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Innovation and Emissions Policy

Submission to the Garnaut Climate Change Review on Issues Paper No.4: "Research and Development: Low Emissions Energy Technologies"

Author: **Professor Joshua Gans**

Date: 7th April, 2008

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I. Introduction

In this submission, I respond to various questions raised in Issues Paper No.4. The discussion here is not exhaustive and does not claim to cover all of the issues raised. Instead, I focus on areas that I have researched in and have clearer views about. My hope is that some of these ideas may prove of use in the Climate Change Review.

The submission is organised as follows.

- I begin, first, with the baseline case for public support of research and development and highlight issues of particular relevance for climate change policy.
- I then turn to consider the impact of environmental policy -- in particular, emissions trading -- on innovation.
- Finally, I outline several approaches to the government support of innovation in a climate change context and present several ideas as to how constructive innovation policy might proceed.

II. Market failures associated with innovation

The market failures associated with innovation are well-known and it is not my intention to review them here. Basically, it is often the case that the private return to investing in research and development is less than the social return to such investment.

- First, there is a problem of *appropriability*. The value of innovations lie beyond the uses a private agent will put them to. Consequently, if an innovation is deployed, there are potential spillovers that are realised by others and not necessarily captured by the innovator. The fact that a private investor can only capture a fraction of the social returns to an innovation will diminish their incentives to invest.
- Second, and related to the first, is the problem of *indivisibility*. Innovative activity cannot be easily de-scaled. Hence, just because a private investor earns a lower return to innovative activity does not mean that that activity can be parceled up amongst all potential beneficiaries. Thus, in the absence of coordination amongst beneficiaries, a single agent may incur a disproportionate share of the costs of innovation.
- Finally, there are problems of *uncertainty*. Put simply, it is difficult to measure innovative outputs and so it is difficult to contract on innovation quality. The end result of this is that a private investor cannot easily diversify risks associated with research and development. This means that on a risk-adjusted basis, the expected returns to innovative activity have to be much higher than standard investment benchmarks to attract investment -- even aside from the social spillovers they generate.

All of these drive a rationale for public support of research and development. But which ones are of particular relevance in the context of climate change policy?

Global social value

Climate change policy involves global reductions in emissions but also local protection against the adverse consequences of climate change. However, whether it be for mitigation or adaptation, there is a mixture of global applicability and local requirements that will mean that some portion of spillovers will be international. This means that even a national support for innovative activity will only target a fraction on the social value from innovation in this space. Consequently, there is a clear need for international cooperation on innovation policy and direction. This is both to ensure that duplicative efforts are kept to a minimum and also to ensure that there is trade and exchange in new technologies to deal with climate change. Thus, **there is a premium on international coordination of research into new technologies for mitigation and adaptation beyond that which might arise for 'standard' innovative activity.**

This is of relevance for any discussion of 'picking winners.' Put simply, we are not just talking about picking technologies that might have promise. We are also talking about picking projects and technologies that might:

- (a) target any comparative advantages Australia might have in trading ideas; and
- (b) allow us to fulfill any agreed contribution to the international pool of knowledge.

Cannibalisation and lock-in

In mitigating climate change there is much discussion about the need to switch over from the installed capital base of technologies that rely too heavily on emitting fuels. It is true that a constraint to the adoption (and hence, innovative returns) from new technologies that are more environmentally friendly is the existence of an installed base. That said, the same can be said of any innovation that involves product displacement or cannibalisation. The key issue is whether the private decision to retire old technology and adopt new technology is socially inefficient as well.

There are two reasons why there might be an insufficient private incentive to retire old technology. First, to the extent that the externalities caused by emissions from those old technologies is under-priced, the true operating cost of using those technologies is not felt by the private decision-maker. Consequently, they will have insufficient incentives to switch to newer more environmentally friendly, technologies in a timely manner.

Second, some existing products are sold by firms with some degree of market power. When we are looking for those firms to reconstitute their products so that they are manufactured differently to produce lower emissions, they may have a diminished incentive to replace those product lines quickly. This is because they are earning rents from those existing technologies and displacement of them will have only a marginal impact on profits. Thus, even if environmental externalities were internalised, the presence of market power can reduce the speed of introduction of more environmentally-friendly products.

Intellectual property protection and adoption

To a large extent, Australia's ability to respond effectively on climate change depends less on innovations it can generate than the adoption of more environmentally-friendly technologies that have been developed elsewhere. The problem is that, to the extent that those technologies have been developed recently, they may still be covered by intellectual property protection and consequently, be relatively costly.

If there is urgency to the adoption of such technologies, there is a case for active government participation to mitigate the adverse consequences of monopoly power while still fulfilling our international obligations on intellectual property protection. Again this may be resolved by international cooperation (say, establishing and participating in global patent pools) or by the government stepping in as a large purchaser to provide countervailing power for those holders of key patents. I will elaborate more on this latter route below.

III. The impact of environmental policy on innovation

There is a hypothesis that is often put forward in the context of environmental policy that, if we get the prices right on environmental goods, innovation will “take care of itself” as the market responds to optimally manage the new mix of relative prices and costs in the economy. Given that innovation incentives are themselves the subject of market failures, it is unlikely that “getting the prices” right will generate the optimal level of innovation. However, there are some ‘weaker’ versions of this hypothesis that can be explored.

- First, is it the case that putting in proper environmental policy will lead to more innovation in environmentally-friendly technologies?
- Second, to the extent that there are different classes of environmental-friendly technologies (e.g., ones that economise on fossil fuels, some that utilise alternative fuels and those that sequester carbon from the atmosphere), what will environmental policy do to the mix of such technologies and the direction of technological change?

To deal with each of these questions I report on new research that demonstrates that conventional hypotheses that ‘getting the prices right’ will improve innovative prospects and efficiency are too simplistic and that the case for government intervention is enhanced when environmental policy is put in place rather than diminished.

Classifying low emissions energy technologies

There are various classes of technologies whose development policy-makers believe will be encouraged by climate change policy.

- First, there are technologies associated with making more efficient use of fuels that cause emissions. Examples of these include energy efficient light-bulbs, more fuel efficient cars and planes, and improvements in the output of coal-fired generators per unit of coal burned. I term these **emitting-fuel augmenting** technologies.
- Second, there are technologies associated with improving the efficiency of the use of non-emitting fuels such as solar, wind, bio or geothermal energy sources. These **non-emitting-fuel augmenting technologies** include solar powered hot water and engines as well as new forms of electricity generation.
- Finally, there are technologies associated with reducing the costs of sequestering carbon and other greenhouse gases from the atmosphere. These include technologies to store carbon at the point of production as well as taking it from the atmosphere. These are **sequestering or offset technologies**.

A key issue here is whether more stringent climate change policy encourages greater development of any or all of these technologies and how it impacts on the mix of technologies developed.

The direction of technological change

While the notion of ‘induced’ innovation or technological change has been around for many years, it is comparatively recently that economists have made breakthroughs in understanding how changes in factor supply conditions (perhaps as a result of government policy) impact on the mix of technological change.¹ Given these advances in economic understanding, I have been investigating the impact of environmental policy (most notably, tighter emissions standards) on the mix of technological progress in a general equilibrium setting.² Here I report on those findings.

To begin consider a situation where goods in the economy can be produced either with an emitting fuel (such as oil or coal) or, alternatively, with a non-emitting fuel (such as solar or wind power). These fuels are imperfect substitutes and have different efficiencies. In addition, the capital associated with utilising each fuel in the production of goods is subject to endogenous technological change whereby entrepreneurs invest in research to improve capital efficiency and are able to earn a return on that investment in competition with other providers of such capital goods.

¹ The seminal paper is from Daron Acemoglu (2002), “Directed Technical Change,” *Review of Economic Studies*, 69, pp.781-809.

² Joshua Gans (2008), “Directed Technological Change and Environmental Policy,” *unpublished paper*, Melbourne Business School.

In this situation, suppose that the government made the emitting fuel either more costly (through a tax) or scarce through an emissions cap. Absent any change in technology this would cause the price of goods utilising emitting fuels to rise and for there to be a substitution in the mix of products consumed towards those produced by the non-emitting fuel. But what impact would this have on the relative incentive of entrepreneurs to invest in R&D to improve capital efficiency?

First of all, the *price effect* implies that the margins earned on products using the emitting fuel will actually rise. This flows back into the return on capital augmenting the emitting fuel and hence, will stimulate profits of innovators. Countering this, however, is a *market size effect*. The relative scarcity of the emitting fuel (as it is not more costly and less available than non-emitting fuels) shrinks the volume of goods produced using that fuel and hence, the scale of any capital equipment deployed as a result of innovation in that area. It turns out that because scale is important in innovation, the market size effect outweighs any price effect. Consequently, **the more stringent emissions cap will cause technological change to be biased towards improving the efficiency of non-emitting fuel production.**

If an emissions trading scheme is put in place, there is an opportunity for firms to sell permits by employing offset technologies. The emissions permit price serves as an inducement for such activities and is itself a function of the overall emissions cap. Thus, offset activities allow a greater volume of the emitting fuel to be used without breaching the overall emissions cap. This scope raises the returns to innovations that improve offset efficiency as well as mitigating the increased costs faced by those producing goods with the emitting fuels.

For those investing in technologies to offset emissions, the price effect and the market size effects from a more stringent emissions cap work in the same direction. Specifically, a more stringent emissions cap increases the prices of goods based on the emitting fuels and hence, raises the price of permits; this stimulates the profits of offset providers. In addition, a more stringent emissions cap reduces the 'competition' for offsetting activities and so actually increases the market size for those activities. Therefore, in comparison to the innovation incentives for capital to make either emitting or non-emitting fuels more efficient, the market size and price effects reinforce one another. Consequently, a more stringent emissions cap will have the greatest relative impact on innovation incentives for offset technologies.

In summary, **putting in a tighter cap on emissions will encourage relatively higher research and development towards technologies that offset carbon use** over other types of environmentally-friendly innovation. It will also **encourage more development of technologies that utilise non-emitting fuels** than those that make existing emitting, fuel uses more efficient. This is basically because the relative size of the market for non-emitting fuels and for the offsetting of emissions rise as the government puts in place a tighter cap.

What this analysis tells us is how the mix of technological change will respond, globally, to global responses to climate change. Of course, for individual sectors in individual countries there may be differential effects. However, this tells us where the most demand for new technologies will come from.

The level of technological change

Of course, while the mix of technological change is useful to understand, there have been many claims that more stringent environmental policy will stimulate incentives for innovation in each and all of the three areas considered above. This notion has been most recently associated with Michael Porter but his analysis concerns the impact of environmental standards as applied to individual industries. With climate change we are talking about a standard impacting on most industries in the economy and hence, a general equilibrium approach is warranted. Specifically, environmental policy will impact both on the demand for new technologies and also on the supply of funds and personnel to conduct research towards them.

My modeling³ demonstrates that **a more stringent environmental policy will diminish the rate of innovation for both emitting and non-emitting fuel technologies** and will have an ambiguous effect on offset technologies. The reason is very simple: a more stringent emissions cap effectively removes resources from the economy that were previously used for the production of goods, capital equipment and for research and development. The production of goods stimulates the market size or scale effect that stimulates innovation. The increased cost of capital increases the cost of conducting

³ *ibid.*

research. Thus, the demand for and supply of research activities falls. Thus, even though there is a substitution of those activities towards non-emitting fuel technologies, even here, the overall incentives and rate of innovation fall.

We have to face a fundamental fact that more stringent environmental policy removes resources from the economy for benefits that cannot be easily monetised (a more stable environment) or for whom the productive benefits arise well into the future. For this reason, there is less to go around for all activities, including research and development. For this reason, stringent environment policy that gets the prices right, **enhances the case for public support of innovation on environmentally-friendly technologies**. To expect otherwise appears to be wishful thinking.

An exception may be for offset technologies where the market size for those activities expands with an emissions cap. However, even there the capital and other costs of research rise so the overall impact may be ambiguous.

Commitment to environmental policy

Because the process of innovation involves investing now and earning returns later, innovators will be concerned about the prices (including those permits) in the future as these will drive adoption of any technologies they invest in. However, as Laffont and Tirole⁴ have demonstrated, this creates a potential commitment problem for the government. Here, I review their findings and discuss potential remedies.

Their initial finding is straightforward. Suppose that someone is considering investing in an innovation that would perfectly substitute for an emitting fuel. Their returns will be determined by how much polluters will pay for the substitute. In an emissions trading regime, they will be willing to pay the permit price for the substitute. Thus, future permit prices will determine the innovator's return. However, to the extent that those prices are high, there is less deployment of the new technology. Thus, a future government would, having noted the existence of the new technology, be tempted to issue more permits, pushing its price down and allowing greater adoption of the new technology. Anticipating this, however, the innovator will not invest because they cannot be assured that a government will maintain high permit prices in the future.

This puts weight on what happens in futures markets for emissions permits -- as spot markets determined by governments at the time create this 'expropriation' problem. By, say, issuing permits in advance rather than at the time, this issue can be mitigated somewhat. However, those who have purchased permits early have no incentive to adopt the new technology in the future and not pollute. In addition, the presence of those permits still means that incentives to innovate are lower than their social value. So advance commitments are an imperfect device to encourage innovation. However, should these take an option form -- you can pollute but you have to pay an additional fee to the government at the time -- then there may be both better commitment and greater incentives to adopt the new technology (should it exist) rather than to pollute.

Of course, the government could take the 'marketing' issue out of the innovator's hands by purchasing the rights to license the innovation into the future. This suggests that governments committing to a prize (or an advanced purchase commitment) for emissions reduction would be more effective in stimulating appropriate innovation.

These considerations indicate how important it is to consider **both the operation of spot and futures markets for emissions trading as it is the latter that will drive innovation incentives**.

⁴ J-J. Laffont and J. Tirole (1996), "Pollution Permits and Environmental Innovation," *Journal of Public Economics*, 62, pp.127-140.

IV. Policy responses

I now turn to consider more specific policy responses that could be deployed to complement environmental policy. As noted earlier, 'getting the prices right' may for various reasons reduce rather than enhance environmentally-friendly innovation. Consequently, other forms of government support will be required.

Allocation of public research funds

Public support for innovation to mitigate and adapt to climate change will invariably take the form of a system of grants and the direct application of funds to particular projects. While this method of resource allocation has difficulties, one key issue faced by policy-makers is in evaluating which projects to fund.

If an emissions trading scheme were set-up, this substantially improves the ability of policy-makers to choose the right projects and, indeed, to 'pick winners.' The reason is this: the appropriate metric to choose one project over another is the expected value of the reduction of emissions per dollar invested. Any given project should be able to forecast its expected emissions reduction and, moreover, the existence of a price of emissions (both today and into the future) given by emissions trading will tell policy-makers the value of that reduction. Thus, **the setting up of an emissions trading regime allows policy-makers to readily evaluate the efficacy of different technological and discipline-based proposals.** This advantage raises our confidence in being able to allocate public research funds appropriately.

Use of prizes

As noted earlier, in the context of emissions trading, prizes may give rise to more effective governmental commitment than relying on the market to develop innovations for mitigation. To generate a prize requires a specified need together with an explicit performance metric. The first research team to resolve the need and exceed that metric gets a cash payment. This is referred to as a 'prize' model. (A variant of this is an 'advance purchase commitment' whereby the winning team obtains a contract for a minimum quantity of the new product).

There are examples of such models being sporadically tried by governments and private benefactors (most notably Google's Larry Page and the X Prize foundation). More recently, the US DVD rental distribution company, NetFlix, has offered a million dollar prize for a better customer information assessment system that outperformed its existing system by a certain amount. The contest will run for 5 years.

Some economists favour prizes over IP protection. [Joseph Stiglitz](#) makes the case for prizes rather than patents.

A scientific panel could establish a set of priorities by assessing the number of people affected and the impact on mortality, morbidity, and productivity. Once the discovery is made, it would be licensed.

Stiglitz notes the problem with patents for medical drugs and technologies: high price = more illness/deaths. His solution is to ensure low prices by having governments fund prizes for proven innovations. So consumers pay indirectly through the tax system.

Prizes tie the innovative reward to performance and they allow for competition in claiming that reward. It is a highly incentivised system that doesn't actually require any money up front or for failure. However, to work the prize amount has to be high enough (there is risk being borne by entrants) and the terms have to be clear enough. What is more, the prize needs to be a credible contract as performance may take years to achieve.

So when it works, a prize system can be highly desirable. The issue is that it doesn't work for all innovations. First of all, many attempts have been made to use the internet to set up markets whereby firms specify needs and a prize and others compete for them. However, these appear to have been rather thin markets. Second, it is sometimes hard to define performance metrics that can be immediately monitored. For instance, a prize for a vaccine might be awarded only to discover years later that the solution has unwanted side effects. Nonetheless, there are many aspects of climate change policies where needs can be articulated and prizes might be a straightforward means of generating solutions.

Facilitating technology adoption

In the context of mitigating climate change, Australia will likely benefit most from adopting appropriate technologies from overseas. This is particularly the case at the consumer level. Specifically, there are many products that can be deployed to support consumer adjustment in response to the increased costs of energy, fuel and other products produced with high carbon costs. The question is: *will pricing pressure be sufficient to cause behavioural adjustments in the near term or is the installed base of household and related products too large to generate a quick transition?* If the latter, then it may be the case that new products that economise on emissions may not earn a sufficient return to developers in the short-term. Moreover, existing intellectual property protection of such products may slow the adoption by households below the rate that would be socially desirable. In this respect, there may be a role for governments in 'sponsoring' technologies and using their coordinating power to speed up adoption.

This situation is not unlike the half century old issue confronting public health policy in Australia. Australia's constitution mandates that suppliers cannot be forced to provide products to the government. In the case of pharmaceuticals, this means that the government could not obtain supplies on terms other than negotiated terms. In response to this, the Pharmaceutical Benefits Scheme (PBS) provides a per unit (dose) subsidy on selected pharmaceutical products. The subsidy is negotiated between the relevant company and the government but the agreement is then to provide products for a fixed low price. As any provider could choose not to accept this deal and charge freely for their products, they cannot be worse off as a result of the agreement with the government (their monopoly profits are maintained). However, they agree to a lower per unit subsidy than a freely chosen price because the government agrees to shield consumers from the direct costs of the subsidy. Thus, the government is procuring on behalf of all consumers but consumers are choosing on the basis of a relatively low price. From a social welfare perspective this is a win-win. Consumption is much closer to its socially desirable level while firms receive as much profits as they would anyway (perhaps more) than in an unfettered market. Even absent spillovers from some products (e.g., vaccines), the PBS removes a distortion to efficient operations in a technologically dynamic industry.

In my opinion, we could do the same thing with respect to products that will support low emission choices on the part of households (and business as well). There are similarities between environmental policy and health policy in this regard. First, the products are consumed by a large proportion of the population. Second, many of the new products are subject to IP protection that will rule out competitive supply. Third, there are products that satisfy different consumers needs differently and so we want to maintain consumer choice with regard to these. Fourth, products need to be rated and approved as to efficacy (in this case, in actually generating low emissions). Finally, there are spillovers from speedy adoption.

Policy institutions

As noted above there is likely to be a need for coordination in public support of innovation to mitigate and adapt to climate change. It is difficult to see how a decentralised approach to managing technology and skill development can function given the time pressures currently upon us. Consequently, it is natural to consider that an independent authority be charged with responsibility for all of the following:

- Allocating public funds for research projects to mitigate and adapt to climate change
- Devise and administer prizes and advance purchase commitments
- Formulate technological efforts to deal with the adverse consequences in terms of weather, health and sea levels associated with climate change
- Coordinate research areas with international efforts to avoid duplication
- Administer adoption programs including standards and public subsidies
- Develop higher education programs to ensure inter-disciplinary expertise for businesses and others to manage the implementation of emissions compliance as well as the development and adoption of new technologies

- Monitor the progress of scientific knowledge on climate change and make recommendations for use in determining emissions caps

This institution should be independent so as to allow its coordinating role to be managed independent of departmental and other interests. Moreover, that independence will allow its performance to be monitored so as to ensure that appropriate actions are taken in all of these areas.