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Luncheon - Canadian Room - April 12, 1997 12:15 p.m. - 1:45 p.m.
Luncheon Speaker: **Dale Jorgenson,** Harvard University

"Computers and Productivity"

[Note: This is a transcription from the session, with editing for purposes of clarification.]

Chair: **Erwin Diewert**, Department of Economics, University of British Columbia:

Ladies and gentlemen, I'm sorry to interrupt your lunch. Dale has a plane to catch this afternoon, and he has to depart here at 1:30. He will be talking for about twenty minutes, and we've allowed twenty minutes for questions. He will be using overheads - copies of these are at the door.

Dale has won many honours over the years and I would just like to mention two:

- He is a winner of the John Bates Clark Medal - this is given to the best American economist under the age of 40, and is a great honour in the U.S.
- He is one of the leading "citation getters" in the economic world.

It is a great privilege to have him come to us. My connection with Dale dates back to 1964-1968 when I was a graduate student at Berkeley, and somehow Dale took me under his wing and really educated me as an economist.

What he is really famous for is the use of micro-economic theory and econometric techniques to study real-life policy problems. Believe it or not, that's what my model of economic activity is really all about. There are two other people that influenced me, and one of them is sitting at the table here - Zvi Griliches. Zvi made me aware of the fact that you just can't accept data that some government agency gives. Up to meeting Zvi, I had no idea that there was any problem with numbers   - I just thought you got them out of some book. In those days we didn't have computers, and that was the end of the story. So he certainly paid a big role in my education as well. The third person is Daniel MacFadden, who introduced me to the joys of duality theory, but that is not really our topic today.

I would like to mention some of the important areas of Dale's research:

- Number one - the econometric estimation of consumer preferences and production functions. Every economic model has a consumer's side and a producer's side, and they interact with the government's tax and expenditure policies. It's very fundamental to model the consumer demand and producers supply side of things. Dale has been a pioneer in the use of flexible functional forms in modeling both sides of the Marshallian scissors.

- The second important area that Dale has been involved in is in modeling the user cost of capital. The fundamental problem of accounting is how to allocate the cost of a purchased durable good over time. Accountants have been wrestling with this fundamental problem for a hundred years and without a great deal of success, although the accountants in the crowd may beg to differ with me on this. Dale's contribution was to deal with this durability problem and apportion the purchase cost of a durable across time, which leads to the user cost of capital, which leads to a proper treatment of interest (which Peter Hill referred to in his comments in the last session). I would like to note that Peter has written an excellent volume that supplements the System of National Accounts. It's an OECD manual on accounting in high inflation countries, and you'll enjoy this book much more than the real national accounts, which is very thick.

Briefly, some of the other contributions Dale has made are:

- in the area of investment theory
- in the role of energy in the economy
- in tax policy

- in the measurement of welfare - in addition to the measurement of individual consumer welfare, Dale has dealt with the problem of aggregating over consumers
- in the measurement of economic growth and productivity. (This dates back to his pioneering article with Zvi Griliches in 1967 on the measurement of productivity.)

And that leads me into today's talk which is entitled "Computers and Productivity". Please welcome Dale Jorgenson.

Dale Jorgenson: I would like to begin by thanking Andrew Sharpe and his colleagues of the Centre for the Study of Living Standards for organizing this very timely conference. Productivity, as you know is a central issue in the Canadian economic debate, and I can assure you that south of the border the matter is of equal concern. The question is - Why has the growth of productivity slowed in North America since 1973; and in Canada, why hasn't Canada shared in the modest revival in productivity growth that has taken place in the United States since the mini-recession of the early 1990s?

In the U.S., the debate focuses on the prospects for long-term growth. Disagreements over this issue have surfaced in the budget debate. This debate, you may remember, led to the closing down of our federal government for a few days a little over a year ago. In both countries the productivity paradox, which is the subject of our conference, has become a focal point in the debate. And this paradox arises from the juxtaposition of two facts:

- first, the slow productivity growth I mentioned
- secondly, the apparent rapid technological change. The change in technology is most apparent in computers and in the very closely related area of telecommunications. But of course there are many other areas of rapid change.

In approaching the subject, I think there are two alternate approaches one can take, and both are represented at this conference. One view is that the methods of measurement that we use to capture output of the economy are subject to measurement errors that conceal the productivity growth that is really taking place. That is a view that has been in this debate for about ten years and has continued to be represented. I think Erwin's own paper this afternoon, very comprehensive as usual, is one version of that. Zvi Griliches also talked about it at lunch yesterday.

However, I'm going to take the second approach, which I'll describe as denying the existence of the paradox. And let me be precise about that. I think the productivity paradox is very revealing, but what it reveals is a gap in our understanding. Namely, the paradox arises from the identification of productivity growth with technological change. In fact, the two are quite distinct, and most of what an engineer would describe as changes in technology is what I would regard as the consequence of investment rather than productivity growth.

To fully exploit this idea, however, we need to have a much broader concept of investment. I'm going to describe such a concept in this talk, and apply it to computers. So my alternative thesis will be that growth is mainly due to investment in capital - tangible capital, human capital and intellectual capital. Productivity growth is a minor contributor to growth and it cannot be identified with technological change.

In fact, technological change involves: investment in intellectual capital to create the ideas; investment in human capital to train the human resources to exploit the new technologies; and then massive investments in tangible assets that embody the new technology.

All these types of investments are made by private parties and are intended to produce long term returns. The policy implications of this viewpoint are fairly obvious, but I should describe exactly what they are. The role of public policy in this view is to create the environment that will foster investment in all of its manifold manifestations - tangible assets, human beings and new technology. However, the government should leave the investment decisions to the parties that have the information:

- the business firms that have the information about the best way to invest in tangible assets;
- the individuals (workers) who have the information about how to enhance their skills and their education; and
- the technologists who invest in the new ideas that are at the heart of the whole process.

It is difficult, but essential, to provide both incentives for the investors (which are the economic rewards), and also to provide penalties for failure (the loss of future opportunities to invest). People who make bad investments are penalized and that's something that has a very healthy function in directing the development of a capitalist economy.

I'm going to begin with a brief review of the sources and uses of economic growth in order to provide a comparison between these two views of economic growth. Then I'm going to digress very briefly and talk about the brief but spectacular reappearance of the productivity view of technological change, in the guise of the so-called new theory of economic growth of (Paul) Romer and (Robert) Lucas. I would like to characterize that as the Hale-Bopp comet of economic theories. It appeared, it was truly spectacular, and it is about to disappear behind the horizon. I will then describe the current state of the investment view of technological change, and illustrate my ideas by describing the role of investment in computers. Then I'll describe the frontier of research in this area, which is the measurement and incorporation into this view of investment in intellectual capital.

This is something which is a problem of long standing; it's a problem which Zvi Griliches identified in a classic article in 1973. It's only recently that Zvi and Bronwyn Hall, in some very recent papers, have suggested how we might approach this problem empirically. I think that their result as suggested is incomplete - we may be on the verge of an important breakthrough here.

For those of you who have the handout, we are now on page 5 and I would like to describe the story here in terms of the sources of economic growth. The sources of economic growth that you see here are for the period 1959 to 1995. I didn't have these coloured slides available to incorporate them into the handout, but you can see that the productivity (in yellow) accounts for about a fourth of economic growth, and that capital (in blue) representing the capitalists as investors, accounts for the predominate share. But red - the share of the workers, the labour input growth - is an important part of the story as well.

Well that's the first view of economic growth. I've selected this period to bring the story as far up to date as I could through 1995, which is as far as we have aggregate economic information that's relevant in the United States. Going back to 1959 enables us to capture the brief history of the role of computers, which on a commercial scale go back go back to around 1958. This is a way of portraying the difference between the investment view and the view that identifies economic growth with productivity. The latter would attribute 11 percent of the growth of labour input to productivity growth, but the investment view attributes that growth to investment in human capital, mainly through formal education. This investment in human capital accounts for a little bit over a third, maybe 40 percent, of the growth of labour input.

If, on the other hand, we were to take the traditional view (the productivity-growth view), we would attribute 6.4 percent of economic growth to productivity that in fact belongs in capital. This is because the heart of the computer problem is the change in technologies associated with the shift from traditional forms of tangible assets into the newer forms that have higher marginal productivity. Of course that's in the 6.4 percent - not an overwhelming margin. At any rate, the traditional view then is that about half of economic growth is accounted for by productivity, but my view is that can't be more than about 30 percent.

Let me proceed, then, to the classification of the different forms of tangible assets. What we see here is that the investment in tangible assets is a very important part of the story. Investment in tangible assets takes the form of four different types:

- equipment such as computers
- structures that house the equipment
- inventories
- land (including natural resources)

Each of these has problems associated with it that we don't have time to go into here, but this [classification] has now been incorporated into our official national accounting techniques in the United States in the most recent revision of the national income and product accounts. Peter Hill, as you've heard Erwin say, is working on spreading this new technology in national accounting more broadly.

The second very important form of investment is investment in human capital, and this is an idea which was created a long time ago. It was brought into its modern dress by Becker, Mincer, Schultz and Machlup in the early 1960s. However, it's only recently that this has been put into the same framework as investment in tangible assets.

The third form of capital that's important here is intellectual capital. This is a concept that is the least familiar to many economists, but in fact is the cutting edge of capitalism. A whole area is now under construction that has created spectacular new forms of wealth. The most conspicuous is the fantastic fortune that has been created from Microsoft and has accrued to Bill Gates, the CEO and chairman of Microsoft. But you can pick up any copy of the *Wall Street Journal* and find things that are similar in character. Here's an example from last Wednesday's *Wall Street Journal* [April 9, 1997]. It reports on the purchase of Web TV Networks Inc. by Microsoft for $425 million. The entrepreneurs included 36-year old Steve Pearlman, who had formerly been a software engineer in Apple computer, but had now formed this new Web TV Networks. Microsoft had a similar product, but they became so impressed, according to the Journal, with Web TV's technology that the company and chairman, Bill Gates, took a minority stake last year. The company concluded in February that buying all of Web TV would enable its technology to get into living rooms faster.

Well, the conclusion there is that what we're witnessing is not something that could be described as productivity growth in the sense of spillovers that don't accrue to individuals in the form of additional incomes. This is rather investment in intellectual capital that creates property rights and results in spectacular gains, as you can see. I emphasize that Mr. Pearlman is 36 years old. He has been engaged in this kind of investment for a good deal less time than Bill Gates, but his rewards have been commensurate. That illustrates the idea of intellectual capital.

Another article in the same issue of the *Wall Street Journal* pointed out that the idea of intellectual capital had come to the fore in the legal profession, although perhaps not so much among economists. In the American Bar Association, the number of lawyers working on intellectual property has increased by 50 percent in the last five years. That's another indication of the fact that this is at the cutting edge.

We've finally arrived at the remaining category of spillovers. The most common example that we see in the textbooks is public research and development, undertaken or subsidized by the government, for the purpose of generating benefits that can't be captured by private investors. Paul Krugman has pointed out a very important limitation of this view, which is that by definition [the returns are] unobservable. If we can observe the returns, then of course there would have to be ways of organizing the economy in order to create property rights and enable somebody to capture those returns. But I digress.

Well let me conclude then with my story of a fourfold classification, three types of investment as sources of growth, namely tangible assets, human capital and intellectual capital. In terms of the wealth that's involved, the way to think about it is that human capital accounts for about 100 on a scale of 10, where tangible assets would be the 10, and intellectual capital would be about one. So the big ticket item here, once we do the measurements, is human capital. Intellectual capital is on the intellectual cutting edge, but at the same time it is quantitatively much less important.

Let me deal briefly with the convergence debate, because this has been very confusing to many people. As I said, it is the Hale-Bopp of the area, so just let me just mention the key references and then move on. The key paper in this literature is a paper that was published in 1987 by Paul Romer entitled "Crazy Explanations of a Productivity Slowdown"(NBER, *Macroeconomics Annual*, 1987). Many of you have seen it. The key implication was that the elasticity of output with respect to capital is equal to one, and there is no convergence. Both of these propositions contradict the basic neo-classical model of economic growth propounded by Robert Solow. No convergence, and the elasticity of output with respect to capital input is equal to one.

That view is precisely the view of supply side economists. Supply side economists believe that all you need to do is invest. But that's not the point that I'm trying to make. What I'm arguing is, in fact, that you need to think about this in exactly the way that Bob Solow did in his famous model. But you need to put a great deal of emphasis on all forms of capital, not just tangible assets, which was the subject of Romer's paper. The first cut against the Romer paper was a paper by Mankiw, Romer and Weil, published in 1992. It produced an augmented version of the Solow model, but then it turned out there was a very important underlying assumption, which was that all the countries in these international cross sections had identical technologies. When that assumption was dropped in 1995, allowing for differences in technology across countries, it turned out that the Solow model reappeared. In other words, we ended up with precisely the story that Solow propounded back in 1956. The elasticity of output with respect to capital was exactly equal to the capital share and the rate of convergence was precisely what Solow's model had predicted.

Well, that's a quick run-through of the recent literature growth, and as I say, the Hale-Bopp comet has just disappeared over the horizon.

Let's turn our attention then to applying the Solow model to the topic at hand, which is the topic of investment and computers. So what I'm going to do is to focus on computers as output and computer services as input. Let me focus on the most recent period which is 1973 to 1995 where we obtained the following picture. This is simply the picture that I gave you earlier, but slightly modified to bring out the role of computers.

First of all, let's talk about modeling the production of computers - that's a fairly straight forward matter. What we really need to do is to think of computers as an output, so I've separated the economy into computer and non-computer output. Fortunately, most computers go directly into final demand, so they show up in GDP. Between 1973 and 1995, they accounted for about 6.5 percent of the growth in GDP in the United States. So computers are a major part of the growth in GDP, but in fact, it's easy to exaggerate that and when you look at it quantitatively , it turns out to be only around 6.5 percent. However, even this would have been concealed from view, except for the fundamental work that was done at the Bureau of Economic Analysis and at IBM by two people who are participating in this conference, namely Jack Triplett and Ellen Dulberger. The IBM/BEA team published a series of papers in the late 1980s in which computer prices were for the first time incorporated into a national accounting framework. This was after a great deal of controversy within the Bureau of Economic Analysis. But so far this - which is taken directly from the U.S. national accounts - is the only official accounting for the output of computers that conforms to this new recipe among the OECD countries, with the sole exception of Canada. All the other OECD countries leave the growth of computers essentially out of the picture. They do not take into account the advances that were made by BEA and IBM in this epic making work of Dulberger and Triplett. The main finding there, of course, was that computer prices declined at something like 20 percent per year since 1959. The counterpart of that development is that expenditures on computers have been growing at 27 percent per year, and this rate of growth has been sustained. However, computers are a very small share of the economy. In fact, the share of computers in economic growth peaked in the early 1980s, about 15 years ago, so this growth rate is the average over this whole period from 1973 to 1995.

That's the first part of the story of measuring the impact of computers. Now let us think about the other side of the story. What about computers as inputs? If you think about the productivity paradox, you wouldn't expect productivity to appear as an important consequence of investment in computers if computer inputs were of comparable magnitude to the computer outputs. Right? So what we need to do is measure computer inputs. That's a somewhat more challenging task, although the basic raw material is exactly the same. What we have to do is to take account of the change in computer prices and put together a capital service price, which Erwin Diewert in his introduction referred to as a user cost of capital for computers. That's going to have three basic components: first, a rate of return; secondly, a depreciation rate; and thirdly, a rate of capital loss associated with the

20 percent decline in the price of computers which has been sustained over this period. Well, if you look at the numbers, the rate of return is around 5 percent, the depreciation rate is also 5 percent, but the decline in computer prices as I've told you already is about 20 percent, making it by far more the most important component in the user cost. Now we multiply the three components by the declining price of assets, which is falling by 20 percent per year. Roughly speaking, what that says is that the price of computer services is declining at about 20 percent per year. But relative to other forms of capital, it has a very important weight relative to its value as an asset, and that, of course, is what shows up here - 4.2 percent of input for this period from 1973 to 1995 can be attributed to computers. The conclusion is that computers do, in fact, show up in the statistics. They are very important, but they're important both as outputs and as inputs. Therefore, it is not at all a paradox that we can have this very substantial growth in computers and, at the same time, have relatively little evidence of productivity growth. That is because productivity growth would result from spillovers of benefits of computers to people who are not involved in investing in them - either in the computer industry where they're produced or in the using industries where their services are consumed. And, so far as I've said here, there's no evidence for these spillovers.

But now we need to be very precise, because there are, in fact, two way in which economists use the term 'spillovers', and it's very important not to confuse them. What I've described here is a very important spillover phenomena, namely, as the price of computers declines very rapidly, people substitute them for everything else in the economy. They substitute them for manual labour and telecommunications gear, in airline reservations; they substitute them for calculators; they substitute them for store clerks in Walmart; they substitute them for the conventional form of automotive technology in the making of cars - all of these substitutions reflect a rapid decline in the price. But they are fully bought and paid for. The users of computers receive spillover benefits of the decline in price, but they pay for those benefits by purchasing the computers and using their services. And that's the sense of the story we've got here. In the older terminology which is sometimes used in this literature, this is referred to as pecuniary benefits, pecuniary because it's bought and paid for.

The other kind of spillovers are, of course, the non-pecuniary spillovers that are the subject of the paradox - namely, these are the spillovers that would show up in productivity and of course, they are by nature, as I say, unobservable.

The analysis I've described here is now established firmly on an empirical basis, first by the Bureau of Economic Analysis along with IBM, and then on the input side by a paper that I prepared with Kevin Styro and published in 1995. This basic idea has now been incorporated into the official productivity statistics produced by the Bureau of Labour Statistics and the productivity statistics that I presented to you just a moment ago.

The conclusion then is that computers make up a very substantial amount of output, but nonetheless, fairly modest, 6.5 percent. In fact, the role of computers as a component of output peaked about 15 years ago in the early 1980s. This leads, of course, to an immediate confrontation with a well known thesis propounded by Paul David which Luc Soete described the other day very eloquently as 'great things to come'. In other words, we have invested in all these computers but it's going to take decades before we see the result.

The difficulty with that theory is that the decline in the price of computers is about three times as fast as the decline in electricity prices which Paul David, the economic historian, compared with the decline in computer prices. The decline in prices of computers is three times as fast. Secondly, this contribution of computers to economic growth peaked 15 years ago. Since that time, the role of computers in economic growth has continued to be important, but is no more important <u>now</u> than it was 15 years ago. We've had 15 years to see these spillovers. I suggest it's no paradox that in fact we can now take the position that this is something that simply is not going to happen.

What about the input side? As you can see on the input side, the study here is simply that computers are <u>extremely</u> important as inputs. They involve very substantial amounts of investment and input and therefore they <u>do</u> contribute much, both to the input and the output side. Let me mention a couple of pitfalls here that I should draw to your attention and then I'll wrap up. The first is that it might be possible to overlook all this by failing to price out computers at the appropriate asset prices, and the corresponding input prices. That leads to the notion of embodied technical change which essentially is the result of a mismeasurement of the prices of output. Since inputs and outputs are about equally important for computers, that turns out to be a wash. If we mismeasured the price of output, it would affect the role of output and input more or less symmetrically and wouldn't change the story about productivity. So that's not something that counts against this thesis.

The second thing is that we could do something that is more fundamentally wrong, but is very common in this literature. Namely we could overlook the fact that the most important single component of computer service prices is the decline in the price. On an annual basis that turns out to be at least 20 percent, and that is a fact that dominates. Therefore what we see is all kinds of measurements of so-called excess returns of investments in computers where people measure the marginal product without taking into account the fact that this decline in price has occurred. I am happy to say that Frank Lichtenberg, who is the author of a paper in this conference, has presented a view of that thesis in which he gets the price change right. But in the older literature, it's very very common to simply overlook this and to attribute excess returns to investment in computers that simply are not there.

We now come to the conclusion. The conclusion is that productivity does not explain economic growth. By and large, economic growth is explained by investment. However, we need a broader form of investment than the one that is traditional. It turns out that computers are very adequately captured by the traditional notion of investment in tangible assets, but if we look behind the use of computers, we can easily see that there are massive investments in intellectual capital that underlie the development of these new technologies, but they are bought and paid for. Bill Gates realizes the benefit of all of the investments that have taken place in Microsoft, except of course for that which he shares among his many collaborators. That is why there are so many millionaires and even a few billionaires in Seattle. Finally, there are many investments that are transforming our institutions of secondary and higher education in human capital, and all three forms of investment are important in understanding this phenomenon completely.

But computers, as I have portrayed them here, are common garden variety tangible assets. The only difference is they happen to have a characteristic that is described as Moore's Law, of increasing physical efficiency at the rate of two times every 18 months, and that produces challenging accounting problems for growth analysts like ourselves, that, however, has a fairly straightforward solution.

Where are we in terms of research frontier? Well, the research agenda now is to measure what I call non-pecuniary spillovers. Pecuniary spillovers are the ones that I have described as showing up in the form of input. The non-pecuniary spillovers are the part of investment, mainly in intellectual capital, that can't be captured by the Bill Gates of the world that are standing around trying to collect intellectual property rights. Fortunately, there is progress, even on this front, even though this is by far the most challenging of all these problems. Brownwyn Hall, in a paper that many of you who work on research and development are familiar with, has in fact attempted to measure the marginal product of intellectual capital, using Griliches' 1973 model. That model is exactly the one that I've used here for tangible assets, and for computers in particular.
What Brownwyn found I think is extremely revealing, and that is that almost all of which he calls excess returns to investment in intellectual capital, are concentrated in two industries: namely electronics and computers, precisely the industries that are behind the figures that you see here.

My explanation for that is one that you may find a little paradoxical, but it's pretty straightforward. It is that the value of intellectual capital in the computer and the electronic industries declines at about the same rate as the value of the product. That's something we don't know because of a gap in our empirical understanding. We do not have a way yet of pricing intellectual capital, even though Bill Gates apparently was able to price Steve Pearlman's intellectual capital at a very precise number, $425 million, only Wednesday of this last week. But nonetheless it's something that is currently on the frontier as far as economists are concerned. The idea that intellectual capital can be encompassed within this same framework - let's call it the user cost framework - is in fact already on the horizon and I think in a finite amount of time - and I am now talking about years and not decades - it's something that will be encompassed in this overarching framework. Let me stop there and take your questions. Thank you.

Question: It's a very simple question. Did I hear you right in your saying that you use a 5 percent per annum depreciation rate for computers?

Jorgenson: Yes

Question: I deal with computer systems in the U.K. Our current practice certainly is to write them off over a much shorter period and therefore use the depreciation rate of at the very least 10 percent, and sometimes as much as 20 percent per annum. I just make that point because I think, if anything, if you apply that it would actually reinforce your argument, rather than in fact, counteract it.

Jorgenson: No, that's not right, but let me tell you where the discrepancy arises here: My analysis is based on retirement figures that were very carefully compiled by an American economist at the Federal Reserve Board of Governors named Steve Oliner. He actually looked at the inventory of computers and argued that computers are, in fact, perfectly durable, but in fact, are occasionally retired. However, they're not retired for a long time and they often sit around in closets and various other places. What would be an appropriate accounting convention is, of course a very interesting matter, because I think people confused two things, namely the decline in the value of the computers, which is indeed 20 percent a year, and the change in the value with age of the computer, which is the depreciation component. So I don't think there's any discrepancy between our two points of view, and I certainly wouldn't want to dispute the point that you made.

Question: Computerization has been used to increase information and the accessibility of information, and by its nature, information has externalities as it's a public good. Is there an argument that this computer revolution that we're going through, relative to previous major technological revolutions, is characterized by a greater gap between the impact on GDP as we measure it, relative to economic welfare in a broader sense.

Jorgenson: Well, the basic question is: are there spillovers associated with information? Many people like to use ideas that are patented by scientists the benefits of which spillover to the rest of us as a prototype. But the prototype I prefer is the more mundane - namely magazines, newspapers, CDs. In the case of magazines and newspapers, the key to realizing the value of the information is the transitory value - it depreciates almost instantaneously and that being the case we don't have any problem protecting the intellectual property rights. The case of CDs is more interesting, because until very recently, people were able to get away with reproducing CDs. In fact, the common mode of acquisition of the services of CDs among teenagers was to copy their friend's CDs. And of course the same was true for videos. But now people who do that have been successfully prosecuted - that practice is vanishing and individual property rights are becoming established.

The same thing is happening in technology. The reason that Steve Pearlman was able to obtain this kind of return for his investment in Web TV was because he has some very clever lawyers working for him. There's another story in the same issue of the *Wall Street Journal* about a famous inventor who has 500 U.S. patents - a world record. His personal fortune is worth 500 million dollars, roughly comparable to what Web TV sold for. But the interesting part of the story is how wealthy his lawyer is! His lawyer is worth 150 million dollars - in other words, roughly a third of the value that the inventor has achieved. And what does this lawyer do? Very, very simple: He goes around suing violators of intellectual property rights and has a very important business built on this that has resulted in a 20,000 square foot home in Aspen and all the rest of it, and a personal fortune of 150 million dollars.

So, I would answer your question by saying we are in the midst of a revolution. Not a revolution about computers, that took place in the 1980s, and we're living with the consequences; we're the beneficiaries of this new technology. We're living in the midst of a revolution in the character of property rights within a capitalist system. A new form of capitalism is coming into existence in which the traditional form of intellectual property, namely government-funded science whose benefits spill over to the public at large, is now being replaced by the successful entrepreneur with his or her lawyer at his side, both realizing substantial gains.

I have time for one more question and then I'm afraid I have to leave. Erwin.

Erwin Diewert: I wonder, Dale, if you could tell us how do constant dollar intellectual capital?

Jorgenson: No. That's what I mentioned as on the frontier. Bronwyn Hall faced that problem and was unable to solve it, and in a lecture that I gave at Industry Canada only yesterday, I said that's exactly where Zvi and Bronwyn and others working in this area have left us - namely that we don't yet have a way of pricing intellectual capital. We only have a way of valuing it, but not separating it into price and quantity. And therefore it's going to be a few years, although you've now got computers in the national accounts, before you get the intellectual capital as an investment in the corresponding services as an input. But I leave that challenge to you. I think it's going to be exciting for all of you to work on this problem and I'm looking forward to the solution. Thank you very much.

Erwin Diewert: As all of you will recognize, there are good and bad aspects to the non-appropriability of intellectual property rights and we have here today a great benefit of an appropriable right that is free to us, and I want on your behalf to extend our thanks to Dale Jorgenson as he trots down the aisle, and we'll have him part with a round of applause.