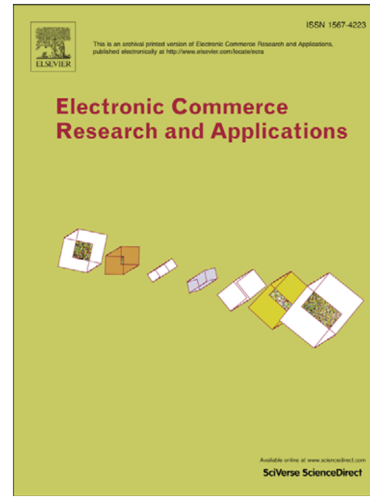

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PII: S1567-4223(12)00045-2
DOI: http://dx.doi.org/10.1016/j.elerap.2012.06.002
Reference: ELERAP 491

To appear in: *Electronic Commerce Research and Applications*

Received Date: 7 September 2011
Revised Date: 14 June 2012
Accepted Date: 14 June 2012

Please cite this article as: S. Lyons, E. Morgenroth, R.S.J. Tol, Estimating the value of lost telecoms connectivity, *Electronic Commerce Research and Applications* (2012), doi: http://dx.doi.org/10.1016/j.elerap.2012.06.002

ESTIMATING THE VALUE OF LOST TELECOMS CONNECTIVITY

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Last revised: June 14, 2012 (edited by Robert J. Kauffman)

ABSTRACT

We describe a practical method for estimating the economic cost of outages in electronic communications networks, accommodating temporal, geographical and sectoral variations in incidence. The method is illustrated with two types of examples: a hypothetical outage of the main fixed line network operator in Ireland, and seven examples of outages affecting individual local exchanges in areas with concentrations of technology-intensive employment or dense residential population. The national fixed line outage has an estimated cost of €42 to €50 per household-day arising from effects on the productive and residential sectors, with possible further losses from effects on retail payments and high societal value facilities such as emergency services. Estimated quantifiable economic costs from outages affecting a single local exchange range from €370,000 to €1.1 million per day.

Keywords: Cost of outages, economic analysis, service continuity, telecommunications, value

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Acknowledgements. We are grateful to Hugh Hennessy for research assistance and to the editor and two anonymous referees for helpful comments. The usual disclaimer applies.

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1. INTRODUCTION

In the public discourse on industrial development, it has long been commonplace to talk about the value or contribution of sectors. This tends to be measured by the gross output of the sector, or in more sophisticated examples by the value added. Some analyses also try to take into account the indirect contribution, for example by using input-output tables. Almost all discussions of the sectoral value or contribution focus on the average contribution over a particular period across a wide range of activities; for example, the total revenue from electronic communications services in Ireland was just over €957 million in the third quarter of 2011 (ComReg 2011) and the communications sector made up about 3% of Irish GNP (DCENR 2008).

In practice though, policymakers are never confronted with choices that either lead to the loss of all the annual output from a major sector or substantially increase its value in the short run. Estimates of the annual contribution can help put the size of the sector in perspective, but do not provide obvious pointers for policy. Instead, the effects of incremental changes of the output of a service sector are normally much more relevant for policy. This includes what is the economic effect of a change to the supply or quality of a service in a geographical area, for a specific service, affecting a particular supplier, during a given period. Since not all the economic effects of incremental service changes are borne by the suppliers themselves, such effects are relevant to areas of policy such as the formulation of universal service obligations, subsidies for rural service provision, interconnection rules, facilities for dispute resolution among suppliers and continuity of service arrangements.

Our contribution is to define and measure a subset of incremental effects in the electronic communications sector, which fills an important gap in the literature. We refer to these as the *value of lost connectivity*. It is directly analogous to the value of lost load in the electricity sector or the cost of supply interruptions in the gas sector, both of which have received some research attention. We recognise that there are analogous incremental changes that may be of a more positive nature and may be valued in a similar way, such as the value of improvements to the quality of a service or extensions of the geographical coverage to previously unserved parts of the market.

In principle, we would like to include as much of the full societal impact of the relevant changes as we can, although data obviously impose some constraints. The effects may be significantly different depending upon how services are affected across several dimensions – temporal, spatial, sectoral and service complementarity and substitutability – which makes estimating them more complex than it would be for similar effects in some other network sectors.

We note that telecoms service continuity has been identified as a regulatory objective in Europe. European Union law contains provisions relating to continuity of service in electronic communications markets. In particular, Article 23 of the Universal Service and Users Rights Directive (EU 2009) places requirements on European Union Member States:

> *Availability of services.* Member States shall take all necessary measures to ensure the fullest possible availability of publicly available telephone services provided over public communications networks in the event of catastrophic network breakdown or in cases of force majeure. Member States shall ensure that undertakings providing publicly available telephone services take all necessary measures to ensure uninterrupted access to emergency services.

Estimates of the marginal value of the reliability of communication will thus help to inform appropriate government action to meet the regulatory objectives. In the course of normal operation, electronic communications networks are very reliable, such that "...most customers will not perceive any outage during an entire year" (Fagerstrom and Healy, 1993). Therefore, we focus on the impact of large-scale, low-frequency events that may affect significant parts of a network.

We first outline a proposed conceptual structure for estimating these effects across the various domains of interest, and we then provide two hypothetical examples: an interruption in all fixed line services for the main supplier in Ireland and an outage affecting an individual local exchange. The Irish case is interesting because the country is a small export-oriented economy with an industrial base that relies heavily on high-technology multinational companies, a group that might be considered particularly reliant on electronic communications services as an input to production.

2. RELEVANT PREVIOUS RESEARCH AND SOURCES OF EVIDENCE

Our focus on the wider economic impact of telecom service interruptions is different from most of the existing literature on telecoms network reliability. Past research, particularly from an engineering perspective, has developed ways to classify and measure interruptions to telecoms services. A seminal contribution by McDonald (1992) proposes a scale for the impact of network outages based on a function of duration and the quantity of average user traffic lost: User Lost Erlangs, or ULEs. Subsequent research, particularly led by regulators and standards bodies, provides a detailed nomenclature and a set of metrics for assessing network outages (Daneshmand and Sawolaine 1993, Glossbrenner 1993, and Tollar and Bennett 1995).

Even if we can quantify them in consistent physical units, two similar outages may have significantly differing value in economic terms depending upon who is affected and what services they were using: not every ULE has the same economic impact. Stoker and Dugan (2004) propose an approach they call Economic Reliability Analysis, which is essentially a cost-benefit analysis of alternative options for investing in network reliability. Private costs and benefits of the network operator are the focus of this method, so externalities are not considered. This is an important omission if one is considering the total societal cost of an outage, which is the appropriate metric for a policy-maker.

This problem has previously been addressed in other utilities sectors, where there are five groups of methods used to estimate the economic impact of an interruption of supply:

one can estimate the demand for reliability from market data if different suppliers offer different products in an otherwise comparable market;

one can survey consumers as to their willingness to pay for reliability;

one can study the implications of past interruptions;

one can study the implications of temporal and geographical variations in reliability; and

one can use a production function to infer the value of reliability as an input.

For the electricity sector in particular, the *value of lost load* has received some attention by academic researchers and is employed as a regulatory parameter in some jurisdictions. For example, de Nooij et al. (2007) used linear production functions to estimate the societal cost of electricity supply interruptions in the Netherlands, distinguishing between effects on productive sectors and domestic consumers. Tol (2007) and Leahy and Tol (2010) estimated similar models for Ireland. These papers focused on lost output in productive sectors and on the lost value of leisure time activities in the household sector. Steinbuks and Foster (2010) estimated the demand of small companies for back-up power generators in Africa, which is an indication of the price companies are prepared to pay to avoid blackouts. The estimated value of lost load is used in some markets for assessing the adequacy of reserve generating capacity, which may be set through administrative decisions or by using market mechanisms). One consistent finding for the electricity sector is that the value of lost load varies considerably across different sectors in the economy.

In the gas supply sector, Oxera (2007) and Ilex Energy Consulting (2006) used data on gross value added and input-output analysis of affected sectors to estimate the cost of supply interruptions for industry. Damigos et al. (2009) surveyed Greek households to discover their willingness to pay for security of the natural gas supply used in electricity generation.

Turning to the electronic communications sector, the economic cost of service interruptions has received less attention. The paper by Dynes et al. (2007) examined the effects of a hypothetical firm-specific Internet outage in several industrial sectors. The study combines impact estimates developed on foot of interviews with industry experts with an input-output model of wider economic effects. The vulnerability of supply chains to Internet outages is found to be associated with the nature of the supply chain and the cause of the outage. In particular, sectors such as oil and gas that are heavily reliant on electronic communications for automation of processes could experience significant effects. Other sectors where Internet applications could readily be replaced by phone or fax communications showed much more limited effects. The authors note that a widespread Internet outage affecting more firms could be "much more disruptive" and speculate that increasing use of the Internet for order placement and processing (e.g., using electronic data interchange – EDI) could also increase the likely effects of outages.

Patterson (2002) proposed a method of estimating the cost of telecoms outages for productive sectors based on multiplying working hours lost by employee wages. This approach might have particular advantages in areas such as the public sector, where output is not necessarily priced, so information on the value of lost output may not be available. However, it will tend to systematically understate the value of output losses because it omits the producer surplus.

A multi-country study published by the World Bank found no statistically significant relationship between firms' costs and the number of days without telecommunications services, whereas it did find such effects for electricity and water supply interruptions. Iimi (2008) used firm level data from 26 European and Central Asian countries to examine the marginal impact of infrastructure quality on firms' costs. However, the author suggests that the failure to find a relationship may be due to the generally high reported level of reliability of telecoms services in the sample. With little evidence of telecoms quality problems in the countries studied, it would be difficult to detect a relationship.

A further source of evidence, though not one that has received much research attention, is the history of breaks in undersea fibre optic cables and national Internet shutdowns. Cable breaks (often due to undersea earthquakes or ships dragging anchors through the cable) are not uncommon; for example:

Pakistan lost Internet connectivity in June 2005 due to a cable break; it took 12 days to restore service;

an earthquake in December 2007 broke seven submarine cables south of Taiwan, accounting for 90% of the region's international telecoms connectivity; and

twice in 2008 there were episodes involving multiple cable breaks in the Mediterranean, severely disrupting communications links between Europe and the Middle East (Bilski 2009).

There are also cases in which national governments shut down electronic communications services voluntarily. The OECD (2011) reported an estimated direct cost of $90 million when the Egyptian government cut off Internet and mobile phone services for five days in early 2011. On an annualised basis this equates to about 3-4% of Egypt's GDP. The authors note that this estimate does not include the likely loss of business in the many other sectors affected by the shutdown, including tourism and IT outsourcing, or longer-term effects on foreign direct investment in the IT sector.

There are estimates in the trade press of the cost of service interruptions to specific companies, but without details of the sources and methods used, it is difficult to generalise from them. For example, Sweeney (2000) reported that a 22 hour crash of Ebay's website in 1999 cost $5 million in returned fees and that Amazon lost about $180,000 per hour in revenue when it was off-line. As Cox and Reinert (2003) have pointed out, the main source for such numbers is equipment vendors (or consultancies acting for them) who tend to have an incentive to overstate rather than understate these effects, so we should treat such estimates with caution. Perhaps the main insight one can draw from this literature is that sales lost during an outage may not be fully replaced when service is restored.

Finally, there are studies that do not directly examine economic impact of outages, but consider ways to predict the pattern or extent of an outage or address ways to mitigate its effects. For example, Bent et al. (2009) compare the performance of different types of public switched telephone network simulators in modelling outages in individual local telephone exchanges. The study by Snow et al. (2000) provides a detailed discussion of potential failures at different levels in wireless and mobile networks, and Sithirasenan and Almahdouri (2010) set out a model for improving the robustness of network connectivity in disaster conditions using a wireless network based on WiMAX technology.[1]

In summary, while some authors have considered partial measures of the value of lost telecommunications connectivity, or *ex post* estimates of the impact of specific outages, a comprehensive methodology to assess the value of lost telecoms connectivity has not been published. We address this gap in the literature by building on the approaches used to estimate the cost of lost electricity load.

3. A MODEL FOR ESTIMATING ECONOMIC EFFECTS OF LOST CONNECTIVITY

3.1. Methods

There are several approaches to estimating the economic costs of service disruption. A production function approach can be applied estimating effects on firms, as we do here. It relies on the idea that the network services being studied form an important input for production and that removing the input will halt production or make it less efficient. Simpler applications consider the likely loss of gross value added from a given sector and sometimes extend this to indirect effects by using an input-output model. More sophisticated approaches involve modelling production formally, including the relevant service as an input, to see to what extent it is a complement or substitute for other inputs. A simple variant of this approach is used later in this paper to provide a sample methodology and application for effects of lost connectivity on the productive sector.

Case studies of specific processes, firms or sectors may be used, but these require considerable engineering and commercial detail. It would be costly to assembly a case-based view representative of the whole economy. Stated preference techniques seek to identify the willingness to pay for system security by asking structured survey questions. This approach is most often used for valuing effects on the residential sector, but it requires elaborate data collection that is beyond the current scope of this work. There are no major variations in reliability in Ireland over space, between providers, or between products, so that we cannot use that to estimate the marginal value of reliability. There are no data on duplication and back-up facilities by consumers of telecommunication services, so that route to estimating value is closed too.

Finally, structural modelling with revealed preference evidence can be used to arrive at valuations for both firms and households. This involves obtaining demand and supply parameters from historical data and using them to form a view of how the market values service continuity. We use this approach to arrive at estimates for the residential sector.

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[1] Worldwide Interoperability for Microwave Access

3.2. Issues

Before setting out models for estimating the value of lost connectivity, it is useful to consider some of the salient features of electronic communications services in the face of an interruption. We organise these features under five headings.

Temporal. The cost of lost connectivity obviously varies with the time and duration of the outage, but the temporal pattern may be complex and may differ by sector. Dynes et al. (2007), in their study of Internet outages affecting single firms, found that firms in some sectors could continue production for days before the outage would begin to have a material effect. However, in sectors where an electronic communications breakdown stops orders from being received (e.g., electronic retailing) or time-sensitive transactions from happening (e.g., parts of the financial sector), the cost impact might be immediate. Indeed, if one defines costs broadly to include reputational effects, depending upon the reason for it, an outage might have a very significant instantaneous cost (due to existing firms and potential investors losing confidence in security of supply, followed by lower ongoing costs). The Egyptian outage mentioned earlier might be an example where this type of cost arises.

A second aspect of the temporal dimension is that some costs may be recovered after the outage has ended. For example, a brief Internet outage could lead to queuing of incoming and outgoing messages that would subsequently be delivered. To the extent that these messages were not time sensitive, the delay involved might not involve a permanent cost to the affected parties.

Spatial interdependence. The availability of electronic communications networks and services varies spatially, so the effect of a spatially-limited outage could be quite different depending upon where it occurred. For example, a fixed line network outage that affected Dublin's International Financial Services Centre would have quite a different sectoral incidence than one that affected a sparsely populated rural area.

In common with other utilities sectors, there are particular pieces of electronic communications infrastructure, especially submarine cables, that are bottlenecks in a spatial sense.

Sectoral incidence. The mix of telecoms services and the intensity of use varies considerably across productive sectors, which means that the incidence of a supply interruption can vary considerably across sectors. Sectors also differ in their tendency to use multiple operators, thus gaining some security benefit from redundancy.

Service complementarity and substitutability. One key difference between electronic communications and other network services is the complex web of substitution and complementarity across different services offered by the sector. Some telecoms services can partly or wholly be replaced by others but equally some services use others as essential inputs.

This means that when a particular service is disrupted, we need to consider secondary effects on other electronic communications services that use the affected facilities. For example, some of the backhaul circuits used in a mobile network may be supplied by the fixed line network operator. A fixed line stoppage could thus affect some mobile services.

An equally important feature is that some services may be able to provide partial or complete substitutes for others. A firm losing its Internet service might be able to switch some transactions that were formerly carried out on the Internet to phone or fax, provided those services remain available. Mobile phones might offer partial substitutes for fixed line services, for at least some applications. However, there might still be some costs (in money, time or efficiency) associated with using such alternatives.

Scope for backup arrangements. Like other sectors, telecom security of supply can be improved by the use of backup networks and facilities. For firms, this may involve subscribing to two network operators rather than one, and for households having mobile phone or data connectivity may provide an implicit backup for some fixed line services, and vice versa. The mesh structure of IP networks also provides some degree of additional resilience for networks against certain types of failures.

Backup arrangements in telecommunications cannot be as complete as backup arrangements are in the electricity or gas sectors, however. The problem is that most communication is two way, and there is no way for one side of a conversation to back up connectivity to all possible counterparties. A hospital can back up its electricity supply using a diesel generator, but it is not possible for the hospital to ensure that all people wishing to call or email the hospital can do so when callers' networks are interrupted.

The non-availability of complete backup arrangements also contributes to another feature of the value of lost connectivity. There are some communications applications that would give rise to very high societal costs if the networks that support them were to fail. Emergency services are the most obvious example. Multiple call centres can be used to back up the capacity for receiving emergency calls, but there is no straightforward way to prevent a widespread failure of fixed and mobile networks from stopping people making such calls. Emergency calls also tend to be extremely time-sensitive, so it is not possible to recover the value of a call when services are later restored.

3.3. Modelling Productive Sector Effects

In this subsection, we describe a simple but general method for estimating the impact of a telecoms outage on the productive sector of the economy. This model is similar to models cited above for sectors such as gas and electricity, but it is extended to allow for situations in which some operators or services are down, but others are not.

Suppose telecom operator *m*'s provision of service *j* is down in region *p*. Additional indices denote productive sectors (*i)* of the economy, other operators (*n)* and other services (*k*). We can estimate the societal loss in the productive sector using the following equation:

$$L_{\text{firms}} = \sum_i \left(Y_i R_{ip} D^{f_i} \left(S_{ij} E_{ij} O_{mjp} + \sum_n \sum_k S_{ik} E_{ik} O_{nkp} A_{nkmjp} \right) \right), \forall (n,k) \neq (m,j) \qquad (1)$$

The variables are defined as follows:

L_{firms}	Societal loss attributable to productive sector.
Y_i	Value added per day from sector *i*.
R_{ip}	Share of value added from sector *i* generated in region *p*.
D	Days of outage.
f_i	Parameter describing decay/growth in impact over time in sector *i*.
S_{ij}	Share of firms in sector *i* using service *j* (across all operators).
E_{ij}	Average share of value added lost in firms in sector *i* that use service *j* if this service were to become unavailable.
O_{mjp}	Share of service *j* delivered by operator *m* in region *p*.
A_{nkmjp}	Share of operator *n*'s supply of service *k* that is lost if service *j* provided by operator *m* is down in region *p*.

The equation first multiplies the regional value added from each sector by the duration of the outage, with the latter term being adjusted by a function reflecting the time profile of losses from the outage ($Y_i R_{ip} D^{f_i}$). This captures the output of firms in a sector that may potentially be affected by an outage, taking into account the time profile of the economic harm.

The key question then is how much of a sector's value added is lost due to the outage. We split the potential harm into two channels. One term, $S_{ij} E_{ij} O_{mjp}$, captures the effects on firms in the sector and affected region that directly use the service that has become unavailable. The other term, $\sum_j \sum_n S_{ij} E_{ij} O_{nkp} A_{nkmjp}$, allows for further disruption due to the fact that other telecoms services in the region may have used the service that is down as an input and thus may also be disrupted. For example, a fixed line network outage might lead to outages in a mobile network that relies on some fixed links to connect its base stations to its core network. The total effect across all productive sectors is then added up.

Some of these parameters will be easy to get in most jurisdictions. Data on sectoral value added (Y) should be available in national accounts. Other parameters, such as the share of output lost in a given sector when a service is unavailable (E), are likely to be much harder to obtain. One way to address lack of such data might be to combine these two terms. If there is an observable element of sectoral output that would be completely eliminated if telecoms services were unavailable, it could be used as a proxy for the effect on output. For example, a sector's e-commerce sales would likely be severely reduced if electronic communications were not available. Using a component of sales as a proxy will tend to understate the estimated effect of an outage, but it may provide a reasonable lower bound in the absence of complete data.

The shares of firms using various telecoms services (*S*), supplier market shares (*O*) and the usage of some communications services as inputs by others (*A*) may be captured in surveys by the regulator or industry sources. There is little research on the profile of output losses as outage duration increases for telecoms services (*f*). Until further work is done in this area, simple assumptions or scenario analysis will likely be required.

We have omitted secondary effects on firms that buy from or sell to those that are directly affected. Such effects could be estimated using input-output modelling. However, if the outage is sufficiently widespread, doing this may not add much to the analysis. We also lack data on any backup or disaster recovery arrangements that may be in place. The output protected by such measures could be reflected in lower values of the *E* terms if data were available.

3.4. Modelling Residential Sector Effects

Given that telecoms demand and supply parameters can be obtained from previous research, it is practicable to estimate welfare costs of lost connectivity by calculating forgone consumer and producer surplus.

The cost of lost connectivity to households is thus assumed to be equal to the consumer surplus that they would have received if the service had been available during the relevant period. Consumer surplus is the difference between the price consumers are willing to pay for a good or service and what they actually pay, and it can be estimated using historical data or parameters drawn from studies of the same market in other jurisdictions. See Appendix 1 for details of the calculation.

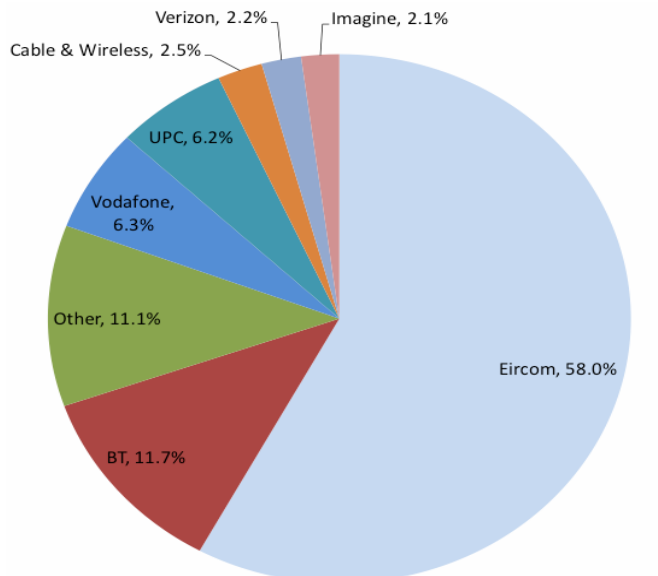
Service providers will suffer a welfare loss in the event of a network outage, and this can be approximated by calculating the lost producer surplus in the period. This is equal to the difference between the revenue obtained for the service and the cost of supplying it. Revenue estimates are straightforward to calculate from data on the average revenue or average price of services, but data on costs are harder to come by.

4. EMPIRICAL EXAMPLE 1: IRELAND'S FIXED LINE NETWORK

We next will specify a worked example of how the loss of connectivity may be valued. The example we consider is a total outage of service for the main fixed line service provider in Ireland, Eircom. This example is chosen partly because the data available on fixed line services is relatively complete. Widespread outages tend to require somewhat fewer detailed assumptions about incidence than more restricted outages. However, it is not a particularly representative example – local network-specific outages would obviously be more common – but it does help illustrate the possible broader economic effects of a network outage. While less common, a widespread outage such as this is also not inconceivable; for example, a serious industrial relations dispute could affect a wide range of network services.

Eircom plc is the fixed line incumbent operator in the Republic of Ireland. It also owns one of the country's four mobile network operators (Meteor) and a mobile service provider (eMobile) that uses the Meteor network. As shown in Figure 1 below, Eircom serves more than half of the fixed line market in revenue terms. However, its share fell from 68% to 58% over the two years prior to Q3 2011 (ComReg 2011).

Figure 1. Fixed line revenue market shares in Ireland, Q3 2011



Source: ComReg (2011), Table 2.1.1.3.

Most of the other operators offering fixed line services in Ireland rely heavily on wholesale network services purchased from Eircom. The main alternative fixed line network is that of UPC, a cable operator.

4.1. Productive Sectors

Since the hypothetical outage is national, we estimate its effects for a single (national) region. Since there is no spatial variation, we do not need to estimate the *R* parameters in Equation 1; by construction, they add to 1 for each sector across the whole country.

Our strategy for estimating the parameters relating to lost economic activity (*Y* and *E*) is to focus on the share of sales from each sector that would normally be made through the Internet or electronic data interchange (EDI). This is different from the approach in Dynes et al. (2007), who consider losses of output regardless of sales channel. Having made the assumption that much voice connectivity remains for businesses during the outage (e.g., via mobile phones), it seems likely that the main areas of dislocation would be for activities involving high volumes of on-line transactions and closely-coupled supply chains, both of which would be difficult to replace in the short run with manual, voice-based processes.

This scenario involves an outage across Eircom's entire fixed line network, including both data and voice services. However, we assume that the Meteor mobile network (owned by Eircom) and other mobile and fixed line operators continue to operate. This is a very conservative assumption, because we know at least some of the backhaul circuits used by Meteor (and undoubtedly others in the market) are provided by Eircom and would thus be affected by the hypothetical outage (ERCIF 2010). In principle, this should be reflected in the *A* parameters in Equation 1. In 2008, Eircom served 84.4% by volume of the market for wholesale terminating segments, the type of leased lines most relevant to this discussion (ComReg 2008a, Table 3). However, there is no published data on the usage of wholesale facilities by operators, so we have no reliable basis for quantifying these effects in the scenario. The fixed narrowband services that competitors supply to businesses are also assumed to be unaffected; that is, we assume that competitors supply their own infrastructure to support these services or that affected firms can use the mobile phone networks to replace lost fixed line voice call capability during the outage. This is another conservative assumption. In effect, we assume all the *A*s to be zero for operators other than Eircom and services other than fixed line when estimating the effects on productive sectors.

To estimate the impact parameters, we combine sector-level data on the sales made via Internet or EDI (CSO 2010, Table 4) with an aggregate estimate of the share of businesses that use Eircom as their sole fixed line service provider (67%) (ComReg 2010a). This amounts to a uniform *O* parameter across industrial and commercial sectors. There is no alternative to making this assumption, since there is no published information on operator market shares at sector level.

The resulting "affected" share of sales for each sector is then applied to value added; that is, we assume that that the loss of value added is proportional to the loss of turnover in each sector. Sectoral value added figures, for which the most recent detailed data relate to 2007, are updated to 2009 using real growth rates for somewhat broader sectors taken from the national accounts.[2]

The results are summarised in Table 1 below. If all sales made by affected customers using Internet or EDI are lost during the outage, the cost would be about €60 million per day. If some portion of these sales were only delayed by the outage and were completed subsequently (i.e., if the *f* parameter were less than 1), this figure would be reduced. Unfortunately, there is no evidence on the likely decay rate for effects of an outage in Ireland.

The largest share of the predicted losses comes from service sectors, especially information and communication firms, but there are also significant losses in some manufacturing sectors.

[2] Sectoral value added data: CSO Output and Value Added (Euros millions) by year, Industry NACE A60 and Activity. Growth in value added calculated from CSO T04 GVA at Constant Factor Cost by Sector of Origin and Gross National Income at Constant Market Prices by Item and Year. See www.cso.ie.

Table 1. Estimates of affected value added by productive sector

Purchases and Sales via E-commerce by NACE Rev 2 Sector, 2010	Enterprises with sales by Internet or EDI (as % of total turnover) (%)	Value added per annum, 2007, €m	Value added per day, 2007, €	Ratio of 2009 value added to 2007, real terms	Daily value added from electronic sales for Eircom-only users, 2009 €
Food, beverages, tobacco, textiles, wearing apparel, leather, wood, printing and paper products (10 to 18)	33	7,382	20,224,658	0.98	4,399,808
Petroleum, chemical, pharmaceutical, rubber and plastic products (19 to 22)	7	14,021	38,413,699	1.20	2,165,027
Other non-metallic mineral products, basic metals and fabricated metal products (23 to 25)	3	2,447	6,704,110	0.98	132,587
Computer, electronic and other equipment, repairs and installation, other manufacturing (26 to 33)	48	7,908	21,665,753	0.77	5,332,527
Construction (F)	1	16,204	44,394,521	0.62	183,923
Wholesale and retail trade; repair of motor vehicles and motorcycles (G), 45-47	18	17,483	47,898,630	0.88	5,075,792
Transportation and storage (H), 49-53	47	3,616	9,906,849	0.88	2,741,206
Accommodation and food service activities (I), 55-56	10	3,955	10,835,616	0.96	700,435
Information and communication (J), 58-63	51	15,550	42,602,740	0.88	12,791,338
Real estate activities (68)	2	13,167	36,073,973	0.62	298,903
Professional, scientific and technical activities (69 to 74)	8	8,455	23,164,384	0.96	1,197,912
Administrative and support service activities (N), 77-82	11	4,084	11,189,041	1.02	844,373
Total Selected services (45 to 63,68 to 74,77 to 82)	26	44,524	121,983,562	0.96	20,501,654
Total Manufacturing (C)	26	7,460	20,438,356	0.98	3,503,143
TOTAL					**59,868,628**

Sources: ERCIF (2010), ComReg (2008a), CSO (2010).

4.2. Residential Sector

Following the approach outlined in Section 3, we assume that the welfare loss from an outage affecting residential consumers is equal to the consumer surplus and producer surplus that would have accrued in the relevant period had the outage not occurred.

To estimate the consumer and producer surplus from fixed line services in Ireland, we divide residential fixed line revenues into three elements: (1) variable usage-related revenue from telephony service, (2) fixed subscription revenue from those with only telephony (not broadband) service, and (3) fixed subscription revenue from those with broadband service. This division is employed to accommodate differing prices among these elements of service. In principle, access and usage probably also have differing elasticities of demand, but for this illustration we use common elasticities for all three components.

We can take some cross-operator effects into account in the residential analysis. We assume that Eircom's network is employed by all xDSL services, either directly as the retail provider or indirectly via provision of wholesale components (bitstream or unbundled local loops). Eircom is the only provider of wholesale xDSL access in Ireland (ComReg 2008b). When the Eircom network hypothetically goes down, we assume it also takes the competitors' residential broadband services that depend upon the network down with it.

For each element of revenue, we estimate the share of users affected by the outage. The usage-related telephony element is based on Eircom and the resellers' share of fixed lines and the share of households with a fixed line. Fixed revenue from those with a fixed line Internet service is based on the share of the population with access to the Internet, the share of users with access from home and the share of users with fixed line access. Fixed revenue from telephony-only users is based on the difference between the share of adults with a fixed line in the home and the share of adults using their fixed lines for Internet service. In each case, the affected proportion is multiplied by the number of households in Ireland to estimate the number of affected households.

The average price per household for each element was obtained from the regulator-run comparison website, callcosts.ie, taking Eircom's list prices without discounts. In the case of usage-related prices, weights were taken from the 140 call PSTN basket in (OECD 2010).

The final assumption needed to estimate the consumer surplus is the elasticity of demand. We draw on estimates from Briglauer et al. (2011), who provide recent estimates of the price elasticity of demand for fixed line telecoms access. Their study uses data from Austria, which like Ireland is a highly developed European market. Two models are reported in this paper, and we use the short run elasticity estimates from both to provide high and low elasticity scenarios: -0.058 and -0.134 (Briglauer et al. 2011, Table 3). (For simplicity, we assume demand to be linear, so Equation A10 in Appendix 1 gives the consumer surplus pertaining to the baseline quantity and price of services.)

The maximum producer surplus is also estimated by multiplying the baseline price and quantity. There is little public information on the cost of providing service, so we do not attempt to further quantify the producer surplus. We show the main parameters and results in Table 2.

Table 2. Estimates of lost consumer and producer surplus for residential sector outage

Fixed revenue – those with Internet service	**Low elasticity scenario**	**High elasticity scenario**
Share of population with access to Internet[(a)]	77%	77%
With access from home[(e)]	95%	95%
Share of users with fixed line Internet (DSL, IDSN or PSTN) [(e)]	49%	49%
Number of households in Ireland[(i)]	1,626,328	1,626,328
Residential users of this service	582,933	582,933
Average monthly bill €[(e)]	28	28
Total monthly bill €	16,322,121	16,322,121
Price elasticity of demand[(d)]	-0.058	-0.134
Total consumer surplus per month €	140,707,936	60,903,435
Total loss of consumer surplus per day €	**4,626,014**	**2,002,305**
Maximum producer surplus loss per day €	**536,618**	**536,618**
Fixed revenue - telephony service only	**Low elasticity scenario**	**High elasticity scenario**
Share of adults with fixed line in home[(e)]	71%	71%
Share of users with fixed line Internet (DSL, IDSN or PSTN) [(e)]	49%	49%
Share of adults using fixed line for telephone only[(e)]	22%	22%
Number of households in Ireland[(f)]	1,626,328	1,626,328
Residential users of this service	357,792	357,792
Average monthly bill €[(g)]	25	25
Total monthly bill €	8,944,804	8,944,804
Price elasticity of demand[(h)]	-0.058	-0.134
Total consumer surplus per month €	77,110,379	33,376,134
Total loss of consumer surplus per day €	**2,535,136**	**1,097,298**
Maximum producer surplus loss per day €	**294,076**	**294,076**
Usage-related revenue - telephony service	**Low elasticity scenario**	**High elasticity scenario**
Eircom and resellers' share of fixed lines[(f)]	92%	92%
Total households[(f)]	1,626,328	1,626,328
Share of adults with fixed line in home[(f)]	71%	71%
Users of this service	1,062,317	1,062,317
Average monthly bill €[(g)]	41.50	41.50
Total monthly bill	44,086,174	44,086,174
Price elasticity of demand[(h)]	-0.058	-0.134
Total consumer surplus per month €	380,053,226	164,500,650
Total loss of consumer surplus per day €	**12,494,901**	**5,408,241**
Maximum producer surplus loss per day €	**1,449,408**	**1,449,408**

Notes: [(a)] ComReg (2010b), pp. 7, 9, 34 and 36; [(b)] 2011 projection from ESRI demographic model used for projections in Bergin et al. (2010); [(c)] calculation based on Callcosts.ie data and OECD weightings, as mentioned in the text of this article;[(d)] drawn from Briglauer et al. (2011), also discussed in the text; [(e)] CSO (2010); [(f)] ComReg (2010a), p. 9; [(g)] sectoral value-added data: CSO Output and Value-Added (Euros millions) by year, Industry NACE A60 and Activity, with growth in value-added calculated from CSO T04 GVA at Constant Factor Cost by Sector of Origin and Gross National Income at Constant Market Prices by Item and Year, downloaded from www.cso.ie; [(h)] Briglauer et al. (2011), Table 3; (i) 2011 projection from ESRI demographic model used in Bergin et al. (2010).

The total estimated economic cost for residential lost connectivity ranges between €8.5 and €19.6 million per day of consumer surplus, and up to €2 million per day (but probably less) of producer surplus. The relatively wide range in the consumer surplus estimates is due to their sensitivity to the assumed price elasticity of demand. Both elasticities we have used in our scenarios are low (i.e., as often found in the literature, telecom access services are inelastic with respect to price), but even a small difference in the precise elasticity used leads to a significant difference in the resulting consumer surplus estimate.

4.3. Retail Payments

A hypothetical fixed line outage could cause considerable disruption to retail payments networks and might affect some automated teller machines (ATMs). System wide risk from operational breakdowns is seen as a major concern by some banking regulators (Sullivan 2007).

Debit card authorisation, in particular, relies on fixed line telephony to connect many small retailers to central payment authorisation systems. There is little public information on how ATMs connect to the accounting systems of the banks that offer them, but it seems likely that fixed line connections are used in many cases. If an outage disrupted authorisation of debit card transactions and caused outages among significant numbers of ATMs, this would make it more difficult for retail customers to make purchases and might deter or delay a portion of retail sales that would otherwise have been made.

Without knowing more about the usage of fixed line services by payments and cash networks, it is hard to quantify this effect. We do know that debit card transactions in Ireland totalled €31.5 million per day in 2010 and ATM withdrawals totalled €61.1 million per day (IPSO 2011a, 2011b). In addition, €31 million per day of sales were made by credit card. In principle, some of these transactions might be affected as well, because electronic “chip and pin” authorisation has become almost universal in Ireland. However, retailers might be able to revert to manual signature-based authorisation if chip and pin systems were affected by a communications outage. Thus, these figures represent upper bounds for the daily impact that our hypothetical outage might have on retail sales.

4.4. Other Applications with Limited Frequency of Use But High Societal Value

Methods commonly used to estimate the value of lost connectivity to households tend to focus on the value to the average household. However, particularly in the electronic communications sector, some uses have low frequency but very high value, and often these same uses have a societal value that exceeds their private value. The obvious example is calls to emergency services. These will be infrequent for any given household and are therefore unlikely to have a significant effect on a household’s willingness to pay for service. However, the average societal benefit from this class of calls is undoubtedly much higher than the average for all calls.

To quantify the value of lost connectivity from uses such as this, a more application-specific approach is required. For example, there is evidence from emergency services trials of a negative association between emergency services response times and cardiac arrest survival rates, see, for example, Nichol et al. (1996). The speed with which the initial call is made and handled contributes to the response time. However, we lack data on the frequency and societal value of emergency calls in Ireland, so we can only make the qualitative point that this source of lost value might be significant.

In the event of a total outage of fixed line services, if mobile networks remain in full or partial operation, this will help to reduce the possible harm on emergency services. The incidence of the outage on callers would be restricted to households without a mobile phone, and some of these might only face a delay rather than a total inability to make calls (i.e., if neighbours or passers-by had a mobile phone). However, we have earlier noted that some mobile traffic is likely to be conveyed over fixed line backhaul circuits that might be affected. In addition, we note that the Tetra Ireland digital radio service used by Ireland's emergency services is partly owned by the fixed line operator Eircom and uses Eircom's fixed line circuits for at least some of its operations (ERCIF 2010).

4.5. Combined Economic Cost of Lost Connectivity in National Fixed Line Outage

The estimated aggregate economic cost in this scenario comes to €70-80 million per day for the production and residential sectors, plus up to €2 million worth of producer surplus from residential services. We can illustrate the scale of the total impact by expressing it as a share of the population: it equates to roughly €42-50 per Irish household for each day of outage. This compares to an average revenue per retail fixed line subscription of about €2.50 per day.[3] There are also potentially large losses relating to the effects on debit card payment systems and ATM networks that could result in reduced or deferred expenditures by consumers and SMEs. Transactions using these two types of systems total over €90 million per day; however, the likely economic losses from this source are impossible to estimate with the available data.

Our estimate omits the costs arising from the effects of a network outage on services with a societal value substantially higher than that captured in their retail prices, such as emergency services, and possible long-run effects such as reputational damage that may depend more upon the reason for the outage than its scale.

5. EMPIRICAL EXAMPLE 2 – FIXED LINE SERVICES FROM LOCAL EXCHANGES

This example uses the same methods to estimate the effect of a different sort of network outage: one in which a limited geographical area is affected. This is a more common type of outage than the national one described above. It might, for example, arise if a local telephone exchange were to be taken out of service due to a fire or flood. The potential impact of lost connectivity to sectors that are not heavily involved in e-commerce but which rely on telecoms for their efficient functioning, such as the public service, is also likely to be significant but more difficult to measure.

In this section, we will illustrate the effects of an individual outage halting service from any one of seven selected local exchanges. The areas in which these exchanges are located are briefly characterised in Table 3 below. The focus is particularly on exchanges which serve sectors that have a high Internet or EDI share as identified in Table 1 above, second column.

[3] Total fixed line revenue divided by the number of fixed market retail subscriptions in the 4th Quarter, 2010 (ComReg 2011, pp. 6 and 22).

Table 3. Fixed line local exchange areas used in examples

Local Exchange Example	Area description
1	Transport hub
2	Service sector concentration
3	Service sector concentration
4	Electronics manufacturing area
5	Electronics manufacturing area
6	Electronics manufacturing area
7	Residential area with significant business activity, especially in service sector

The geographical specificity of these hypothetical outages requires us to identify how much economic activity and how many residential customers are located in specific areas. For the productive sector effects, this involves estimating values for the R_{ik} parameters in Equation 1 above, which we did not need to estimate in the national example. Since areas differ widely in their mix and intensity of production and their level of housing density, it is natural to use geographical information system (GIS) data to assist with this part of the exercise.

GIS datasets are available for Ireland (and most other countries) and can be combined to perform these tasks. We use three new data sets in addition to those discussed earlier:

In Ireland, a Census of Population is carried out every five years, and for the 2006 Census the data identifies not only the place where people reside but (for those at work) where they work. Using this data Morgenroth (2009) established an economic geography of Ireland covering the location of employment by two-digit NACE (Rev 1) sector at the most spatially disaggregated level (so called Electoral Divisions). Electoral divisions are currently the smallest spatial unit for which data is collected for the entire country. There are just over 3,400 electoral divisions in Ireland and they range in area from 5 hectares to just under 13,000 hectares, in population from 39 persons to just over 16,000 persons, and in employment from 2 and just over 21,000 jobs.

A GIS map showing the area served by each fixed line local exchange in Ireland.[4]

In addition to the employment data which is available for Electoral divisions, the exact location of each business and residential address in Ireland is held in a database by the postal operator An Post (it is known as the Geodirectory), and the version we use relates to July 2008.

Although the data sets used in this section are not precisely matched the processes they represent (i.e., the spatial distributions of business and residential locations) change slowly, so they should provide a reasonable approximation, and therefore serve to illustrate the potential impact. [5]

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[4] We are grateful to Eircom and the Irish communications regulator ComReg for access to this dataset.

[5] The Census data used is for 2006 while the other data is more recent and the Census data is for NACE Rev 1 sectors while our other data is classified using the more recent NACE Rev 2 classification. With regard to the industrial classification a close match with NACE Rev 2 is achieved by applying a concordance table.

5.1. Productive Sectors: Affected Shares

We use the location of employment for each sector as a proxy for the location of economic activity, since the latter is not measured on a sufficiently geographically disaggregated basis. This implies an assumption that the output per worker is uniformly distributed across the country for each sector. This approach has previously been used to impute regional emissions (Tol et al. 2009) and to estimate the spatial incidence of carbon taxes (Leahy et al. 2009), for example.

To see what share of a sector's economic activity is located in an area affected by an outage, we first tag each business address in the area of the relevant local exchange.[6] We then calculate the proportion of affected addresses in the total number of addresses in the electoral divisions that overlap with the exchange area. These affected proportions are multiplied by the share that employees in the ED make up in the total employees for a given sector nationally (as a proxy for economic output).

Assuming local exchange area *x* is denied fixed line service by the outage, Equation 2 below gives the affected share of output for sector *i* and electoral division *k*:

$$R_{ik} = \frac{W_{ik}}{\sum_k W_{ik}} \left(\frac{B_x \cap B_k}{B_k} \right) \qquad (2)$$

where *W* is the number of employees and *B* is the number of business addresses.

The results of this analysis are illustrated for three sets of sectors in Table 4 below.

Table 4. Share of national employment in example areas for selected sector groupings

Exchange area	Manufacture of elec-trical/optical equipment (NACE R1.1 30-35) %	Transport and storage (NACE R1.1 60-63) %	Services, including communications (NACE R1.1 64-72) %
1	1.3	8.4	0.6
2	0.2	2.2	3.2
3	0.6	0.4	3.5
4	6.7	0.7	0.7
5	7.4	1.0	1.4
6	3.0	0.5	0.7
7	0.1	0.1	0.5

This table shows that there are small areas in Ireland accounting for a significant share of employment (and thus by assumption, output) in sectors that make substantial use of electronic communications and commerce. If an exchange in such an area were to go down, the value of affected activity might be correspondingly large. Table 5 below shows the relevant estimates, arrived at by multiplying the national estimates arrived at in the previous section (Table 1).

[6] GIS analysis was carried out in ArcMap 10.

Table 5. Value of productive sector activity that might be affected by an outage in the relevant local exchange (€ per day)

Exchange area	Estimated loss per day (€)
1	369,000
2	483,000
3	493,000
4	465,000
5	501,000
6	226,000
7	789,000

The impact of lost connectivity identified in these illustrative examples will be biased downward as the intangible impact to the reputation of Ireland or a specific area within Ireland would also need to be considered. This is particularly relevant in a small open economy like Ireland where foreign direct investment is important as a source of employment and output. For example, in the computer electronics, other equipment, repairs and installation other manufacturing (NACE 26 to 33) sector 91% of Ireland's gross value added (derived from CSO 2009a) is accounted for by foreign multinational firms. Likewise, 84% of gross value added in the information and communications sector is produced in foreign owned firms (derived from CSO 2009b).

5.2. Residential Sector: Affected Share

Identifying the share of residential customers in the country affected by a specified outage is relatively straightforward using these data. We merged the maps of local exchange areas with the locations of residential addresses, and divided the number of residential addresses in each area by the national total. The shares vary widely, from close to zero in areas with few residences up to 1.42% of the national population in the most densely populated exchange area.

Table 6. Share of national residential addresses in example areas

Exchange area	Share of national residential addresses (%)
1	0.000941
2	0.0315
3	0.161
4	0.304
5	0.465
6	0.685
7	1.42

These shares can be applied directly to the national totals estimated in the preceding section, if we make the further assumption that resident ial demand for electronic communications services is homogeneous across areas in Ireland. The results are shown in Table 7 below.

Table 7. Estimates of residential consumer surplus and maximum producer surplus loss for an outage in selected local exchanges (€ per day)

Example exchange	Loss of consumer surplus (low elasticity scenario)	Loss of consumer surplus (high elasticity scenario)	Maximum loss of producer surplus
1	185	80	21
2	6,199	2,683	719
3	31,672	13,709	3,674
4	59,685	25,834	6,923
5	91,460	39,587	10,609
6	134,553	58,239	15,608
7	279,992	121,191	32,479

5.3. Combined Economic Cost of Lost Connectivity for a Single Exchange

The estimated aggregate economic cost is obviously going to be much smaller for a hypothetical outage in one exchange than in a national outage scenario. Nevertheless, the figures are not insignificant. For the most important local exchange we analysed, economic losses from an outage could be as high as €1.1 million per day (see Table 8 below). To arrive at these estimates we included the estimated productive sector cost and, for the residential sector, the maximum loss of producer surplus and the low elasticity scenario for the loss of consumer surplus.

Table 8. Estimated total economic cost of outages in selected local exchanges (€ per day)

Example exchange	Estimated total economic cost
1	370,000
2	490,000
3	528,000
4	532,000
5	603,000
6	376,000
7	1,100,000

As with our estimates for a national outage, these local estimates omit possible further costs associated with disruption to payment systems, inward investment and high value applications such as emergency services. However, they also omit possible protective measures by telecoms users such as redundancy in network services or use of disaster recovery sites. These are likely to be more important in the case of outages with a restricted geographical footprint such as the ones discussed in this section than in more widespread outages.

6. CONCLUSION

We have argued that the effects of incremental changes in the output of a service sector are normally much more relevant for policy than the total size of the sector. In particular, such effects are relevant to areas of policy such as the formulation of universal service obligations, subsidies for rural service provision, interconnection rules, facilities for dispute resolution among suppliers and continuity of service arrangements.

This paper has set out an approach to defining and measuring one such form of incremental change: the value of lost connectivity in the electronic communications sector, which is analogous to the value of lost load in the electricity sector or the cost of supply interruptions in the gas sector. In doing this, we have tried to allow for effects that may vary across several dimensions – temporal, spatial, sectoral and service complementarity and substitutability. Practicability given available data is also an important consideration.

To illustrate how the method may be applied, we have estimated the value of lost connectivity arising from an outage affecting the main fixed line network operator in Ireland and outages in several individual Irish local exchanges. Despite adopting very conservative assumptions for several impact variables, the likely aggregate cost of a national fixed line outage seems to be substantial: €42-50 per household per day. By way of comparison, Leahy and Tol (2010) estimate an economic cost of about €103 per capita for a national gas interruption in Ireland on a midweek winter day.

These estimates omit some important cost items we could not quantify due to data limitations. Payment systems might be affected by a widespread outage, leading to reductions or deferral in expenditures. Some applications with high societal value such as emergency services might be affected. The communications-intensive sectors in Ireland are dominated by multinational firms, so there are additional unquantifiable risks from possible deterrence of foreign direct investment.

The exchange-level example demonstrates that it is possible to add a spatial dimension to estimates of telecoms outage effects using data that should be readily available in most countries: GIS data on exchange locations and on the locations of business and residential premises, along with census data on the geography of employment by sector. In Ireland, we find that communications-intensive sectors are subject to substantial geographical concentration, which means that an outage affecting an important local exchange could have substantial economic effects. In the examples we modelled, quantifiable economic losses from a single exchange outage could be as high as €1.1 million per day assuming the affected firms have no backup facilities outside the exchange area.

Because it can assess the economic impact of lost connectivity for individual exchanges, our approach could be used to carry out a societal risk assessment of exchanges and help identify those that should be given highest priority for additional measures to reduce the likelihood of lost connectivity (e.g. enhanced security, flood prevention, backup arrangements, etc.). More generally, identifying the broader economic costs of lost connectivity is a key requirement to assess the economic value of risk reduction measures.

To our knowledge, this is the first study to estimate the broader economic effects of a loss of communications service at national or regional level. It shows the practicability of making such an estimate for a small developed economy, but it also highlights some data and policy gaps.

EU law recognises the objective of ensuring continuity of public telephony services and, in particular, emergency services, in the face of "... catastrophic network breakdown or in cases of force majeure ...". Our research suggests that similar consideration should be given to ensuring continuity of public data services such as broadband access, which is of increasing economic and social importance. Backup and redundancy of key components such as emergency service call centres can help protect service continuity, but due to the nature of two way communications they cannot offer a full guarantee of service in cases where other important network services or facilities become unavailable.

Data availability imposed several limitations on the coverage and precision of our examples. Further research is needed into the time profile of costs from a telecoms network outage in different sectors of the economy. There is little published information (in Ireland, at least) on the use of operators' networks by other operators, which is vital for estimating secondary effects of an outage. We also found little published information on the prevalence of off-site backup facilities, which would be important for assessing local failures in particular. An issue specific to the Irish data was that some published data sources use different NACE classifications than others, making sector matching more difficult than it needs to be.

Analysing some domains in which significant effects seem likely such as payment systems and emergency services requires sector-specific data. Published information may not suffice in such cases, but regulatory bodies may have access to better data.

It would be interesting to apply a method such as this to an actual loss of connectivity event, although with most economic data collected nationally on an annual or quarterly basis and most outages much shorter and more local than that, some imputation is always likely to be necessary. Input-output modelling could be used to take account of effects on sectors supplying intermediate goods. It would also be interesting to combine the estimates of the value of lost connectivity with the probability of interruptions and compare these to estimates of the cost of reducing the interruption frequency.

ACKNOWLEDGMENTS

This study was funded by the Economic and Social Research Institute from its own resources.

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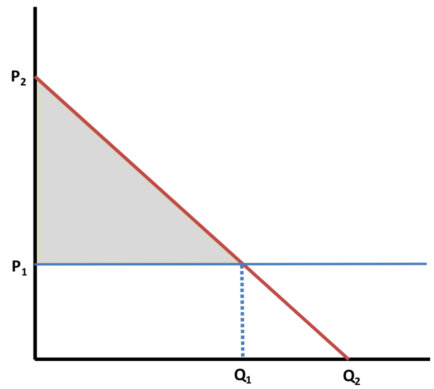
Appendix 1. Derivation of consumer surplus for residential effects



Elasticity of demand (at P_1, Q_1):

$$\varepsilon = \frac{\partial Q}{\partial P}\frac{P_1}{Q_1} \tag{A1}$$

$$\frac{\partial P}{\partial Q} = \frac{P_1}{\varepsilon Q_1} \tag{A2}$$

Inverse linear demand curve:

$$P_1 = P_2 + \frac{\partial P}{\partial Q} Q_1 \tag{A3}$$

$$P_1 = P_2 + \frac{P_1}{\varepsilon Q_1} Q_1 \tag{A4}$$

$$P_2 = P_1 + \frac{-P_1}{\varepsilon} \tag{A5}$$

$$P_2 = \left(1 - \frac{1}{\varepsilon}\right) P_1 \tag{A6}$$

Consumer Surplus (at P_1, Q_1):

$$CS = \frac{1}{2} Q_1 \left(P_2 - P_1\right) \tag{A7}$$

$$CS = \frac{1}{2} Q_1 \left(\left(1 - \frac{1}{\varepsilon}\right) P_1 - P_1\right) \tag{A8}$$

$$CS = \frac{1}{2} Q_1 \frac{-1}{\varepsilon} P_1 \tag{A9}$$

$$CS = \frac{-1}{2\varepsilon} Q_1 P_1 \tag{A10}$$

To illustrate this with some parameter estimates, consider the consumer surplus for those with Internet service in the low elasticity scenario in Table 2 above. The consumer surplus per month is estimated using:

$$CS = \frac{-1}{2(-0.058)}(582{,}933)(€28) = €140{,}707{,}936 \tag{A11}$$

Highlights for Estimating the value of lost telecoms connectivity
by Sean Lyons, Edgar Morgenroth and Richard S.J. Tol

> Economic cost from potential telecoms outages is relevant for policymakers. > We describe a practical method for estimation. > This is applied to hypothetical outages of main fixed line network in Ireland. > Quantifiable daily economic cost is estimated at €42-50 per household. > Economic costs from single exchange outages can be up to €1.1 million.