Testimony of Professor Jerry Hausman

April 7, 1998

A. Please state your name and business address.
Q. My name is Jerry A. Hausman. I am the MacDonald Professor of Economics at the Massachusetts Institute of Technology in Cambridge, Massachusetts, 02139.

Q. Do TSLRIC and TELRIC estimates correctly capture the long run costs faced by Pacific?
A. No, they omit three categories of costs which must be taken into account, or Pacific will not be able to cover its costs. The first category is that Pacific must also cover its shared and common costs. These shared and common costs are omitted from a TELRIC calculation.\(^1\) Almost all economists and the FCC agree that shared and common costs must be included in prices set for unbundled elements so that an ILEC can recover its costs of investment. I leave the calculation of this factor to other witnesses.

Q. What is the second category of costs which TELRIC calculations miss?
A. The TSLRIC and TELRIC calculations that I have described omit the change in price of capital goods, which is an element of economic depreciation, used to provide the service. This type of depreciation is not captured in the depreciation rates included in Pacific’s TELRIC studies. I now describe the efficient investment rule in a competitive, unregulated industry to demonstrate the problem with the omission of price changes in capital goods in the TELRIC calculation. Consider the value of a project under no demand uncertainty with a risk adjusted discount rate of \(r\) and assumed known exponential economic depreciation at rate \(\delta.\)\(^2\) This assumption on depreciation can be thought of, in part, as the price of the capital decreasing over time at this rate due to technological progress. Assume that price, net of the effect of economic depreciation of the capital goods, is expected to decrease with growth rate \(-\alpha.\)\(^3\) The initial price of output is \(P.\) The value of the project is:

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1. From this point on I will refer to TELRIC with the understanding that my remarks also refer to TSLRIC.
2. The assumption of exponential depreciation rates means that a constant percentage amount of depreciation occurs in each period and is commonly used in economic models.
3. This factor arises due to changes in demand and changes in total factor productivity.
where $\lambda = r + \alpha$. The formula can be understood as follows: (1) the term $(\lambda \exp(-\lambda t))$ takes account of the present discounted value adjustment which allows for the time value of money earned in the future and the risk of the project and also of the effect of decreasing price of the service $\alpha$ (2) the term $(1 - \exp(-\delta t)/\delta)$ accounts for the economic depreciation at constant rate $\delta$. Note that $\delta$ is added to the expression to account for the economic depreciation, including the decreasing price of capital goods. This term, omitted from most TELRIC calculations, accounts for technological progress in equipment prices, which is one economic factor that leads to lower prices over time. Thus, the value of the project in equation (1) is the initial price $P$ divided by $\lambda + \delta$ which account for the usual discount term $r$ plus the effect of expected change in price $\alpha$ and the expected economic depreciation $\delta$. The "traditional" and incorrect TELRIC formula only uses $r$ in the denominator and omits the effect of expected price changes and economic depreciation. But expected price changes and economic depreciation are important factors in telecommunications that arise from technological advances and increasing competition.

Q. What effect on the economically efficient level of investment will omission of economic depreciation have?

A. Suppose that the cost of the investment is $I$. The rule for a competitive firm is to invest if the value of the project is greater that the cost of the investment or $V(P) > I$. Equivalently from equation (1), $P > (\lambda + \delta) I$, so that the cost of capital depends on $r$, the interest rate, and the expected change in price and expected economic depreciation. The economic interpretation of this expression is that the price net of variable cost (i.e. price minus variable cost) must exceed the cost of capital, which includes the change in price of the capital good to make the investment worthwhile.\(^4\) Note that the net change in the output price and the price of the capital good both enter the efficient investment rule. If the price change of the capital good is omitted from the calculation, i.e. the formula uses $\delta = 0$, the TELRIC computed price will be too low. The ILEC will not be able to recover the cost of its investment because a competitive firm can begin to provide the service in the future and it will have a lower investment cost and thus charge a

\[ V(P) = \int_0^\infty \lambda \exp(-\lambda t) P \frac{1 - \exp(-\delta t)}{\delta} \, dt = P/(\lambda + \delta) \]  

\(^4\) For simplicity, I am assuming only capital costs and no variable costs in this calculation. Variable costs can be included by reinterpreting $P$ to be price minus variable costs which will lead to the same solution.
lower price. The ILEC will be forced by competition to decrease its price, and thus will not recover its cost of investment. The ILEC will then not invest at the economically efficiency level because its knows it will not be able to recover its investment cost in the future.

Q. Can economic depreciation be important from a quantitative viewpoint in a correct TELRIC calculation?
A. Most TELRIC calculations do not include $\delta$, but instead assume that the price of capital goods does not change over time. This assumption is extremely inaccurate. Take a Class 5 Central Office Switch (COS) for example. Nine years ago an AT&T Class 5 switch (5-ESS) was sold to a BOC for approximately $200 per line (J. Hausman and E. Kohlberg, in J. Hausman and S. Bradley, Future Competition in Telecommunications, Harvard Business School Press, 1989, p. 204). Today, the prices of new AT&T 5-ESS switches and similar NTI switches are in the $xx per line or lower range. A BOC who paid $200 per line made the efficient investment decision when it purchased its COS. But TELRIC, by omitting economic depreciation due to technological progress, leads to a systematically downward biased estimate of costs. Indeed, I have estimated the rate of price decrease of central office switches to be near $yy\%$ per year over the past five years, while the cost of fiber optic carrier systems has decreased at approximately $zz\%$ per year over the same period. The omitted economic factor $\delta$ can be quite large relative to $r$, the traditional ILEC cost of capital used by regulators, for telecommunications switching or transmission equipment due to technological progress. Thus, omitting the economic factor $\delta$ can lead to a significant underestimate of TELRIC. Prices set on the basis of the underestimated TELRIC will be too low, and the ILEC will be required to sell its unbundled elements at a price below their economic cost. This outcome will cause an inefficiently low level of investment by an ILEC because it will not recover its cost of investment. For existing plant and equipment the regulators will be requiring the ILEC to sell unbundled elements below the economic cost which can create financial problems for the ILEC and will discourage future investment because the ILEC will not have a credible commitment from the regulator that it will recover the cost of new investment.

Q. What is the third factor which TELRIC calculations omit?
A. TELRIC calculations recognize the fixed nature of much investment in telecommunications networks, but TELRIC calculations fail to recognize the sunk and irreversible nature of many investments in

5. This price is for a replacement (changeout) of an existing switch.
telecommunications networks. TELRIC makes no allowance for the sunk and irreversible nature of telecommunications investment, so that it adopts incorrectly the perfect contestability standard. The distinction between "fixed" and "sunk" is crucial.

Q. Please explain the difference between a fixed cost and a sunk cost.
A. A fixed cost is a cost which must be incurred in a given period to produce a good or service. However, in the next period if the service is not produced, the fixed cost is not incurred. To the contrary, a sunk cost cannot be avoided in the next period; indeed, the sunk component of the investment cannot be recovered. Thus, investment which is fixed but not sunk can be costlessly redeployed the next period to another production process. An example is a PC which can be reused. However, specialized software which is written for the particular project and cannot be reused in another project would be an example of a sunk cost. In telecommunications much network investment is sunk such as investment in fiber optic networks or additional residential loops.

Q. Does failing to consider the effect of sunk investments create an economic problem in TELRIC calculations?
A. Yes. TELRIC calculations provide the incorrect economic incentives for efficient investment once technological and economic uncertainty exist in the presence of sunk and irreversible investment. Fixed assets may become un-redeployable, violating the costless exit assumption of the fixed, but not sunk, investment cost assumptions of TELRIC models, which depend on the perfect contestability assumption.

Q. Can the sunk and irreversible nature of much of the telecommunications network be quantitatively important?
A. Yes, it can make a large difference in the risk adjusted cost of investment. TELRIC calculations make the following assumptions: (1) the investment is always used at the designed capacity, (2) the demand curve does not shift inwards over time (i.e. competing products or services do not arise which create decreased demand), and (3) a new technology does not appear that leads to lower cost of production. Of course, these conditions are unlikely to hold true over the life of the sunk investment. Thus,

6. A fixed cost is a cost which does not vary with the level of output during a given period.
7. Perfect contestability assumes that all capital costs are fixed and that no capital costs are sunk. Thus, it assumes the ability of firms to enter and exit an industry costlessly. For a further discussion of perfect contestability in the context of telecommunications networks, see J. Hausman, "Valuation and the Effect of Regulation on New Services in Telecommunications", op. cit.
8. The examples of Centrex services demonstrate that this assumption need not hold.
uncertainty needs to be added to the calculation of sunk investment costs because of the sunk nature of much the investment in telecommunications networks.

Q. Please demonstrate the qualitative effect that sunk investment can have on correct economic calculations.

A. I now account for the sunk nature of the investment and its interaction with fundamental economic and technological uncertainty. Given the fundamental uncertainty and the sunk nature of the investment, a "reward for waiting" occurs because over time some uncertainty is resolved. The uncertainty can arise from at least 4 factors: (1) Demand uncertainty, (2) Price uncertainty, (3) Technological progress (input price) uncertainty, and (4) Interest rate uncertainty. These 4 factors lead to a "markup" factor which increase the "cost of capital" in the investment decision which I derived in equation (1). Now the fundamental decision rule for investment changes to:

\[ P^S > P \]  

where \( \beta_1 > 1 \) so that \( m = \beta_1/(\beta_1 - 1) > 1 \). The parameter \( \beta_1 \) takes into account the sunk cost nature of the investment coupled with inherent economic uncertainty. Parameter \( m \) is the markup factor required to account for the effect of uncertain economic factors on the cost of sunk and irreversible investments. Thus, the critical cut off point for investment is \( P^S > P \) from equation (1).

Q. Please demonstrate the quantitative effect that sunk investment can have on correct economic calculations.

9. The FCC incorrectly assumed that taking into account expected price changes in capital goods and economic depreciation is sufficient to estimate the effect of changing technology and demand conditions; see the FCC "First Report and Order", para. 686. Thus, the FCC implicitly assumed that the variances of the stochastic processes which determine the uncertainty are zero, e.g. that no uncertainty exists. Under the FCC approach the values of all traded options should be zero (contrary to stock market fact), since the expected price change of the underlying stock does not enter the option value formula. It is the uncertainty related to the stochastic process as well as the time to expiration which gives value to the option as all option pricing formulae demonstrate, e.g. the Black-Scholes formula. The inventors of the Black-Scholes formula have been awarded the Nobel Prize in economics this year.

10. I do not derive this equation here since it is the solution to a differential equation. For a derivation see e.g. A. Dixit and R. Pindyck, Investment Under Uncertainty, Princeton U.P. 1994, pp. 254-256, pp. 279-280, and p. 369. The parameter \( \beta_1 \) depends on the expected risk adjusted discount rate of \( r \), expected exponential economic depreciation \( \delta \), and the net expected price \( -\alpha \), and the amount of uncertainty in the underlying stochastic process.
A. To see how important this consideration of sunk costs can be, I evaluate the markup factor $m$. This markup factor accounts for the 4 sources of economic uncertainty that I discussed in the previous questions: (1) Demand uncertainty, (2) Price uncertainty, (3) Technological progress (input price) uncertainty, and (4) Interest rate uncertainty. The parameters $\beta_1$ and $m$ depend on a number of economic factors. It can be demonstrated that as uncertainty increases, i.e. the variance of the underlying stochastic process, $\beta_1$ decreases and the $m$ factor increases. Thus, as uncertainty increases the markup factor, $m$ increases, as expected since $m$ accounts for uncertainty. Also, as $\delta$, economic depreciation, increases, $\beta_1$ increases which means that the $m$ factor decreases. As $r$, the cost of capital, increases $\beta_1$ decreases so that the $m$ factor increases. Using parameters for LECs and taking into account the decrease in capital prices due to technological progress and because the expected change in (real) prices of most telecommunications services is also negative given the decreasing capital prices, I calculate the value of $m$ to be approximately 3.2-3.4.\footnote{Because of the expected decrease in the price of capital goods, even if the standard deviation of the underlying stochastic process were 0.25 as high as a typical stock, the markup factor would still be 2.1. For a standard deviation 0.5 as high, the markup factor is 2.4. I have also explored the effect of the finite expected economic lifetimes of the capital investments in telecommunications infrastructure. Using expected lifetimes of 10-15 years leads to only small changes in the option value formulas, e.g. for a project with a 12 year economic life the markup factor changes by only 5%.

\footnote{R. MacDonald and D. Siegel, "The Value of Waiting to Invest", Quarterly Journal of Economics, 101, 1986, pp. 707-728, and Dixit and Pindyck, op. cit., p.153) calculate $m = 2$ so that, for instance, $V_S = 2I$ for a non telecommunications example. This equation means that the investment cost must be increased by a factor of two because of the effect of uncertainty on the cost of sunk and irreversible investment. I calculate a larger factor mainly because of the equipment price decreases which take place in telecommunications.

\footnote{Pacific estimates that these costs are potentially stranded which is a particular type of sunk investment in terms of economic analysis.}}

Thus, a markup factor must be applied to the investment cost component of TELRIC to account for the interaction of uncertainty with sunk and irreversible costs of investment. Depending on the ratio of sunk costs to fixed and variable costs the overall markup on TELRIC will vary, but the markup will be significant given the importance of sunk costs in most telecommunications investments.\footnote{R. MacDonald and D. Siegel, "The Value of Waiting to Invest", Quarterly Journal of Economics, 101, 1986, pp. 707-728, and Dixit and Pindyck, op. cit., p.153) calculate $m = 2$ so that, for instance, $V_S = 2I$ for a non telecommunications example. This equation means that the investment cost must be increased by a factor of two because of the effect of uncertainty on the cost of sunk and irreversible investment. I calculate a larger factor mainly because of the equipment price decreases which take place in telecommunications.

\footnote{Pacific estimates that these costs are potentially stranded which is a particular type of sunk investment in terms of economic analysis.}}

Q. What effect would the markup have on a correct forward looking cost calculation?

A. The markup is applied only to the sunk investment proportion investment of the unbundled element. For links Pacific has estimated that sunk costs represent $x$ of the TELRIC estimated cost.\footnote{R. MacDonald and D. Siegel, "The Value of Waiting to Invest", Quarterly Journal of Economics, 101, 1986, pp. 707-728, and Dixit and Pindyck, op. cit., p.153) calculate $m = 2$ so that, for instance, $V_S = 2I$ for a non telecommunications example. This equation means that the investment cost must be increased by a factor of two because of the effect of uncertainty on the cost of sunk and irreversible investment. I calculate a larger factor mainly because of the equipment price decreases which take place in telecommunications.

\footnote{Pacific estimates that these costs are potentially stranded which is a particular type of sunk investment in terms of economic analysis.}} The correct markup to TELRIC would then be $(1-x) + 3.3^* x = y * TELRIC$ where I use the 3.3 markup factor that I calculated above. The first term in the equation is the variable costs and fixed (but not sunk) costs and...
the second term is the sunk costs of investment. Thus, for links I calculate a markup factor on TELRIC of y to take account of the sunk and irreversible investment in the unbundled element. For ports, the sunk costs are a much lower proportion of TELRIC costs. Pacific estimates that sunk costs represent xx of the TELRIC estimated cost. The correct markup to TELRIC would then be \((1-xx) + 3.3^* xx = yy^*\) TELRIC where I use the 3.3 markup factor that I calculated above. Thus, for ports I calculate a markup factor on TELRIC of yy to take account of the sunk and irreversible investment in the unbundled element. In Table 1 I include the calculation for local switching markups:

<table>
<thead>
<tr>
<th>UNE</th>
<th>Proportion Sunk Costs</th>
<th>Markup Factor for TELRIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Link x</td>
<td>y</td>
<td></td>
</tr>
<tr>
<td>2. Port xx</td>
<td>yy</td>
<td></td>
</tr>
<tr>
<td>3. Local Switching</td>
<td>xxx</td>
<td>yyy</td>
</tr>
<tr>
<td></td>
<td>Originating Setup</td>
<td></td>
</tr>
<tr>
<td>4. Local Switching</td>
<td>xxxxx</td>
<td>yyyy</td>
</tr>
<tr>
<td></td>
<td>Orig. Duration</td>
<td></td>
</tr>
</tbody>
</table>

Of course, further adjustments for shared and common costs would still need to be made.

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Q. Please explain a method which uses TELRIC but avoids having to calculate the markup for the investment in sunk and irreversible capital for each service?

A. When a CLEC buys an unbundled element it can be given the choice to sign a contract over the entire economic life of the investment of the sunk investments used to provide the service. Subsequently, the CLEC can sell the use of the unbundled element to another CLEC at a market determined price. In this situation the CLEC bears the risk of the investment that it causes when the CLEC requests the unbundled element. The CLEC no longer receives a "free option" on the investment as it does if it can purchase the use of the unbundled element on a monthly basis. I note that the FCC recognized this possibility in its Interconnection Order since it stated in para. 687: "We believe that this increased risk can be partially mitigated, however, by offering term discounts, since long-term contracts can minimize the risk of stranded investment." Thus, the FCC has recognized that unbundled element pricing must reflect correct levels of risk and that the use of long term contracts helps to decrease the risk of sunk and irreversible investments.
Q. If a CLEC is willing to sign a long term contract for the economic life of the unbundled element, does TELRIC provide the correct pricing basis?
A. If the CLEC signs a long term contract over the economic lifetime of the unbundled element, then TELRIC provides the correct basis for pricing the unbundled element. However, TELRIC provides the correct floor for the price, since a markup factor for shared and common costs is still required. A shorter contract requires higher prices to take account of the value of the option that a CLEC receives when the ILEC invests. Options are valuable as a glance at the financial section of the Wall Street Journal (or other newspaper) will demonstrate.

Q. What if a CLEC doesn't want to sign a long term contract, but instead wants to buy on a monthly (spot) basis?
A. This situation begins to approach the retail sales environment and the cost of the unbundled element to the CLEC should then be increased to reflect the option to stop using the service which the CLEC receives. If the CLEC has the option to stop buying the element at any time, the average markup factor of 3.3 which I calculated above would be applied to the sunk cost component of the unbundled element. If the CLEC is willing to sign a term contract, the markup factor would be reduced. The exact markup factor could be calculated for each unbundled element. However, as a reasonable approximation, an average economic lifetime of the sunk investment could be used, say 8.25 years or 100 months, and a linear approximation could be used. Taking the markup of 3.3 (and subtracting off 1.0) and dividing by 100 gives a decrease of 0.023 per month in the markup as the term of the contract increases. Thus, for a 1 year contract the markup would be 3.02 on the sunk cost component, for a 3 year contract the markup would be 2.47, for a 6 year contract the markup would be 1.64, and, of course, for a contract of 8.25 years, the markup would be 1.0, which is no extra markup. In terms of the overall markup to TELRIC for links which I discussed above, the markup to TELRIC for a 1 year contract would be z * TELRIC, while for ports the markup would be zz * TELRIC; for a 3 year contract the markup to TELRIC for links would be q while for ports the markup would be qq; for a 6 year contract the markup to TELRIC for links would be s while for ports it would be ss; and for a contract of 8.25 years, the markup would be 1.0, so no extra markup would apply. Similar calculations would be done for switching, using the markup factors from Table 1. These calculated markups do not include the markup factor that arises from shared and common costs, which would be applied uniformly across different contract lengths.