) is that this is a stylized approach to hedonic price index construction. If data permitted, it might be more accurate to consider individual prices, p_i say, and to define a quality adjusted price, $p_{A,i}$ say, where

$$p_{A,i} = \theta_i p_i \qquad (6)$$

with θ_i a function of the various attributes that change with improvements in quality. That is, $1/\theta_i = \sum_{j=1}^{m} \kappa_{ji} x_j$ for preference parameters κ_{ji} and a set of attributes x_j, so that the observed price of an individual product in the market, p_i, is related to an underlying quality-adjusted price, $p_{A,i}$ as $p_i = \left(\sum_{j=1}^{m} \kappa_{ji} x_j\right) p_{A,i}$. If p_i is a representative market price for a product that is improving in quality over time, then p_i will be rising relative to $p_{A,i}$ and hence θ_i should be falling over time to reflect the quality advances. Rather than concentrate on constructing the various hedonic sub-components of price corresponding to specific attributes, however, at the level at which we will be working with a representative consumer model, it is the average price that matters, albeit ideally the average quality adjusted price.

In addition, however, working with aggregate data pooled across a number of economies, even individual prices p_i, unadjusted for quality, are difficult to obtain in a harmonized form. Hence (5) applies the quality adjustment paradigm at the level of the official GDP deflator. If one conceives of the GDP deflator being at least roughly approximated by a Cobb-Douglas price index of the form $P_{GDP} = \Pi_{i=1}^{n} p_i^{\omega_i}$ for some weights ω_i which could be time dependent (for example, lagged shares), then (6) suggests that $P_A = \left(\Pi_{i=1}^{n} \theta_i^{\omega_i}\right) P_{GDP}$. At the aggregate level, we do not have information on the individual hedonic characteristics making up the θ_i parameters for particular products. However, if we can find relevant information on particular ICT innovations we can presume that these correlate with improved quality of individual attributes and construct an overall quality adjustment factor θ, as designated by (5) as an approximation to $\Pi_{i=1}^{n} \theta_i^{\omega_i}$.

In the current research, (5) is used as the point of entry for examination of downward shifts in the Engel Curve for food as a result of ICT innovations. Applying (5) to (4), the CHI-MAIDS Engel Curve for food is:

$$s_1 = \frac{(\alpha - \beta\eta \ln\theta) + \beta\eta \ln\left(c / P_{GDP}\right)}{(1 - \eta \ln\theta) + \eta \ln\left(c / P_{GDP}\right)} + \varepsilon_1 \qquad (7)$$

A useful way to interpret (7) is to write it in two components:

$$s_1 = \frac{(\alpha - \beta\eta \ln\theta)}{(1 - \eta \ln\theta) + \eta \ln\left(c / P_{GDP}\right)} + \frac{\beta\eta \ln\left(c / P_{GDP}\right)}{(1 - \eta \ln\theta) + \eta \ln\left(c / P_{GDP}\right)} + \varepsilon_1 \qquad (8)$$

and to note from the discussion following (5) that $\ln\theta \le 0$. The parameters α, β and η are all positive (or, at least, non-negative). Hence, in the denominator of the share equation, the 'intercept', $1 - \eta \ln\theta$, is positive. So too is the numerator. The first term on RHS (8) is a hyperbola that asymptotes to zero. The second term asymptotes to β. The first term dominates when c / P_{GDP} is low (near unity). The second term begins to have more influence as c / P_{GDP} rises. In the case of the food share, Engel's Law should be reflected in parameter estimates satisfying $\alpha > \beta$.

Specifications for the individual food price elasticities in the two price indexes

In the previous sub-section it was argued that the parameter θ defined in (5) will be falling as advances in technology occurred that are not fully reflected in official prices. This also has implications for the specification of the individual food price elasticities α and β. To investigate these implications, observe that another way to write (7) is to define a bounded real expenditure indicator:

$$Z = \frac{\eta \ln\left(c / P_{GDP}\right)}{(1-\eta\ln\theta)+\eta\ln\left(c / P_{GDP}\right)} \tag{9}$$

and hence rewrite (7) as:

$$s_1 = \frac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}(1-Z)+\beta Z \tag{10}$$

Then, with further re-arrangement we can write the pseudo-'linear' form:

$$s_1 = \frac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}+\frac{\beta-\alpha}{1-\eta\ln\theta}Z \tag{11}$$

where of course the 'linearity' is due to the construction of Z.

In (11), the intercept $\dfrac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}$ is a proper weighted average of α and β, and is greater than β since $\alpha > \beta$ in the case of the food share. It is also apparent that:

$$\partial\left(\frac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}\right) / \partial\ln\theta = \frac{(\alpha-\beta)\eta}{(1-\eta\ln\theta)^2} > 0 \tag{12}$$

and consequently the intercept in (11) will be falling as θ falls, cet. par.

Extensive experimentation with specifications like (11), undertaken as background to the research reported in this paper, shows that in the (s, Z) space the Engel Curve for food is flattening out over time. In (11), the intercept is falling and the slope is also falling in absolute value. The curve is pivoting about β on the $Z=1$ upper bound axis. β itself may or may not be constant, but it is certainly small, though difficult to estimate with precision because the upper bound axis $Z=1$ in (s, Z) space is approached with substantial extrapolation (that is, as $c / P_{GDP} \to \infty$). However, it is also apparent that the intercept in (11) may vary over time for reasons other than the fall in θ.

In this research we treat η as a constant parameter. However, we should at least investigate the possibility that α and β are variable. As the discussion following (4) pointed out, P_A has an interpretation as a cost of living indicator. Given that, it might be reasonable to suppose that its individual price elasticities could vary with changes in preferences. While it is not necessary for α to fall over time in order to observe a fall in the intercept in (11), this could occur and so not all of the flattening of the pseudo-linear Engel Curve (11) might be attributable to the cost reduction effects of technological advances incorporate in θ. This motivates our decision to specify α as a variable parameter function in its own right. After initial experimentation in which a variety of possible influences on changes in α were considered, the specification finally chosen was simply:

$$\alpha_t = \psi s_{1,t-1} + (1-\psi) s_{R,t-1} \qquad (13)$$

where ψ is a freely estimated parameter. The specification (13) means that the price index P_A is being continually reweighted with updated (one-period-lagged) share weights, compatibly with its interpretation in (4) as a cost of living indicator. The lower ψ, however, the less rigidly current preferences are linked to immediate past behaviour.

It is also possible in principle to model β as a function of time. In the event, it proved to be difficult to obtain statistically significant estimates of β. This is really a reflection of the fact that β is the long run food share as real expenditure tends to infinity. It is an extrapolated value well outside the bounds of experience. To pre-empt a later result, we have found that there is no significant difference to modelling results if β is treated as effectively zero. This means that P_B will be effectively a function of all other prices, with no influence coming from the price of food. It turns out that this result does not affect the remainder of the modelling and is simply a reflection of the ultimate unimportance of the food share in the limit. For generality in formulas that might be applied in principle to shares other than that for food, in what follows we retain β_t as a potential time varying parameter in the described specification. However, in the empirical application we set this parameter to zero.

The food share Engel Curve in a cross-country context

An issue investigated in this research is the degree to which innovative Internet-based public sector IT infrastructure, obtained for government by the contracting out of problems for solution by research oriented private sector firms, leads to reduced costs, generates quality improvements in services, and ultimately leads to increased consumer welfare. The parameter estimates required for this investigation are based on examination of actual consumer behaviour and need to be obtained in that context. With limited aggregate time series data covering a period of ICT innovation, the dataset needs to be extended in another way.

In the discussion above we have presented a simplified variant of the final estimating form, which we now need to generalise slightly to allow for a country specific effect in pooled time series/cross section estimation. In the pooled data context, the need for a country specific effect is in part related to different data definitions for food across countries. In addition to this issue, however, the need to allow for a country specific effect can also be given a purchasing power parity interpretation. These two concerns are of course related. One reason for differences in purchasing power parity is incompatible data definitions across countries. Another reason is differences in the provision of public infrastructure, the services of which might be consumed as a public good complementary to consumption of any purchased product. This difference can apply even with compatible product definitions. It reflects different public sector infrastructure provision and different taxation arrangements for the funding of such provision.

No adjustment for differences in purchasing power has been made in the data, and it is possible to interpret an additional country specific parameter γ, now to be introduced, as controlling for these differences. Instead of making arbitrary adjustments to the data prior to estimation, our procedure effectively endogenises the purchasing power parity (PPP) adjustment. This would appear to be more in spirit with the compelling arguments on an appropriate approach to PPP adjustments put by Pant and Fischer (2007). To allow for this, the IUF (1) can be generalised slightly. Consider (1) in a multi-country context with an additional country specific scaling parameter initially applied to total expenditure:

$$V(c,p)=\left(\frac{c/\tilde{\gamma}}{P_B}\right)^{\eta}\ln\left(\frac{c/\tilde{\gamma}}{P_A}\right) \tag{14}$$

This is equivalent to:

$$V(c,p)=\tilde{\gamma}^{-\eta}\left(\frac{c}{P_B}\right)^{\eta}\left[\ln\left(\frac{c}{P_A}\right)-\ln\tilde{\gamma}\right] \tag{15}$$

Since utility is ordinal and we are not intending to attempt inter-country utility comparisons, without loss of generality the country-specific scaling constant $\tilde{\gamma}^{-\eta}$ can be ignored. However, the adjustment term $-\ln\tilde{\gamma}$ within the square brackets in (15) is a non-monotonic transformation of utility in the context of MAIDS preferences and thus it does affect the form of the share equations. For convenience we redefine this parameter as $\gamma=\ln\tilde{\gamma}$ and write the cross-country variant of MAIDS as:

$$V(c,p)=\left(\frac{c}{P_B}\right)^{\eta}\left[\ln\left(\frac{c}{P_A}\right)-\gamma\right] \tag{16}$$

Re-applying Roy's Identity to (16) and following through the previous steps from MAIDS to CHI-MAIDS, the stochastic specification of the CHI-MAIDS food share Engel Curve now becomes a slight extension of (7), *viz.*:

$$s_{1t}=\frac{\left[\alpha_t-\beta_t\eta\ln\theta_t\right]+\beta_t\eta\left[\ln\left(c_t/P_{GDP,t}\right)-\gamma\right]}{\left[1-\eta\ln\theta_t\right]+\eta\left[\ln\left(c_t/P_{GDP,t}\right)-\gamma\right]}+\varepsilon_{1t} \tag{17}$$

where the additional parameter γ is fixed over time but varies across countries and where explicit time subscripts have been added for all variables as well as for the time varying parameters previously discussed.

Time varying parameter specification for the cost reduction effect

In order to estimate (17), it is necessary to parameterise the functional form for θ. In the empirical component of this research, the time varying θ_t parameter is specified to investigate the influence of the Internet-based public sector IT infrastructure of interest as well as other controls, especially spillover effects from other economies. Two forms of the latter are accommodated: *i)* externalities that are available consistently over time but to a greater degree to those economies that have the most opportunity to gain costlessly, having not invested heavily in their own R&D; and *ii)* general spillovers from technological leader economies, available to all economies due to globalisation, but that are time varying depending on the historical context. After a good deal of experimentation the chosen specification is:

$$\theta_t = \theta_{1,t} + \theta_{2,t} = \frac{INNOV_t}{INNOV_b + OTHER_b} + \frac{OTHER_t}{INNOV_b + OTHER_b} \qquad (18)$$

$$INNOV_t = 1 + \theta_{1,C} \frac{AVGIT\%GDP_t}{1 + AVGIT\%GDP_t} \qquad (19)$$

where AVGIT = annualised value of government IT contracts (USD m.) awarded to high research intensive firms for development of innovative solutions to the provision of Internet-based public IT infrastructure. AVGIT%GDP is this value expressed as a percentage of GDP.

By construction in (18), $\theta_t = 1$ in the base period (denoted by subscript $t = b$). The explicit cost reduction effect due to AVGIT is controlled by a parameter $\theta_{1,C}$ which represents the key cost reduction effect of contracted Internet-based public sector IT innovations. With limited time series data on AVGIT for any country (indeed, no information for some), a common cost reduction parameter is estimated for a pooled cross-country time series dataset.

The variable OTHER primarily relates to spillover effects, either of ICT innovations or of other technological advances that may lead to quality improvements in various countries without being reflected in a reduction in the quality-adjusted prices of consumer products. One measure of this effect is captured by a parameter $\theta_{2,E}$ in (20) below, which is attempting to catch spillover effects applicable for countries whose level of e-readiness is below that of the United States in the base period. Another annually varying measure, meant to capture world-wide innovations in a globalised economy, is represented by the set of specific year dummies with associated parameters $\theta_{2,year}$. The specification is shown for an estimation period running from 2001 to 2008, with 2001 treated as the base period.

$$OTHER_t = \theta_{2,E} \max\left\{1 - \frac{EREADY_t}{EREADY_{US,b}}, 0\right\} + \sum_{year=2002}^{2008} \theta_{2,year} DUM_{year} \qquad (20)$$

Data and data construction

The model represented by the estimating form (17) was estimated by pooling time series data from 2001 to 2008 across 31 countries, using the non-linear estimation routine NL in Shazam. As (17) indicates, this requires data on the food share s_1, total consumption expenditure c, the GDP deflator P_{GDP} and the sundry variables making up the variable parameter specifications θ_t (cf. eqns. (18)-(20)). Because of the use of lagged food shares in construction of α_t, data on the food share is required from 2000 onwards. The food share, total consumption and GDP deflator data are available from official sources over the full range of 31 countries examined in this research. Attention here is concentrated on the special data constructed for the purposes of this research. Effectively, this is the data defined in discussion of (18)-(20)). Of this, the year and country dummy variables are the usual constructions. The EREADY series is directly taken from publications of country specific e-readiness indicators prepared by the

Economist Intelligence Unit. The main task here is to describe the key AVGIT (annualised value of government IT) contracts data that enters the $\theta_{1,t}$ component of the specification. This data has been constructed by the author from announcements of major contracts by governments for the awarding of IT solutions contracts. The actual announcements database is the proprietary data of Datamonitor Pty Ltd, and interested readers will need to consult the provider to obtain access to the original data. For the purposes of this research the announcements of expenditures over a given number of years have been annualised by dividing the announced contract value by the stated length of the contract. For any given country and year, the value recorded in AVGIT will represent an aggregation of work on all contracts that are current at that time.

There are a number of important qualifications that should be understood about the background data and the specific AVGIT data construction process. First, the background proprietary data consist generally of announcements prior to commencement of a project, with information provided on the contracting parties, the estimated contract length and value, as well as some detail on the nature of the contract. Generally, no follow-up information is available on whether the contracts actually ran to budget. Second, to construct AVGIT from the contract announcements data, this author has allocated the estimated contract value evenly over the announced life of the contract. Third, it is implicitly assumed that from the perspective of consumers' welfare, the value due to the project actually comes on stream in direct proportion to funds spent, and at the time that they are assumed to have been spent. Fourth, while information is available in some cases where projects have been abandoned, no detailed information is available on success of most of the contracts from a project management perspective. While some will have been managed well, others may not have had effective government oversight. The results should be indicative of average economy-wide returns for a range of public sector IT infrastructure projects of differing quality, and should be used cautiously in considering the potential returns for any given project. Fifth, there is a whole class of ICT activity, namely that related to telecommunications, that is missing from the current data, which relates to IT only. Given the strong linkage between telecommunications and IT, evidenced by the growth of the Internet, this is a serious gap.

As a result, the AVGIT figure for any given year and country should be thought of simply as an indicator of the new stock of publicly funded IT infrastructure coming on line at any time for some general mix of consumer and producer usage. Despite its limitations, it seems worthwhile to link this data to a consumer demand study to investigate whether it really does seem to make a difference to consumer behaviour. If it does so, this can be taken as indirect evidence of an impact due to the ICT economy. After processing by the author in the manner described above, it is impossible to reconstruct the original contracts data from the AVGIT data series. Consequently, as suggested above, the interested reader should contact the data provider to access the original data. On the positive side, the constructed AVGIT data, being divorced after construction from the proprietary contracts data series, can be made freely available with this paper (see Table 1). Using it or other relevant data, alternative modelling that can produce comparisons with the results reported in this paper is invited.

In the analysis, we have attempted to include as many as possible of the 34 current OECD member economies. Of these, three (Chile, Slovenia and Israel) were not members in the period under investigation but have nevertheless been included in the modelling. However, three current smaller member economies of the OECD (Estonia, Iceland, Luxembourg) were not included in the analysis because of a lack of compatibly defined economic data available to the author at the time of database construction.

Table 1: Annualised and aggregated public sector IT contracts data (USD m.)

	Canada	Denmark	Italy	Switzerland	Slovakia
2001	81.4	1.1	21.5	0	0
2002	130.8	11.2	118.3	1.1	4
2003	173.1	26.5	152	1.5	1.1
2004	176.4	23	196.4	0.4	2.9
2005	268.7	53.3	144.2	0.9	0.8
2006	252.7	122.4	245.4	2	2.7
2007	362.9	151.7	293.6	2	7.3
2008	408.5	160.8	387.6	2	11
	Mexico	Finland	Netherlands	Turkey	Australia
2001	3	0	6.8	0	68.4
2002	4	8.9	82.9	0	119.2
2003	7.9	22.9	105	0	197
2004	12.1	48.7	121.2	31.2	231.5
2005	11.6	37.7	79.2	32.8	440.2
2006	10.6	65.5	110.6	0	530.9
2007	13.4	72.7	121.7	14.7	621
2008	12.9	88.7	121.6	51.8	742.9
	United States	France	Norway	United Kingdom	Japan
2001	8547.3	6.1	98.3	1261.2	0
2002	10865.5	13.1	90.7	1608.1	0
2003	14260.5	58.3	31.2	2448.4	0.2
2004	20101.5	138.9	67.4	3694.3	16.7
2005	24761.4	217.9	85.8	5476.5	10.5
2006	30151.9	167.1	145.3	7297.9	19.3
2007	36328	224.1	235.8	7991.9	38.7
2008	43302.6	256.7	197.9	8853.3	48.4
	Chile	Germany	Portugal	Czech Rep.	New Zealand
2001	0	0	0	0	12
2002	0	25.2	0	0	14.6
2003	0	133.3	0	0.3	23.5
2004	3.2	209.5	0	0.8	33.3
2005	5	182.3	0	3	17.4
2006	1.8	173.6	3.1	2.7	20.3
2007	0.5	1118.1	3.4	13.4	18.2
2008	0.5	1101.9	3.4	18.1	21.6
	Austria	Greece	Spain	Hungary	Korea
2001	0	5.8	7.3	2.5	0
2002	0	2.9	138.9	10.7	0
2003	0.3	159.5	169.8	22.7	0
2004	23.1	195.6	85.8	31.9	0
2005	26	10.1	18.8	25.1	0
2006	12.2	13.3	46	15.3	0
2007	0	24.1	98.1	15.5	18.4
2008	0	44.9	190.2	15.7	29.8

	Belgium	Ireland	Sweden	Poland	Israel[2]
2001	0	0.2	12.7	13.8	0
2002	2.5	7.6	68.8	15.6	0
2003	73.3	13.1	103.6	9	0
2004	153.3	27.3	208.2	0.1	0.7
2005	209.7	8.7	271.7	7.3	7.1
2006	205.8	7.9	204.5	15.2	15.2
2007	168.8	13.9	184.2	8.5	20.4
2008	174	59.5	176.6	5.8	24.5

Source: Calculations by the author from announced public sector IT contracts data provided by Datamonitor

Table 1 provides the constructed AVGIT data for 30 of the 31 countries included in the analysis. One country included in the econometric modelling, Slovenia, had no recorded public sector IT contracts announcements in the Datamonitor database. The fact that Slovenia has no AVGIT data does not prevent it being included in the pooled time series cross-country database for estimation of the full set of parameters that describe preferences. All countries have been assumed to share a common cost-reduction-due-to-IT-innovation parameter $\theta_{1,C}$. Many of the countries have low or erratic values of AVGIT and this is largely responsible for the need to estimate a common pooled parameter. Given the common $\theta_{1,C}$ parameter, Slovenia can be included along with all the other countries in counterfactual experiments. The simple assumption is that, had it undertaken AVGIT expenditure, this would have had similar effects as for other countries which have other economic variables (total expenditure, official prices, e-readiness) in a similar range.

To put the AVGIT data in perspective it is helpful to also present it as a proportion of GDP for each country over time. This is the form in which it appears in the model, as the variable AVGIT%GDP. Table 2 presents the annualised and aggregated IT contracts data in this form.

2 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Table 2: Annualised Public Sector IT Contract Values as a Proportion of GDP (%)

	Canada	Denmark	Italy	Switzerland	Slovakia
2001	0.01142	0.00069	0.00192	0.00000	0.00000
2002	0.01785	0.00644	0.00971	0.00040	0.01634
2003	0.02004	0.01244	0.01009	0.00046	0.00332
2004	0.01784	0.00943	0.01138	0.00011	0.00688
2005	0.02379	0.02059	0.00812	0.00024	0.00168
2006	0.01990	0.04432	0.01319	0.00052	0.00485
2007	0.02539	0.04984	0.01400	0.00048	0.00977
2008	0.02708	0.04917	0.01660	0.00042	0.01156
	Mexico	Finland	Netherlands	Turkey	Australia
2001	0.00048	0.00000	0.00170	0.00000	0.01833
2002	0.00062	0.00659	0.01894	0.00000	0.02856
2003	0.00124	0.01394	0.01951	0.00000	0.03695
2004	0.00177	0.02583	0.01990	0.00844	0.03583
2005	0.00151	0.01932	0.01256	0.00724	0.06106
2006	0.00127	0.03123	0.01657	0.00000	0.06967
2007	0.00148	0.03036	0.01591	0.00248	0.06907
2008	0.00140	0.03319	0.01410	0.00835	0.07876
	United States	France	Norway	United Kingdom	Japan
2001	0.08439	0.00046	0.05767	0.08751	0.00000
2002	0.10378	0.00090	0.04741	0.10185	0.00000
2003	0.13010	0.00324	0.01390	0.13451	0.00001
2004	0.17201	0.00674	0.02619	0.17105	0.00036
2005	0.19915	0.01022	0.02864	0.24523	0.00023
2006	0.22852	0.00744	0.04389	0.30544	0.00044
2007	0.26044	0.00887	0.06178	0.28840	0.00089
2008	0.29857	0.00965	0.04456	0.34665	0.00098
	Chile	Germany	Portugal	Czech Rep.	New Zealand
2001	0.00000	0.00000	0.00000	0.00000	0.02331
2002	0.00000	0.00125	0.00000	0.00000	0.02442
2003	0.00000	0.00546	0.00000	0.00033	0.02950
2004	0.00335	0.00763	0.00000	0.00073	0.03426
2005	0.00423	0.00653	0.00000	0.00241	0.01602
2006	0.00123	0.00597	0.00159	0.00189	0.01945
2007	0.00031	0.03388	0.00154	0.00786	0.01510
2008	0.00029	0.02981	0.00141	0.00839	0.01876
	Austria	Greece	Spain	Hungary	South Korea
2001	0.00000	0.00430	0.00120	0.00469	0.00000
2002	0.00000	0.00190	0.02024	0.01607	0.00000
2003	0.00012	0.08012	0.01923	0.02690	0.00000
2004	0.00788	0.08249	0.00822	0.03123	0.00000
2005	0.00852	0.00398	0.00167	0.02274	0.00000
2006	0.00377	0.00478	0.00374	0.01354	0.00000
2007	0.00000	0.00746	0.00693	0.01136	0.00194
2008	0.00000	0.01194	0.01098	0.01018	0.00360

	Belgium	Ireland	Sweden	Poland	Israel[3]
2001	0.00000	0.00019	0.00573	0.00725	0.00000
2002	0.00099	0.00620	0.02824	0.00787	0.00000
2003	0.02365	0.00834	0.03406	0.00415	0.00000
2004	0.04272	0.01484	0.05962	0.00004	0.00057
2005	0.05627	0.00433	0.07602	0.00240	0.00538
2006	0.05210	0.00360	0.05325	0.00445	0.01066
2007	0.03764	0.00540	0.04162	0.00205	0.01265
2008	0.03451	0.02263	0.03740	0.00094	0.01227

Source: Table 1 and GDP in current USD millions. Figures are proportions expressed as a percentage – eg AVGIT for Canada in 2001 was just over 81 USD m. with GDP approx 722,444 USD m. giving AVGIT%GDP just over 0.0001 or 0.01 of 1 % of GDP.

Estimation results

Table 3 summarises maximum likelihood estimates and t-statistics for the various parameters making up components of the complete time varying parameter θ under three alternative modelling assumptions: *i)* that the same ICT cost reduction parameter, $\theta_{1,C}$, applies to all countries; *ii)* that the common cost reduction parameter applies to all countries except the United States, which has its own parameter $\theta_{1,USA}$; *iii)* that, in addition to the United States, the United Kingdom also has its own parameter $\theta_{1,UK}$.

Table 3: Cost reduction parameter estimates

	Model 1		Model 2		Model 3	
	estimate	t-statistic	estimate	t-statistic	estimate	t-statistic
$\theta_{1,C}$	-0.05	-2.5	-0.05	-2.6	-0.05	-2.5
$\theta_{1,USA}$			5.69	0.6	5.77	0.6
$\theta_{1,UK}$					0.25	0.6
$\theta_{2,E}$	-0.11	-2.1	-0.13	-3.1	-0.13	-2.8
$\theta_{2,2002}$	-0.05	-4.1	-0.06	-4.9	-0.06	-4.7
$\theta_{2,2003}$	-0.12	-6.2	-0.13	-7.0	-0.13	-6.7
$\theta_{2,2004}$	-0.10	-4.9	-0.11	-5.6	-0.11	-5.5
$\theta_{2,2005}$	-0.05	-2.5	-0.06	-3.2	-0.06	-3.2
$\theta_{2,2006}$	-0.03	-1.3	-0.04	-1.9	-0.04	-1.9
$\theta_{2,2007}$	-0.06	-2.3	-0.07	-3.0	-0.07	-2.9
$\theta_{2,2008}$	-0.05	-2.0	-0.06	-2.7	-0.07	-2.7

These results have very substantial implications. Setting aside the United States and United Kingdom results as special cases, there is clear evidence that the awarding of contracts for provision of Internet-based public sector IT infrastructure leads to an overall reduction in costs. This is despite the fact that the

3 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

econometric results allow for other general effects (technology improvements over time via the year dummies) that can also explain substantial cost reductions as well as spillover effects from technological innovators to other economies, especially to those that are lagging in their own e-readiness and stand to benefit from quality improvements in products that generally circulate through trade, even though they may not have invested in the R&D required to produce the innovative products. These 'θ_2' effects are of course competing in explanation for the same cost reductions as the 'θ_1' effects.

It is arguable that the United States and the United Kingdom are sufficiently different from other countries as to require separate specification of the public sector IT innovation cost reduction effect. This is because these countries engage in so much more public sector contracting out of IT solutions than does any other country. In addition, in the United States in particular, so much more of these contracts relate to military requirements and, further, a substantial amount of this expenditure takes place in other countries. Arguably, the benefits from this expenditure will not flow as directly to quality advances in products of interest to domestic consumers whose preferences we are examining. To allow for this possibly different impact on preferences, Model 2 specifies a separate parameter $\theta_{1,USA}$ which replaces, for the case of the United States alone, the otherwise common cost reduction parameter $\theta_{1,C}$. The estimated result is unexpectedly positive, but it is insignificant, and changes in other parameter estimates between Models 1 and 2 are minimal. Model 3 extends this approach to allocate a separate parameter for the United Kingdom. This is also positive and insignificant. Again, the other parameters do not change to any appreciable degree. In principle this process could be extended to allow a separate cost reduction parameter to be estimated for each country. However, the very small, not uncommonly zero, values for AVGIT%GDP in many countries, and the erratic nature of the data due to their compilation by aggregation of a small number of infrequently announced contracts, suggests that this process is not sustainable at the present level of available data. Rather, it is necessary to pool information across countries to have any real chance of determining the average size of the cost reduction effect at this stage.

Table 4 completes the summary of information from the alternative models by exhibiting the remaining Engel Curve parameters and overall fit statistics. In interpreting these results the reader should note that only the t-statistics for the parameter estimate of the MAIDS parameter η are constructed for the test against the null hypothesis that the true parameter value is zero. In the case of ψ, the parameter controlling the degree of influence of past food shares on the elasticity of the aggregate cost of living index P_A with respect to food prices, the null hypothesis is that $\psi = 1$, which reflects complete dependence on the lagged food share. In the case of the country specific γ parameters, since these relate to adjustments for purchasing power parity and/or other differences in food data definitions, the test is for the difference between the country specific estimate of γ and the average value of γ across all countries, which is 3.42, 3.41 and 3.41 for Models 1, 2 and 3 respectively.

Table 4: Engel curve parameter estimates and overall fit statistics

	Model 1		Model 2		Model 3	
	estimate	t-statistic	estimate	t-statistic	estimate	t-statistic
η	1.41	7.6	1.43	7.4	1.44	7.4
ψ	0.99	-6.3	0.99	-6.7	0.99	-7.0
γ_{Canada}	3.44	0.6	3.44	0.9	3.44	0.9
γ_{Mexico}	3.48	2.2	3.48	3.5	3.48	3.4
γ_{USA}	3.49	2.9	3.39	-0.6	3.39	-0.6
γ_{Chile}	3.45	1.0	3.45	1.3	3.45	1.3
$\gamma_{Austria}$	3.41	-0.4	3.40	-0.3	3.40	-0.3
$\gamma_{Belgium}$	3.44	0.6	3.43	0.8	3.43	0.8
$\gamma_{Denmark}$	3.40	-0.8	3.39	-0.8	3.39	-0.8
$\gamma_{Finland}$	3.45	0.8	3.44	1.0	3.44	1.0
γ_{France}	3.39	-0.9	3.38	-1.1	3.38	-1.0
$\gamma_{Germany}$	3.41	-0.5	3.40	-0.4	3.40	-0.4
γ_{Greece}	3.42	-0.1	3.41	-0.1	3.41	-0.1
$\gamma_{Ireland}$	3.41	-0.4	3.40	-0.4	3.40	-0.3
γ_{Italy}	3.39	-1.1	3.38	-1.1	3.38	-1.1
$\gamma_{Netherlands}$	3.38	-1.2	3.37	-1.5	3.37	-1.4
γ_{Norway}	3.37	-1.4	3.37	-1.4	3.37	-1.4
$\gamma_{Portugal}$	3.36	-2.0	3.36	-2.0	3.36	-1.9
γ_{Spain}	3.40	-0.5	3.40	-0.5	3.40	-0.5
γ_{Sweden}	3.44	0.6	3.43	0.8	3.43	0.7
$\gamma_{Switzerland}$	3.40	-0.9	3.39	-0.8	3.39	-0.8
γ_{Turkey}	3.46	1.2	3.46	1.4	3.46	1.4
γ_{UK}	3.44	0.6	3.43	0.8	3.41	0.0
$\gamma_{Czech\ Republic}$	3.36	-1.6	3.35	-1.7	3.35	-1.7
$\gamma_{Hungary}$	3.39	-1.0	3.38	-1.0	3.38	-1.0
γ_{Poland}	3.42	0.1	3.42	0.2	3.42	0.3
$\gamma_{Slovakia}$	3.39	-0.7	3.38	-0.8	3.38	-0.8
$\gamma_{Slovenia}$	3.37	-1.3	3.36	-1.5	3.36	-1.5
$\gamma_{Australia}$	3.42	0.0	3.42	0.1	3.42	0.2
γ_{Japan}	3.51	4.1	3.51	5.1	3.51	4.8
$\gamma_{New\ Zealand}$	3.38	-1.1	3.37	-1.2	3.37	-1.2

	Model 1		Model 2		Model 3	
$\gamma_{South\ Korea}$	3.49	2.3	3.49	2.8	3.49	2.8
γ_{Israel}	3.50	3.9	3.50	4.9	3.50	4.7
$\gamma_{average}$	3.42		3.41		3.41	
R^2	0.96		0.97		0.97	
DW-statistic	1.86		1.84		1.84	
Log-likelihood	1299.08		1308.14		1308.63	

Table 4 shows that the MAIDS parameter η is highly significant and compatible across all specifications. This is consistent with strongly non-homothetic preferences.

The parameter Ψ appears as part of the determination of the time varying parameter α as defined in (13). The role of specification (13) is to allow the parameter α to vary over time in a manner consistent with past behaviour. As the food share s_1 typically falls over time, the same characteristic can be captured by α ,according to (13), as long as ψ is greater than 0.5. The parameter ψ can be interpreted as an indicator of the importance of recent past preferences on current preferences. Its estimated value of 0.99 is obviously close to unity, but it is very precisely measured and it is in fact statistically significantly below unity.

The actual values of α are not only time varying but they also vary across countries. While they are not reported in detail here, the estimates of the time-varying parameter α typically range from about 0.045 down to about 0.03 over time in most countries. With β set to zero and the results for θ reported in the previous table, this suggests a gradual flattening out of each country's Engel Curve over time. Specification (13), which relates α to lagged shares, is also successful in mopping up residual autocorrelation, as suggested (to an approximation, in the context of this non-linear model) by the very satisfactory Durbin-Watson statistic which is 1.86, 1.84 and 1.84 across the three alternative models reported in Table 4.

The γ parameters have been estimated to allow a country-specific effect. This is necessary to allow for differences that may be due to varying data definitions with respect to food across countries and possibly to differences in purchasing power parities. The differences are not substantial in most cases, and there are only four out of 31 cases where the country specific effect is consistently statistically different from the average (the cases of Mexico, Japan, South Korea and Israel). The United States is also statistically different from the average in the case of Model 1, where the change in its value relative to Models 2 and 3 is almost certainly due to the forced commonality of the θ_C parameter in Model 1.

The log-likelihood values, when compared via a likelihood ratio test, suggest that the Model 2 dominates the other two models. On the other hand, the additional coefficient in Model 2 relative to Model 1, $\theta_{1,USA}$, is not statistically significant on the standard t-test. As Tables 3 and 4 demonstrate, all other parameter estimates are very similar in the two models. Given the insignificance of the country-specific public sector IT contract expenditure effects for the United States and the United Kingdom in Models 2 and 3, and the very compatible nature of other parameter estimates and overall fit statistics we continue from this point with Model 1.

Approach to welfare evaluation

Even when measured real *per capita* GDP has not necessarily risen, (17) allows an avenue for the share of food in the budget to fall following an innovation in ICT through the effect of a time varying parameter θ_t in the level of the Engel Curve. This is an important effect to measure because it is an indicator of the 'hidden productivity' of ICT, where advances in ICT induce changes in consumer behaviour. These changes in behaviour may be construed as indirect indicators of welfare improvements, even though official statistics such as real GDP *per capita* (proxied in this model by c / P_{GDP}) may show no change associated with the ICT innovation.

Of course there may be a variety of influences affecting θ_t, quite apart from the innovation of interest. As described in detail in (18), we write

$$\theta_t = \theta_{1,t} + \theta_{2,t} \tag{21}$$

where $\theta_{1,t}$ represents an ICT effect of specific interest and $\theta_{2,t}$ controls for all other influences on θ_t, *viz.* other events that are not necessarily related to the ICT event of interest but that might have led to quality advances and/or quality-adjusted price reductions that have also failed to be recorded at the appropriate time in official price statistics. In what follows, for notational convenience we use the same symbols for estimated values of parameters as have been used above in describing the 'true' population parameters in the model. We apply (21) to (17), drop the disturbance term, and represent a predicted share form of (17) as:

$$\hat{s}_{1t} = \frac{\left[\alpha_t - \beta_t \eta \ln(\theta_{1,t} + \theta_{2,t})\right] + \beta_t \eta \left[\ln\left(c_t / P_{GDP,t}\right) - \gamma\right]}{\left[1 - \eta \ln(\theta_{1,t} + \theta_{2,t})\right] + \eta \left[\ln\left(c_t / P_{GDP,t}\right) - \gamma\right]}$$

A model-consistent evaluation of the welfare generated at this point in time makes use of the same estimated parameters to construct the predicted utility consistent with the model's IUF, *viz.*:

$$u_t = \left(\frac{c_t}{P_{B,t}}\right)^{\eta} \left[\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma\right] \tag{22}$$

At this point we have no way of constructing the necessary time series estimates of the price index $P_{B,t}$ in (22) because although we can construct estimates of the time varying parameters α_t (and also of β_t in principle, if it is specified as non-zero) following estimation, this is all done for the current model without information on the individual prices $p_{1,t}$ and $P_{R,t}$ that are necessary ingredients of $P_{B,t}$. Despite this we now propose a method that avoids this lack of data and nevertheless allow us to consider two counterfactual questions.

Compensating variation

Firstly, we can ask:

Suppose that a certain proportion of the ICT innovation implied by the parameter value $\theta_{1,t}$ had not occurred. The counterfactual situation is one in which $\theta_{1,t,counterfactual}$, say, is greater than $\theta_{1,t}$ due to θ_1

not falling so much from its previous value $\theta_{1,t-1}$. This reflects the fact that some degree of innovation has not occurred in the counterfactual situation. Hence $\theta_{1,t,counterfactual} = \theta_{1,t} + \theta_{1,S}$ where $\theta_{1,S} > 0$. In this circumstance, by how much would a consumer's total consumption expenditure c have to be increased (*i.e.* from c_t to c_t^C, say) in order for us to predict that they could attain the welfare level u_t, *cet. par*.?

This amount of increase, say $c_t^{CV} \equiv c_t^C - c_t$, is the 'compensating variation' required to allow generation under the counterfactual conditions (absence of the innovation) of the utility predicted as achievable in time t in the presence of the innovation that actually did occur. It is therefore a money metric measure of the *per capita* value of the innovation. Relative to the *per capita* expenditure required to achieve the innovation, it would then give a measure of the return on the innovation.

From (22), the relevant new consumption level c_{t+1}^C under these circumstances can in principle be found as the solution of:

$$u_t = \left(\frac{c_t^C}{\tilde{P}_{B,t}} \right)^{\eta} \left[\ln c_t^C - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma \right] \qquad (23)$$

where $\tilde{P}_{B,t}$ denotes the value achieved by the (unobservable) price index P_B under the counterfactual circumstance in which $\theta_{t,counterfactual} = \theta_{1,t} + \theta_{1,S} + \theta_{2,t}$.

In order to calculate c_t^C, we need to eliminate the unobservables u_t and $\tilde{P}_{B,t}$ from (23). We can begin by combining (22) and (23). In ratio form, these imply:

$$1 = \left(\frac{c_t^C / c_t}{\tilde{P}_{B,t} / P_{B,t}} \right)^{\eta} \frac{\ln c_t^C - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma} \qquad (24)$$

A difficulty in using this equation to solve for c_t^C is that it contains the unknown price index P_B. A reasonable assumption is required to eliminate this term. We may note from (5) and (21) that $P_{A,t} = (\theta_{1,t} + \theta_{2,t}) P_{GDP,t}$. It is therefore natural to define:

$$\tilde{P}_{A,t} = (\theta_{1,t} + \theta_{1.S} + \theta_{2,t}) P_{GDP,t}.$$

Now this implies

$$\tilde{P}_{A,t} / P_{A,t} = (\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) / (\theta_{1,t} + \theta_{2,t}) \qquad (25)$$

Thus $\tilde{P}_{A,t} > P_{A,t}$ in the counterfactual situation under examination.

But what about $\tilde{P}_{B,t} / P_{B,t}$? As the interpretation surrounding (3) and (4) indicates, P_B could be interpreted as a price index more relevant to a wealthy society than is the case for the current cost of living price index P_A. In a cross-sectional analysis, if there is no 'digital divide' it might be reasonable to assume that $\tilde{P}_{B,t} / P_{B,t} = \tilde{P}_{A,t} / P_{A,t}$. More generally, in a time series analysis, if there is a digital divide but it is likely to be gradually eliminated we might at least expect that $\tilde{P}_{B,t} / P_{B,t} \le \tilde{P}_{A,t} / P_{A,t}$ but that $\tilde{P}_{B,\tau} / P_{B,\tau} \to \tilde{P}_{A,\tau} / P_{A,\tau}$ as $\tau \to \infty$ following a one-off shock at time t. In any event, in a counterfactual experiment involving a lower degree of innovation, we would certainly expect $\tilde{P}_{B,t} / P_{B,t} \ge 1$. In general, we could assume that $\tilde{P}_{B,t} / P_{B,t}$ lies between unity and $\tilde{P}_{A,t} / P_{A,t}$. Using (25) we could specify:

$$\tilde{P}_{B,t} / P_{B,t} = (1-\phi) + \phi\,(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) / (\theta_{1,t} + \theta_{2,t}) \qquad (26)$$

for some parameter $0 \le \phi \le 1$ with the value of ϕ perhaps depending upon the type of ICT innovation, upon its likely effects on different sectors of society, and upon the perceived degree of permanence of its transformative technology. This parameter could conceivably be related to the degree of e-readiness in the economy. However, it is not possible to recover a probable value of this parameter simply from estimation of the food share equation without the aid of further rather arbitrary assumptions. In this paper we present an evaluation of the welfare effects in summary form for three possible values of this parameter: 0, ½ and 1. The degree of sensitivity of the results with respect to alternative settings is evident from this. We then focus on the most conservative results for detailed presentation. Determination of the most appropriate value for ϕ in any given welfare experiment invites further research.

It is convenient to rewrite (26) as

$$\tilde{P}_{B,t} / P_{B,t} = \frac{(1-\phi)(\theta_{1,t} + \theta_{2,t}) + \phi\,(\theta_{1,t} + \theta_{1,S} + \theta_{2,t})}{\theta_{1,t} + \theta_{2,t}} = \frac{\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t}}{\theta_{1,t} + \theta_{2,t}} \qquad (27)$$

Then, given (27), we can now use (24) to solve for $\ln c_t^C$. We have an implicit expression:

$$\exp\left(\eta \ln c_t^C\right)\left(\frac{\theta_{1,t} + \theta_{2,t}}{(\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t})c_t}\right)^{\eta} \frac{\ln c_t^C - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma} = 1$$

(28)

from which c_t^C can be calculated numerically for any given choice of ϕ.

Equivalent variation

On the other hand, a second counterfactual question that can be asked is:

Given that the innovation did occur, by how much could a consumer's total expenditure be reduced so that they would feel no noticeable change in the utility from that which could have been achieved had the innovation not have occurred?

To answer this question, we first need to compute a utility level that would be compatible with the innovation not having occurred in circumstances where expenditure c_t was available. This hypothetical utility level is:

$$\tilde{u}_t = \left(\frac{c_t}{\tilde{P}_{B,t}} \right)^{\eta} \left[\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma \right] \qquad (29)$$

However, given that the innovation did occur, this utility level $\tilde{u}_t$ could have been reached if an alternative expenditure level, $\tilde{c}_t$ say, had been allocated to achieve:

$$\tilde{u}_t = \left(\frac{\tilde{c}_t}{P_{B,t}} \right)^{\eta} \left[\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma \right] \qquad (30)$$

From the ratio of (30) to (29) we can obtain an implicit expression for the hypothetical expenditure level $\tilde{c}_t$, viz:

$$1 = \left(\frac{\tilde{c}_t / c_t}{P_{B,t} / \tilde{P}_{B,t}} \right)^{\eta} \frac{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} \qquad (31)$$

Using (27) we can eliminate the unobservable $P_{B,t} / \tilde{P}_{B,t}$ and rewrite this as:

$$\exp(\eta \ln \tilde{c}_t) \left(\frac{\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t}}{(\theta_{1,t} + \theta_{2,t}) c_t} \right)^{\eta} \frac{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} = 1 \qquad (32)$$

which we note that, for a given selection of ϕ, can be solved numerically for $\tilde{c}_t$.

With this level of $\tilde{c}_t$ defining an expenditure level that would have given utility level $\tilde{u}_t$ in the presence of the innovation, we can now reframe our second counterfactual question as:

By how much could a consumer's total expenditure be reduced from the level $\tilde{c}_t$, given that the innovation did occur, and still allow achievement of a further hypothetical utility level, u_t^E, say that would have been achievable with expenditure of $\tilde{c}_t$ in the absence of the innovation?

This amount, say $c_t^{EV} \equiv \tilde{c}_t - c_t^E$, is the 'equivalent variation'. To find c_t^E, we need to compare two equivalent ways of obtaining the counterfactual utility level u_t^E. These are:

$$u_t^E = \left(\frac{\tilde{c}_t}{\tilde{P}_{B,t}} \right)^{\eta} \left[\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma \right] \tag{33}$$

which gives the utility associated with $\tilde{c}_t$ if the innovation had not occurred, and which needs to be equated to:

$$u_t^E = \left(\frac{c_t^E}{P_{B,t}} \right)^{\eta} \left[\ln c_t^E - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma \right] \tag{34}$$

which implicitly defines c_t^E as the expenditure that would have given the equivalent utility in the actual presence of the innovation.

From the ratio of (34) to (33) we now obtain:

$$1 = \left(\frac{c_t^E / \tilde{c}_t}{P_{B,t} / \tilde{P}_{B,t}} \right)^{\eta} \frac{\ln c_t^E - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} \tag{35}$$

Once again using (26) with $\phi = 1$, we can eliminate the unobservable price indexes to get an expression that can be solved implicitly for $\ln c_t^E$:

$$\exp\left(\eta \ln c_t^E \right) \left(\frac{\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t}}{(\theta_{1,t} + \theta_{2,t})\tilde{c}_t} \right)^{\eta} \frac{\ln c_t^E - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} = 1 \tag{36}$$

To summarise, to compute the compensating variation $c_t^{CV} \equiv c_t^C - c_t$ we make use of actual expenditure c_t and the solution of (28) for c_t^C. To compute the equivalent variation $c_t^{EV} \equiv \tilde{c}_t = c_t^E$ we first find $\tilde{c}_t$ from (32) and then calculate c_t^E from (36).

Results of the welfare experiment

In this section, parameter estimates from the model are used to calculate the compensating variation $c_t^C - c_t$ and the equivalent variation $\tilde{c}_t - c_t^E$ by solving (28) and (36) respectively under the following scenario. The ratio of AVGIT to GDP is increased by an amount equal to 0.001 of a percent. This experimentally small increase is needed for realism because, as Table 2 attests, AVGIT is either non-existent or a tiny proportion of GDP in most countries. With zero values in a number of cases, the experiment cannot be conducted in terms of a reduction in IT innovation. Therefore the experiment is conducted as an increase in public sector IT innovation contracts rather than the decrease used in the previous section to describe the welfare calculations. Consequently the signs on the variations are reversed from the formulas given in the previous section to calculate the compensating and equivalent variations. In the model, c_t is total nominal consumer expenditure in *per capita* terms. To give a reasonable quantitative estimate of the welfare effect, the compensating and equivalent variations are reported as returns per dollar of expenditure. Let x_t denote the actual increase in AVGIT in current USD *per capita* required to move AVGIT%GDP, which is expressed as a percentage, up by 0.001. Allowing for the experimental direction reversal, we calculate

$$CVR = \left[-(c_t^C - c_t) - x_t \right] / x_t \quad \text{and} \quad EVR = \left[-(\tilde{c}_t - c_t^E) - x_t \right] / x_t \qquad (37)$$

The results are thus in units of USD returns per dollar of public sector IT contracts expenditure.

Table 5 gives the results in the final year of the estimation/simulation period, 2008, under the scenario described above. The final two columns (EV return and CV return) were obtained using (37), solving (28) for c_t^C, (32) for $\tilde{c}_t$ and (36) for c_t^E, in each case using the NL command in Shazam. For each of the 31 member countries of the OECD that have been included in the analysis, the table gives *i)* AVGIT in current USD millions; *ii)* AVGIT%GDP prior to the experiment (these are the figures that are increased by the amount of 0.001 in the experiment); *iii)* the aggregate increase in AVGIT required for the experimental scenario (*i.e.* x_{2008} times population); *iv)* the *per capita* increase in AVGIT, x_{2008}; *v)* the EVR and *vi)* the CVR as defined in (37).

Table 5: Evaluation of a small public infrastructure IT innovation in 2008

Country	AVGIT	AVGIT %GDP	$\Delta AVGIT$	$\frac{\Delta AVGIT}{POPN}$	EV return	CV return
	(USDm.)	(%)	(USDm.)	(USD)	(USD)	(USD)
Canada	408.5	0.027	15.1	0.45	53.43	40.84
Mexico	12.9	0.001	9.2	0.08	522.15	416.99
United States	43302.6	0.299	145.0	0.48	-0.22	-0.37
Chile	0.5	0.000	1.7	0.11	680.68	500.00
Austria	0.0	0.000	4.2	0.51	682.25	513.06
Belgium	174.0	0.035	5.0	0.49	37.94	28.43
Denmark	160.8	0.049	3.3	0.60	20.87	15.64
Finland	88.7	0.033	2.7	0.51	41.37	30.06
France	256.7	0.010	26.6	0.42	189.77	143.72
Germany	1101.9	0.030	37.0	0.45	47.06	35.46
Greece	44.9	0.012	3.8	0.35	165.95	117.92
Ireland	59.5	0.023	2.6	0.63	74.04	53.06
Italy	387.6	0.017	23.4	0.40	104.19	80.01
Netherlands	121.6	0.014	8.6	0.52	126.86	95.54
Norway	197.9	0.045	4.4	0.96	25.37	18.56
Portugal	3.4	0.001	2.4	0.23	526.68	407.83
Spain	190.2	0.011	17.3	0.41	179.85	127.35
Sweden	176.6	0.037	4.7	0.52	33.43	24.76
Switzerland	2.0	0.000	4.8	0.63	622.07	474.96
Turkey	51.8	0.008	6.2	0.08	237.87	169.17
United Kingdom	8853.3	0.347	25.5	0.42	-0.4	-0.53
Czech Rep.	18.1	0.008	2.2	0.21	242.94	166.17
Hungary	15.7	0.010	1.5	0.16	196.68	139.46

Country	AVGIT	AVGIT %GDP	$\Delta AVGIT$	$\frac{\Delta AVGIT}{POPN}$	EV return	CV return
Poland	5.8	0.001	6.2	0.16	663.06	450.68
Slovakia	11.0	0.012	1.0	0.17	184.2	123.15
Slovenia	0.0	0.000	0.6	0.28	737.03	524.54
Australia	742.9	0.079	9.4	0.45	8.84	6.46
Japan	48.4	0.001	49.5	0.39	535.91	434.38
New Zealand	21.6	0.019	1.2	0.28	88.65	67.91
South Korea	29.8	0.004	8.3	0.17	397.56	289.37
Israel[2]	24.5	0.012	2.0	0.28	144.76	113.18

Table 5 suggests that a small amount of additional innovative public sector IT expenditure in 2008 would have generated very large returns in most countries. The only countries where returns would have been negative are the United States and the United Kingdom. Both of these countries were already engaging in these expenditures to a degree far exceeding all other countries and this suggests that diminishing returns may have set in for these two cases. However, it should also be noted that these two countries are special cases in another respect. The proportion of contracts that are of a military type are much higher in the United States than for any other country, and a substantial number of contracts actually relate to spending outside the United States. In the case of the United Kingdom, it has been the leader in overall IT contract expenditure by government for many years and its expenditure as a proportion of GDP is substantially higher even than the United States. For example, the United Kingdom expenditure as a proportion of GDP is a factor of 7 higher than that of Denmark, greater than 20 times that of the Netherlands and almost a thousand times that of Switzerland. It is not too difficult to conjecture that diminishing returns may have set in for the United Kingdom and the United States even while there are substantial returns still available for other countries. The results reflect this, with the highest returns available to those countries that have not so far availed themselves of this source of potential gains from provision of publicly supported IT infrastructure.

In Table 5, the EV return is uniformly higher than the CV return. The differences reflect the non-homotheticity of preferences in the MAIDS model. While this is an important design feature aimed to address the empirical facts, it creates some ambiguity in reporting numerical results. In what follows we concentrate on the more conservative CV return. Following the comparison of AVGIT%GDP expenditures in the United Kingdom compared to Denmark, the Netherlands and Switzerland, it is interesting to note that the calculated return on the dollar in these countries is approximately USD 15, 95 and 475 respectively. The lowest positive return is USD 6 in the dollar for Australia. Correspondingly, it may be noted that the baseline AVGIT%GDP for Australia is 0.079, well below the United Kingdom at 0.347 but also considerably above Denmark at 0.049, the Netherlands at 0.014 and of course Switzerland at effectively zero.

There are many interesting comparisons that can be made from the table. For example, comparing Spain and Portugal it can be seen that the return per dollar from this experiment in Spain is calculated to be USD 127 whereas for Portugal it is calculated to be a much higher USD 407. To attempt to explain the difference we could note that Portugal is coming from a much lower base in terms of baseline expenditure by government on innovative IT solutions compared to Spain. AVG%GDP for Portugal is 0.001 whereas it is ten times that value for Spain.

These results are startling. Yet they are conservative based on modelling that has attempted to control for a variety of other influences that might have been reducing costs quite apart from the programmes of public sector IT innovation covered by the contracts database. These other effects include the year dummy variables which allow for a global reduction in costs regardless of source and the spillover variable that allocates an explanation for cost reductions due to countries' opportunities, for example through trade linkages, to benefit from quality advances in products even though they have not necessarily spent funds on development of their own e-readiness to the same extent as the ICT innovators.

Of course, there could be many other missing factors whose influence might be mistakenly attributed to a cost reduction effect due to the AVGIT variable. However, the results are so startling that they invite much more investigation. It should also be noted that these are estimated economy-wide returns, implied by the behaviour of consumers in what appears to be a substantially welfare increasing situation due to innovations in ICT. These returns are not available to private sector providers. They might be expected to be much higher than returns that can be privately captured in the market, because of special features of ICT such as network effects, spillovers and the permeation of ICT advances throughout the economy.

One reason why the results reported in Table 5 might be unrealistically high is because they have been computed on the assumption that the parameter ϕ is unity in (27). One way of interpreting a value of unity for this parameter is that it means that cost of living reductions due to ICT advances are judged by consumers to have permanent effects. Hence, the long run high income price index P_B is assumed to be affected by the ICT advance to the same extent as the short run or current cost of living index P_A. At the other extreme, we could set $\phi = 0$. This would effectively mean that the long run price index P_B would not be influenced by the innovation considered in the experiment. This could be interpreted as having welfare effects confined to the short run. An intermediate case would be obtained by setting $\phi = 0.5$. Table 6 presents the CV returns for the experiment described above repeated under these alternative parameter settings. For convenience of comparison, the original results obtained for the case $\phi = 1$ are repeated in this table and some of the columns in Table 5 that describe the experimental scenario are also repeated.

Table 6: Comparison of results for 2008 under alternative parameter settings

Country	AVGIT	$\Delta AVGIT$	$\frac{\Delta AVGIT}{POPN}$	CV return $\phi = 1$	CV return $\phi = 0.5$	CV return $\phi = 0$
	(USDm.)	(USDm.)	(USD)	(USD)	(USD)	(USD)
Canada	408.5	15.1	0.45	40.84	34.57	28.30
Mexico	12.9	9.2	0.08	416.99	366.42	315.85
United States	43302.6	145.0	0.48	-0.37	-0.45	-0.53
Chile	0.5	1.7	0.11	500.00	412.55	325.12
Austria	0.0	4.2	0.51	513.06	431.51	349.96
Belgium	174.0	5.0	0.49	28.43	23.69	18.95
Denmark	160.8	3.3	0.60	15.64	13.03	10.42
Finland	88.7	2.7	0.51	30.06	24.42	18.77
France	256.7	26.6	0.42	143.72	120.93	98.15
Germany	1101.9	37.0	0.45	35.46	29.68	23.90
Greece	44.9	3.8	0.35	117.92	94.07	70.21
Ireland	59.5	2.6	0.63	53.06	42.60	32.15
Italy	387.6	23.4	0.40	80.01	67.99	55.98
Netherlands	121.6	8.6	0.52	95.54	79.99	64.45
Norway	197.9	4.4	0.96	18.56	15.16	11.77
Portugal	3.4	2.4	0.23	407.83	350.33	292.83
Spain	190.2	17.3	0.41	127.35	101.28	75.22
Sweden	176.6	4.7	0.52	24.76	20.44	16.11

Country	AVGIT	$\Delta AVGIT$	$\frac{\Delta AVGIT}{POPN}$	CV return $\phi = 1$	CV return $\phi = 0.5$	CV return $\phi = 0$
Switzerland	2.0	4.8	0.63	474.96	404.01	333.06
Turkey	51.8	6.2	0.08	169.17	135.16	101.14
United Kingdom	8853.3	25.5	0.42	-0.53	-0.60	-0.67
Czech Rep.	18.1	2.2	0.21	166.17	128.11	90.05
Hungary	15.7	1.5	0.16	139.46	111.08	82.70
Poland	5.8	6.2	0.16	450.68	346.87	243.09
Slovakia	11.0	1.0	0.17	123.15	92.80	62.46
Slovenia	0.0	0.6	0.28	524.54	421.49	318.46
Australia	742.9	9.4	0.45	6.46	5.27	4.08
Japan	48.4	49.5	0.39	434.38	385.81	337.24
New Zealand	21.6	1.2	0.28	67.91	57.60	47.28
South Korea	29.8	8.3	0.17	289.37	236.25	183.13
Israel[4]	24.5	2.0	0.28	113.18	97.55	81.91

Previously we reported in Table 5, looking at Denmark for example, that the CV return would have been about USD 15 per dollar invested if the cost reduction passed fully through from current prices to prices in the long run, that is if $\phi = 1$ in (27). Now Table 6 shows that if $\phi = 0$ so that there is no effect on long-run prices, then the CV return for Denmark would have been USD 10, or two thirds of the return previously predicted. Looking at the final three columns of Table 6, this finding is uniform. From this point we will again take the conservative option and look at the CV returns for the parameter setting $\phi = 0$. By doing so, we are allowing for the possibility that the failure of official statistics to record a quality-adjusted price is only temporary. However, as Table 6 attests, while the returns are lower under this assumption, they are still substantial.

It could be argued that the experimental scenario is too constrained, involving a very small change in public sector expenditure on innovative IT solutions, for which the marginal return might be high, but that over a more substantial change in expenditures the average effect could be much lower. The experimental results reported in Tables 5 and 6 were based on a scenario in which the innovation involved expenditures of an average of USD 0.38 per person across all countries. This varied across countries, as the experiment was based on a uniform change in expenditure relative to GDP. The expenditure change scenario in *per capita* terms is given in the column headed $\Delta AVGIT / POPN$. It ranges from a low of 8 cents in Mexico and Turkey up to 96 cents in Norway. However, the extremes are to some extent an artifact of the data presentation, which is in US dollars at current exchange rates, although they also reflect differences in the relative wealth of the countries. As an average, the figure of USD 0.38 per person is a reasonable indicator of the small but realistic size of the experiment. However, in order to investigate a possible bias upwards in results because of the size of the experiments, Table 7 presents the results for the most conservative case above, the CV return under parameter setting $\phi = 0$, and compares this with two alternatively size experiments, an experiment with an ICT innovation shock ten times as large and another experiment with a shock one hundred times as large.

4 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Table 7: 2008 CV returns for parameter setting $\phi = 0$ and alternative-sized shocks

	$\Delta AVGIT\%GDP = 0.001$		$\Delta AVGIT\%GDP = 0.01$		$\Delta AVGIT\%GDP = 0.1$	
country	$\frac{\Delta AVGIT}{POPN}$	CV return	$\frac{\Delta AVGIT}{POPN}$	CV return	$\frac{\Delta AVGIT}{POPN}$	CV return
	(USD)	(USD)	(USD)	(USD)	(USD)	(USD)
Canada	0.45	28.30	4.54	22.70	45.41	7.14
Mexico	0.08	315.85	0.84	182.54	8.41	34.25
United States	0.48	-0.53	4.77	-0.55	47.67	-0.65
Chile	0.11	325.12	1.06	180.51	10.56	32.40
Austria	0.51	349.96	5.12	192.06	51.16	34.11
Belgium	0.49	18.95	4.85	15.65	48.47	5.28
Denmark	0.60	10.42	5.96	8.93	59.62	3.32
Finland	0.51	18.77	5.10	15.43	50.95	5.10
France	0.42	98.15	4.15	68.06	41.53	16.11
Germany	0.45	23.90	4.49	19.40	44.88	6.27
Greece	0.35	70.21	3.51	50.16	35.07	12.41
Ireland	0.63	32.15	6.33	25.15	63.26	7.41
Italy	0.40	55.98	4.02	41.97	40.16	11.42
Netherlands	0.52	64.45	5.18	47.18	51.81	12.24
Norway	0.96	11.77	9.56	9.99	95.63	3.59
Portugal	0.23	292.83	2.26	169.30	22.60	31.73
Spain	0.41	75.22	4.14	53.09	41.35	12.86
Sweden	0.52	16.11	5.22	13.43	52.20	4.62
Switzerland	0.63	333.06	6.27	185.84	62.66	33.56
Turkey	0.08	101.14	0.82	68.74	8.19	15.71
United Kingdom	0.42	-0.67	4.19	-0.67	41.91	-0.74
Czech Rep.	0.21	90.05	2.11	61.21	21.12	13.93
Hungary	0.16	82.70	1.55	57.76	15.52	13.77
Poland	0.16	243.09	1.61	138.33	16.11	25.33
Slovakia	0.17	62.46	1.75	44.38	17.45	10.79
Slovenia	0.28	318.46	2.75	174.83	27.46	30.99
Australia	0.45	4.08	4.49	3.62	44.90	1.42
Japan	0.39	337.24	3.89	192.08	38.93	35.49
New Zealand	0.28	47.28	2.76	36.07	27.59	10.16
South Korea	0.17	183.13	1.71	112.93	17.13	22.68
Israel[5]	0.28	81.91	2.81	58.78	28.08	14.78

Table 7 shows that the average return does in fact fall off for larger shocks. However, it falls off initially at a fairly modest rate. For example the results from three alternatively sized shocks are summarised in Table 7. For comparison, the shock size previously examined, averaging (across the

5 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

economies) an expenditure of about USD 0.38 *per capita*, is recorded again in the first two columns of figures in Table 7. Then follow, in the middle two columns, results for a shock ten times larger. There is a fall off in average returns, but it is not substantial. Of course, the fall off does become substantial for very large shocks. However, even if one looks at what might be, for political reasons, shocks that are far too large to be countenanced, such as those reported in the two far right columns of Table 7 that correspond to a shock one hundred times larger than that summarised in the left two columns of figures, the returns are still impressive.

It is difficult, in the face of these results, to conceive of a reasonably sized innovation that produces small returns except of course for the cases of the United States and the United Kingdom which are different for reasons previously discussed. The results remain remarkable both for their size and their robustness to alternative assumptions.

Conclusion

In response to the Internet economy measurement problem, the approach of the current paper has been to utilise an economic model that looks at the end result – observations on changes in the pattern of consumer spending behaviour – and econometrically estimates the extent of the link between these behavioural changes and some of their drivers: traditional economic stimuli as well as changes in the economic environment due to advances in technology and improved provision of public sector IT infrastructure. Counterfactual simulations with the estimated model provide money-metric measures of the welfare benefits of innovations in Internet-based public sector IT infrastructure in a variety of OECD economies.

The model and the experiment undertaken have necessarily been limited by the availability of data. The results on the implied impact of the Internet can reasonably be described as startling. However, in view of model and data limitations some caveats are in order. The CHI-MAIDS model seeks to measure an effective (quality adjusted) cost reduction effect due to advances in Internet-based technology, with special reference to the provision of public sector IT infrastructure. An important caveat concerns the need to control other influences on quality adjusted cost reduction. In the model, these effects are partially allowed for by the inclusion of year dummy variables that allow for worldwide technology improvements over time. These effects are statistically significant. A useful next research step would be to attempt to replace these crude dummy variables with explicit data on competing explanations for the cost reduction effect. Indeed, this research process probably should continue until the crude dummy variables are no longer statistically significant. This could then be accepted as some evidence towards the proposition that other effects have been adequately controlled for.

Although the model developed and used in this research is highly aggregative and cannot trace out the precise process of transmission of IT productivity enhancements, it nevertheless corroborates the hypothesis of a positive end result for the macro-economy, implicit in the views of Huttner (2007), quoted in the Introduction. In the same opinion piece, she also documented what she suggested is the more complex, and possibly hidden, intermediate demand for the Internet: 'What is perhaps less apparent is that Internet-based applications underlie major advances in science, business organisation, environmental monitoring, transport management, education and e-government.' These are the outcomes of IT developments that are implemented at the micro level. Not all such R&D comes to fruition, but the promise of just some of the possible breakthroughs remains nothing short of amazing. Some might argue that the ICT revolution is spent, and that while extremely high returns may be possible at the introduction of any new general purpose technology, these types of returns are unlikely to be available for further advances in the same technology in the future. Against this, in 2008, the final year of the data period examined in this research, substantial innovations seemed to be just around the corner. Sydney Morning Herald Science Editor Deborah Smith reported at the time the invention, by a team of Australian, Dutch and Chinese researchers, of a device with the potential to speed up the Internet 100 times. 'The device, a photonic integrated circuit, could overcome the gridlock that occurs when information travelling along optical fibres at the speed of light has to be processed by slow, old-fashioned electronic components' (SMH, 10 July 2008, p. 3). If just a small part of some potential IT innovations is achieved, further IT induced productivity surges are highly likely.

In the spirit of the desirability of evidence-based policy, this paper has sought to measure the impact of micro-level IT productivity advances in terms of an improvement in the standard of living at the macro level. The paper has examined the hypothesis that innovative IT solutions are welfare enhancing through econometric estimation and subsequent counterfactual simulation of a model that links announcements of specific Internet-based public sector IT contracts to changes in a measure of the standard of living. The results are intriguing and invite further research, verification and extension.

REFERENCES

Cooper, R. and K. McLaren (1992) 'An empirically oriented demand system with improved regularity properties', *Canadian Journal of Economics* 25: 652-67.

Cooper, R. and K. McLaren (1996) 'A system of demand equations satisfying effectively global regularity conditions', *Review of Economics and Statistics* 78: 359-64.

Deaton, A. and J. Muellbauer (1980) 'An Almost Ideal Demand System', *American Economic Review* 70: 312-326.

Diewert (1971) 'An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function', *Journal of Political Economy*, 79: 481-507.

Huttner, S. (2007) 'The Internet Economy: Towards a Better Future', *OECD Observer*, November.

Pant, H. and B. Fisher (2007) 'Alternative Measures of Output in Global Economic-environmental Models: Purchasing Power Parity or Market Exchange Rates? - Comment', *Energy Economics*, 29:375-389.

SHAZAM (2004) User's Reference Manual Version 10, Northwest Econometrics.

Smith, D. (2008) 'Chip may speed up Internet 100 times', Sydney Morning Herald (SMH), 10 July. p. 3.