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The Green Entrepreneurial State

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The Green Entrepreneurial State

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Abstract: The paper considers the direct, strategic investments that have been made by international public institutions creating and shaping (not only fixing) green technology. It builds on the key themes found in the The Entrepreneurial State: debunking public vs. private sector myths.

JEL key words: **:** G20 (financial institutions and services: general); 013 (Environment); O16 (economic development: financial markets); O38 (technological change: government policy); L52 (industrial policy).

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Introduction

Never more than today is it necessary to question the way in which we discuss the role of the State in the economy. This is because in most parts of the world we are witnessing a massive *withdrawal* of the State, one that has been justified in terms of debt reduction and – perhaps more systematically – in terms of rendering the economy more 'dynamic', 'competitive' and 'innovative'. Business is accepted as the innovative force, while the State is cast as inertial – necessary for the 'basics', but too large and heavy to be the dynamic engine.

This paper is committed to dismantling this false image. The paper, builds on the work on *The Entrepreneurial State: debunking public vs. private sector myths* (Mazzucato, 2013) applied specifically to the opportunities for 'green' technology and innovation. Unsurprisingly, we find that across the globe the countries that are leading in green transformations (solar and wind energy are the paradigmatic examples explored) are those where the State is playing an active role. And the public sector organizations involved, such as development banks[1] in Germany, Brazil and China, are not just providing countercyclical lending (as Keynes would have asked for), but are even 'directing' that lending towards the most innovative, risky, and uncertain parts of the 'green' economy. Questions about whether such 'directionality' should raise the usual worries about the State's inability to 'pick winners' are confronted head on, demystifying old assumptions.

Green entrepreneurship – what every policy-maker today seems to want to encourage – is not (just) about start-ups, venture capital and 'garage tinkerers'. It is about the willingness and ability of economic agents to take on risk and uncertainty: what is genuinely unknown. Most of the radical, revolutionary innovations that have fuelled the dynamics of capitalism – from railroads to the Internet, to modern-day nanotechnology and pharmaceuticals – trace the most courageous, early and capital-intensive 'entrepreneurial' investments back to the State. Such

radical innovations did not exist before the State envisaged and developed them, consequently, *markets* for these new products or services had also to be *created and shaped* by the 'visible hand' of the State.

Yet most economists talk simply of fixing 'market failures'. Standard economic theory justifies State intervention when markets fail to efficiently allocate resources and reach a 'Pareto equilibrium',[2] as when the social return on investment is higher than the private return – making it unlikely that a private business will invest. Classic cases include cleaning up pollution (a negative 'externality' not reflected in prices) and funding basic research (a 'public good' difficult to appropriate privately). But State investment must be more than this. Visionary investments are exemplified today by confident State investment banks that are directing lending to new uncertain areas that private banks and venture capitalists (VCs) fear. The State can act as a force for innovation and change, not only 'de-risking' the economic landscape for risk-averse private actors, but also boldly leading the way, with a clear and courageous vision – exactly the opposite image of the State that is usually sold.

In economics, the 'crowding-out' hypothesis is used to analyse the possibility that increased State spending reduces private business investment, since both compete for the same pool of savings (through borrowing). This in turn might result in higher interest rates which reduce the willingness of private firms to borrow, and hence invest. While Keynesian analysis has argued against this possibility during periods of underutilized capacity, the point is that even in the boom (when in theory there is full capacity utilization), there are in practice many parts of the risk landscape where private business fears treading and the State must lead the way – therefore, the crowding-out hypothesis would not apply here either, if government is 'transforming' creating and shaping markets not only fixing them.

Thus, to dismantle that false image, a proper defence of the State should argue that it not only 'crowds in' private investment (by increasing GDP through the multiplier effect) – a correct but limited point made by Keynesians – it does something more. It is necessary to build a theory of the State's role in shaping and creating markets – more in line with the work of Karl Polanyi (2001 [1944]) who emphasized how the capitalist 'market' has from the start been heavily shaped by State actions. In innovation, the State not only 'crowds in' business investment but also 'dynamizes it in' – creating the vision, the mission and the plan. This paper explains the process by which this happens as a central feature of green transformations.

The paper in particular focuses on the role of the 'entrepreneurial' risk-taking State in launching specific 'green' technologies, in this case wind turbines and solar photovoltaic (PV) panels. It was State funding and the work of particular State agencies that provided the initial push, early stage high-risk funding and institutional environment that could establish these important technologies. Currently, it is also State funding, particularly through development banks, that is promoting the *diffusion* of those green energy technologies, which highlights that States have a role to play throughout the entire innovation chain and not just in public good areas such as research and development (R&D). The paper emphasizes the role of countries like Germany, Denmark and China in directing green transformations. The paper thus provides a fuller understanding of the public sector's centrality to risk-taking activities and radical technological change, essential to promote green transformations.

Transforming the energy sector

We cannot influence the emergence of innovative new 'green' companies, technologies, or transform energy markets without policies directed at both the demand- and supply-side

(Edler and Georghiou, 2007). Each influences either the structure and function of markets or the investment of firms attempting to grow or transition into green technology sectors. So, in the case of the energy sector, demand-side policies include environmental regulations, public procurement, support of private demand, and other systemic policies that have an impact on energy consumption patterns. Supply-side policies are focused on how energy is generated and distributed, and influence the development of innovation in energy technologies through the provision of finance (e.g. grants, equity support, tax incentives) or through service support (e.g. information brokerage, networking, development of common visions). Examples of demand-side policies include Renewable Portfolio Standards, greenhouse gas (GHG) emission reduction targets, energy-intensity targets (a measure of energy use per unit of GDP), new building standards, or even a 'carbon tax' that affect consumer preferences. Each targets energy consumption patterns, and establishes a demand for reduced pollution, increased clean energy, or better energy-system efficiency. State stimulus to green energy technologies is therefore indirect, via changes in consumer demand that stimulate the development of innovations. Supply-side policies could include tax credits, subsidies, loans, grants or other monetary benefits for specific energy technologies, favourable energy pricing schemes (such as 'feed-in tariffs'), R&D contracts and funding for discovery and development of innovations, and so on. Such policies directly support the development of technologies, complementing and providing a 'solution' to demand-side policies. Understanding how businesses transform government support mechanisms into lower-cost, higher-performance products through the innovation process is typically the 'missing link' in discussions of energy policy, and this missing link can undermine not just our desire to push an energy transition – but to do it with high-road investments in innovation. State support for clean technologies must continue until they overcome the sunk-cost advantage of incumbent technologies, and these sunk costs are a century long in some cases (Unruh, 2000). That is

why much of this paper focuses on supply-side support mechanisms. In the current policy environment, many countries have been aggressively deploying public finance with the aim of promoting green industry – and this is the most direct support possible for business development.

Funding a 'green' industrial revolution

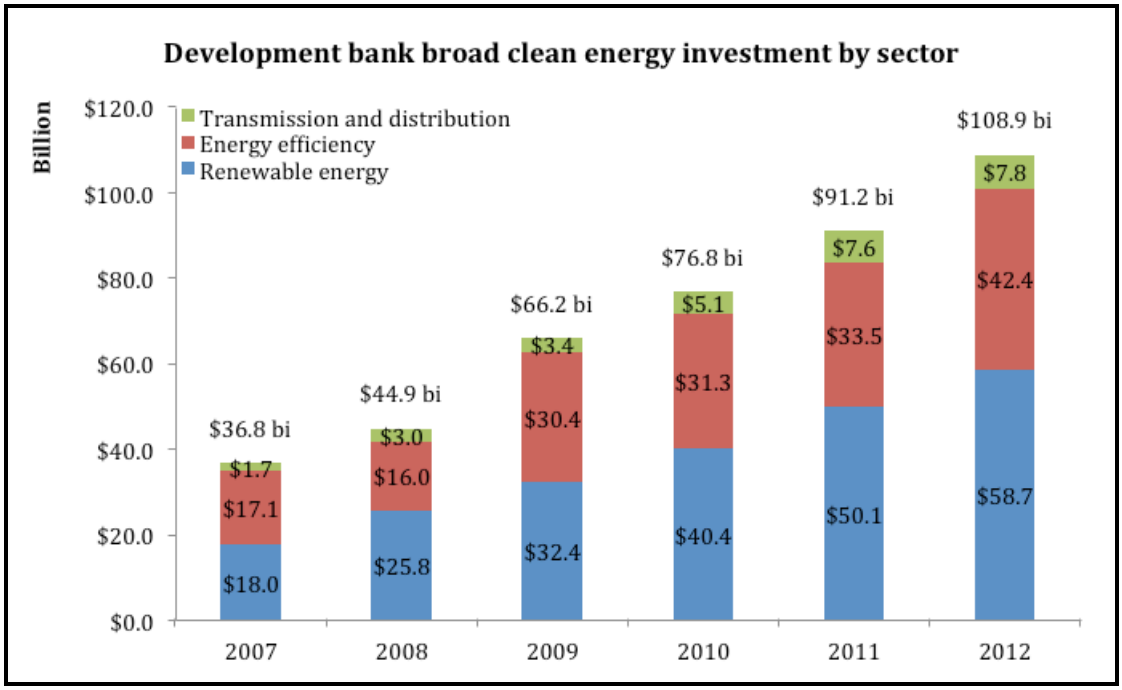
Advanced clean technologies, like all radical technologies, have many hurdles to clear. Some hurdles may relate to technical development (such as improving or inventing production techniques), others are due to market conditions or competition. In the case of renewable energy sources, like wind or solar power, broad social acceptance or the need to provide energy at a price lower than possible by other firms and technologies are also major hurdles (Hopkins and Lazonick, 2012). Given these challenges, the financial risk of supporting a firm until it can mass produce, capture market share and reach economies of scale, driving down unit costs is too great for most VC funds (Hopkins and Lazonick, 2012, p7).

In the innovation game, it is therefore crucial that finance be 'patient', and be able to accept the fact that innovation is highly uncertain and takes a long time (Mazzucato, 2013a). Patient capital can come in different forms. The German feed-in tariff (FIT) policy is a good form of public 'patient capital' supporting the long-term growth of renewable energy markets (Lauber and Mez, 2006). By contrast, the availability but also frequent uncertainty surrounding tax credits in the US and the UK are a form of 'impatient capital' – which indeed has not helped industry take-off (Porritt, 2011; Cowell, 2012). The most visible patient capital made available to renewable technology manufacturers and developers has been delivered through State-funded investment or 'development banks'. According to the Global Wind Energy Council (GWEC):

> The main factor that distinguishes development banks from private sector lending institutions is the ability of development banks to take more risk associated with political, economic and locational aspects. Further, since they are not required to pay dividends to private stakeholders, the development banks take higher risks than commercial banks to meet various national or international 'public good' objectives. Additionally, long-term finance from the private sector for more than a ten year maturity period is not available (Fried et al, 2012, p6).

The role and scope of development banks is more diverse than simply financing projects (Griffith-Jones and Tyson, 2013; Mazzucato and Penna, forthcoming 2014). Development banks can set conditions for access to their capital, in an effort to maximize economic or social value to their home country. Most development banks deliberately seek to invest in areas that have high social value, and are willing to make risky loans that the commercial sector would shy away from. Additionally, while these banks support consumption of renewable energy, they can also support manufacturing. Development banks are flexible financiers, and can provide significant capital to renewable energy projects, which can represent as great an investment risk as the development of new technologies. Given the amount of financial resources in their possession, their investment decisions play an important role in economic development trajectories. In this sense, it came as good news that in 2013 some development banks (such the World Bank and the European Investment Bank) decided to curtail funding for coal power (FS-UNEP/BNEF, 2014). And in recent years, development banks have been a key source of funding for 'clean energy' projects, committing more than US$100 billion in 2012 (Figure 1).[3]

Fig. 1 (source BNEF)



In 2012, China announced its plan to produce 1000 GWs of wind power by 2050. That would be approximately equal to replacing the entire existing US electric infrastructure with wind turbines (Liu, 2012). Are the US and Europe still able to dream so big? It appears not. In many countries, the State is asked to take a back seat and simply 'subsidize' or incentivize investments for the private sector. We thus fail to build visions for the future similar to those that two decades ago resulted in the mass diffusion of the Internet.

What then is the role of 'patient' finance – for example that supplied by State development banks – in creating the 'catalytic' early, and risky, investments necessary to make it happen (Mazzucato and Penna, 2014)? Clean energy is a paradigmatic example of technology that needs to be widely deployed in order for the green industrial revolution to succeed. In recent years, governments around the world have once again taken the lead in pumping up R&D of many clean technologies like wind and solar power, and efforts are being made to establish modernized energy grids. They also subsidize and support the growth of leading manufacturers that compete for domestic and global market leadership. And governments

deploy both policy and finance to encourage stable development of competitive markets for renewable energy. As has been the case in the development of other industries such as biotech and IT, private businesses have entered the game only after successful government initiatives absorb most of the uncertainty and not a little risk of developing new energy technologies in the first place.

The 'green' energy industry is still in its early stages: even though development of wind and solar power technologies received a big push in the 1970s (due to the energy crisis), they are both still characterized by market and technological uncertainty.[4] It will not develop 'naturally' through market forces, in part because of embedded energy infrastructure, but also because of a failure of markets to value sustainability or to punish waste and pollution. In the face of such uncertainty, the business sector will not enter until the riskiest and most capital-intensive investments have been made, or until there are coherent and systematic policy signals in place. In a recent interview, Microsoft founder Bill Gates, one of the principals of the American Energy Innovation Council (AEIC) recognized that 'a key element to get an energy breakthrough is more basic research. And that requires the government to take the lead. Only when that research is pointing towards a product then we can expect the private sector to kick in.'[5]

As in the early stage of IT, biotech and nanotech industries, there is little indication that the business sector alone would enter the new 'green' sector and drive it forward in the absence of strong and active government policy. Indeed, the Climate Policy Initiative (2013) reports that institutional investors contributed with only US$0.4 billion to climate change mitigation and adaptation projects (a minimal figure considering the US$70 trillion in assets that they manage); venture capital, private equity and infrastructure funds invested other US$1.0 billion only. Thus, while 'nudging' might incentivize a few entrepreneurs to act, most

business actors will need stronger signals to justify their engagement in clean technology innovation. Only long-term policy decisions can reduce the uncertainty of transforming core business from legacy into clean technologies. In fact, no other high-tech industry has been created or transformed with a 'nudge' (Mazzucato, 2013b). Most likely, a strong 'push' is needed.

National approaches to green economic development

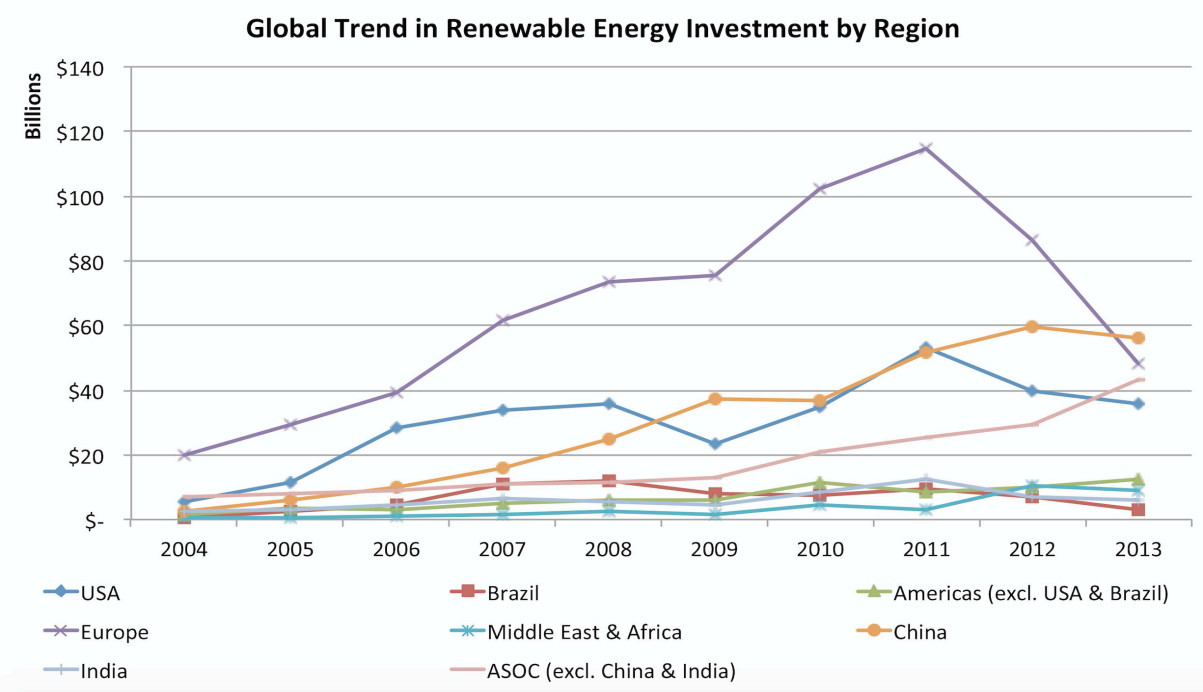
There are differences in how countries are reacting to the challenge of developing a green economy. Some countries have used the post-crisis stimulus spending as a way to direct government investments into global clean technology industries, with two goals: to provide economic growth, while mitigating climate change. While some countries lead, others are lagging behind. As investments in innovation are cumulative and the results are 'path dependent' (innovation today is dependent on innovation yesterday), it is likely that the leaders emerging from this race will remain leaders for years to come. In other words, those acting first or as a fast-follower will enjoy a early-mover advantage, as in the success case of Toyota, who pioneered hybrid vehicle technology and benefitted from an early 'halo effect', which later resulted in it being the biggest winner of the US 'cash for clunkers' scheme[6] (Sperling and Gordon, 2009; USDOT, 2009).

Yet, failure of some governments to provide the vision and to 'push' clean technology is having an impact on the amount of investment occurring. Countries that pursue a patchy policy towards clean technology will not stimulate enough investment to alter their 'carbon footprints', nor should they expect to host the clean technology leaders of the future. An example of a country going for a 'big push' is China; Germany is also a first mover among European countries. The US has shown contradictory trends, with the State making early and

substantive investments in green technologies. By proceeding without a clear vision and goal in mind, however, and without a long-term commitment to several key technologies, the US has failed to alter significantly its energy mix, despite the bigger push at the state level (notably in California, North Carolina and, surprisingly, Texas) (Carley, 2011; Prasad and Munch, 2012). The UK is also lagging behind.

In the US, the 2009 American Recovery and Reinvestment Act stimulus packages devoted 11.5 per cent of their budget to clean technology investments, lower than China (34.3 per cent), France (21 per cent) or South Korea (80.5 per cent), but higher than the UK (6.9 per cent). In July 2010, the South Korean government announced that it would double its spending on green research to the equivalent of US$2.9 billion by 2013 (almost 2 per cent of its annual GDP), which means that between 2009 and 2013 it will have spent US$59 billion on this type of research in total. Figure 2 shows that Europe, the US and China have dominated global new investment in renewable energy between 2004 and 2012, with other economies from Asia (such as South Korea and Japan) and Oceania catching up in 2013. In Europe, investments are led by Germany.

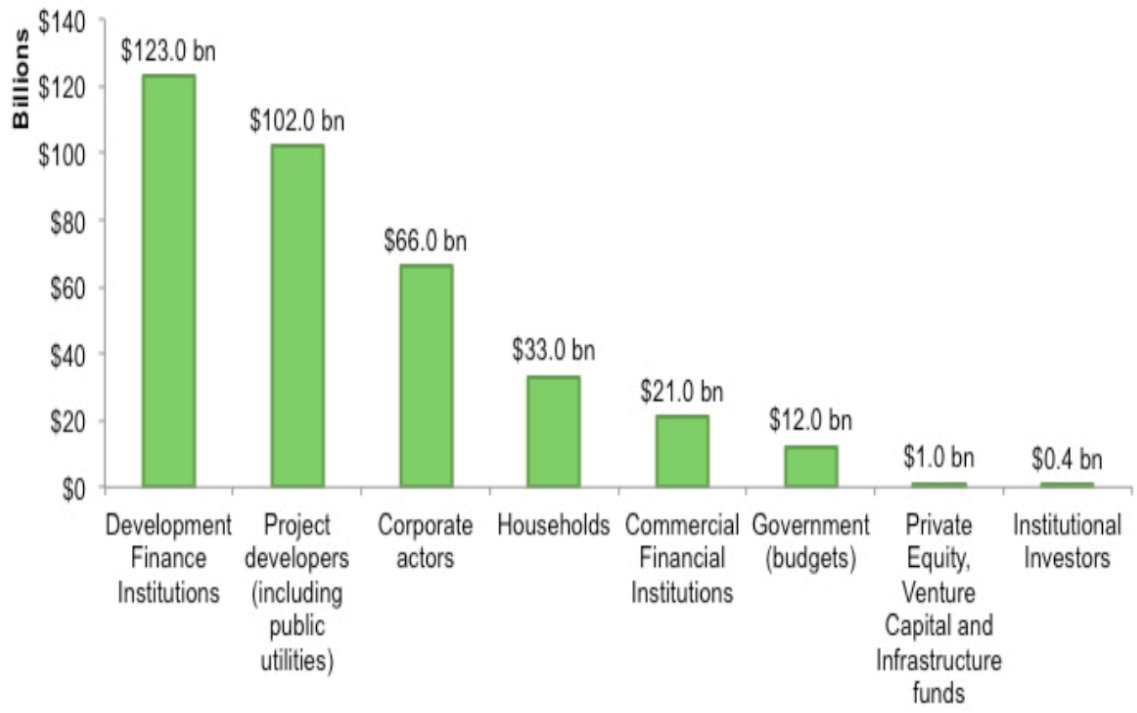
Fig. 2 (source: FS-UNEP/BNEF, 2014)



Other than R&D expenditures, State investment banks are taking a leading role in clean technology development and diffusion in some emerging countries (Mazzucato and Penna, 2014; 2015). In 2011, Germany's KfW bank announced it would make available €100 billion (US$120-130 billion) over the following five years to promote renewable energies and contribute to Germany's *Energiewende* plan ('Energy Turnaround'), which will promote the complete decommissioning of the country's nuclear power plants by 2022 (OGFJ, 2011; Reuters, 2012). Indeed, in 2012 KfW was the top development bank in terms of clean energy investments, with its total commitments amounting to US$34 billion (Louw, 2013, p6). In China, investments by the China Development Bank (CDB) are a key source of its success in solar power (Mazzucato and Penna, 2015). CDB funding to green energy projects in general is indeed generous: between 2007 and 2012, CDB committed US$78 billion to clean energy, US$26 billion in 2012 alone (Louw, 2013, p6). The CDB extended US$47 billion after 2010 to approximately 15 leading Chinese solar PV manufacturers to finance their current and

future expansion needs; though firms had drawn on approximately US$866 million in 2011 (Bakewell, 2011). The rapid scaling of solar PV manufacturing firms made possible by public finance has quickly established Chinese solar technology manufacturers as major international players. As such, they are able to slash the cost of solar PV panels so quickly that much of the financial media argues that this access to credit is the reason behind bankruptcies of solar companies based in the United States and Europe (e.g. Forbes, 2011). The Brazilian Development Bank (BNDES) approved over US$4.23 billion in clean technology financing in 2011 (Fried et al, 2012, p5). Today, state investment banks are spending over US$100 billion annually on energy efficiency and renewable projects (Louw, 2013), while clean energy project bond issuance reached just US$3.2 billion in 2013 (FS-UNEP/BNEF, 2014, p44). While precise figures comparing all public and private sources of finance for *renewable energy* projects are not available, the picture is likely to be similar to the 'Global Landscape of Climate Finance' (Climate Policy Initiative, 2013), which includes all types of climate change mitigation and adaptation projects (Figure 3).

Fig. 3 Global Landscape of Climate Finance (Source: Climate Policy Initiative)



China's 'green' 5-year plan

Facing backlash in European and US markets (through trade war and tariffs backed by government and initiated by competing firms) against the success of its nascent solar industry in lowering prices, China opted to revise its domestic solar power development goal to 20 GWs by 2015 – at a time when just three GWs exists in the country currently (Patton, 2012). Complementing these targets are regional feed-in tariffs that fix the price of energy produced by wind and solar projects on more favourable terms (Landberg, 2012). Other incentives for Chinese energy developers ensure that today's technologies can recover their costs in seven years, and generate returns for decades, while manufacturers continue to improve technologies (Liu, 2011). China's goal of 100 GWs of wind power by 2015, and 1000 GWs by 2050 is a second aggressive goal promoting economic development and reduced carbon emissions (Liu, 2012). So far, China's targets have only been revised upwards; suggesting that ample opportunity for domestic industry will persist into China's foreseeable future.

What is more, China's green strategy is guided by an overarching vision encapsulated in its ongoing 12th 5-year plan (2011–15). China's visionary and ambitious plan aims to invest US$1.5 trillion (or 5 per cent of GDP) across multiple industries: energy-saving and environmentally friendly technologies, biotechnology, new generation ITs, advanced manufacturing, new materials, alternative fuels and electric cars (Yuan and Zuo, 2011b; Mathews et al, 2011). Overarching these investments are intentions to adopt a 'circular' approach to economic development that places sustainability first, a directive which defines pollution- and waste- control as forms of competitive advantage (Mathews et al, 2011). Accompanying investment in industrial development are energy-intensity reduction targets, emission controls, and renewable development goals; a combination of supply-side and demand-side policies.

Recognizing that the competitive advantage of the future depends on effective resource management as well as reduced waste and pollution, China's 'green development' strategy is re-framing the notion of how 'optimal' economic development unfolds with aggressive demand- and supply-side measures. China's 'win–win' plans make 'profit' and 'environment' complementary pursuits rather than trade-offs, as they are often treated in many Western economies. As a result, China is poised not only to continue as a major manufacturer of solar PV panels, but also become a major market for them.

In sum, China now prioritizes clean technologies as part of a strategic vision and long-term commitment to economic growth. While already providing billions of dollars for new renewable energy project finance, China is in fact just beginning its serious investment in solar and wind technology (Lim and Rabinovitch, 2010; Zhang et al, 2014). Given the huge size of its economy, however, China's GHG emissions are still poised to grow in absolute terms, and it is still to be seen whether the country will be able to decouple economic growth from GHG emissions – which would represent an original development path, never before seen in the history of industrialization.

United States: An ambiguous approach to green technologies

A clue to what is required to accelerate green transformations is found in the US, where government-funded initiatives are busy building on their understanding of what has worked in previous technological revolutions. While the US has been good at connecting academia with industry, in its own push into clean technologies, its performance has been uneven. As one of the first countries to push into wind and solar power in the 1980s, the US failed to sustain support and watched as Europe, Japan and now China take the lead. Worse, the US failed to alter its energy mix significantly, setting up its position for decades as a world-

leading CO_2 emitter. With world-class innovative capability, the world's largest economy and a massive energy grid, the US is ideally positioned to kick off a clean technology revolution, yet it has not.

A key reason for uneven US performance has been its heavy reliance on venture capital to 'nudge' the development of green technologies. The United States is the VC capital of the clean technology world, with US$7 billion invested in 2011 versus US$9 billion globally (Hopkins and Lazonick, 2012). But VCs have shown themselves to be 'impatient capitalists': They are not interested in sustaining the risks and costs of technological development over a long-term period. Indeed, together, private equity, venture capital, and infrastructure funds provided just US$1 billion for climate change mitigation/adaptation projects in 2012, much less than State development banks (US$123 billion) and even other governmental agencies (US$12 billion) that obtain their own funding from limited budgets (Climate Policy Initiative, 2013). VCs also have limits to the financial resources they can allocate to finance fully the growth of clean technology companies. Since some clean technologies are still in very early stages, when uncertainty is highest, VC funding is focused on some of the safer bets, rather than on the radical innovation that is required to allow the sector to transform society so as to meet the double objective of promoting economic growth and mitigating climate change. Ghosh and Nanda (2010, p9) argue that it is virtually only public sector money that is currently funding the riskiest and the most capital-intensive projects in clean technology. Federal and state incentives provide billions to support the establishment and growth of a domestic solar PV market, ensuring that companies have an opportunity to capture market share and reap economies of scale.

Impatient capital can destroy firms promising to deliver government-financed technology to

the masses, but critics often focus on the government as the source of failure, rather than examining the behaviour of the smart, profit-hungry business community in producing that failure by jumping ship, restricting their total commitments, or demanding financial returns over all other considerations. If VCs are not interested in capital-intensive industries, or in building factories, what exactly are they offering in terms of economic development? Their role should be seen for what it is: limited. More importantly, the difficulties faced by the growing clean technology industry should highlight the need for better policy support – not less, given that existing financing models favour investors and not the public interest.

'Nudging' economies is not conducive to igniting a real green transformation. Those nations that cling to the bogus idea that government investment has some sort of a natural balancing point with the business sector will miss their opportunity to seize on an historic energy transition, or be forced to import it from elsewhere. In reality, government and business activities frequently overlap. Clean technology businesses, like most businesses, are apt to call for subsidy and government-led R&D. Venture capitalists and technology entrepreneurs respond to government support in choosing technologies to invest in, but are rarely focused on the long-term.

Getting to much-needed green transformations presents a serious problem: given the risk aversion of businesses, States need to sustain funding for the search for radical ideas that push a green industrial revolution along. Governments thus have a leading role to play in supporting the development of clean technologies past their prototype stages through to their commercial viability.

Real courage exists in those countries that use State resources to give a serious 'push' to

clean technologies, by committing to goals and funding levels that attempt seemingly impossible tasks. Courage is China's attempt to build a US and European electric grid–sized market for wind turbines by 2050 and to increase its solar PV market by 700 per cent in just three years. Courage is also development banks stepping in where commercial banks doubt, promoting development, growth of the firm and a return on investment to taxpayers that is easier to trace. It is important that tax money is traceable in its promotion of technologies and generation of returns. Success makes support for another round of risky investments more likely, and creates better visibility for the positive role that government can play in fostering innovation (Lazonick and Mazzucato, 2013).

If some European countries have demonstrated the value of long-term policy support for R&D and market deployment, the United States has in contrast demonstrated how maintenance of a state of uncertainty can lead to missed opportunities. The US failed to adopt a long-term national energy plan that places renewables at the forefront, while also refusing to reduce or abandon support for other, more mature energy technologies, leaving the task of direction setting with its states.

Nurturing green technologies

Historically, different types of government policies have played important roles in the origins of many green technologies. This section looks at the history of two renewable energy technologies: wind turbines and solar PV modules.

As characteristically 'intermittent' and 'diffuse' sources of energy, wind and solar power have benefitted from what Madrigal (2011, p263) describes as 'throwing software at the problem': increasing the productivity and reliability of wind and solar projects with advanced

computer modelling, management of power production and remote monitoring. Investments in a 'smart grid' are meant to digitize modern energy systems to optimize the flexibility, performance and efficiency of clean technologies while providing advanced management options to grid operators and end users. Such flexibility and control is not unlike the sort that emerged with digitized communication networks. Given time and broad deployment, the smart grid could change the way we think about energy, create new commercial opportunities and improve the economics of renewable energy by establishing new tools for optimal energy supply management and demand response.

Were it not for the commitments of governments around the world to R&D and the diffusion of technologies like wind turbines and solar PV panels, the energy transformation taking off in the last decade would not have occurred. The 'push' has required major regulatory shifts, financial commitments and long-term support for emerging companies. It is not always clear how to connect the dots between dominant firms and their technologies and the efforts of governments around the world, but it is clear that no leading clean technology firm emerged from a pure 'market genesis', that is, as if the State played no role at all.

The apparent willingness of the State to accept the risk of clean technology development has had a positive impact. In the last few decades, wind turbines and solar PV panels have been two of the most rapidly deployed renewable energy technologies on the planet, spawning growing industries that are emerging in many regions of the world. In 2008, US$194 billion was directed at emerging clean technologies in an effort to provide badly needed economic stimulus to counteract the global economic crisis (NSB, 2012, p62). An unofficial global 'agreement' was thus reached out of the economic crisis, and that agreement was that the time for clean technologies had come (again). A green energy revolution seemed to be within

the realm of possibility – but such 'green transformation' is yet to be seen.

Wide-scale deployment of solar PV panels and wind turbines are two technological solutions for meeting future energy needs and mitigating climate change. The 'ecosystem' of innovation in clean technology is one in which the public sector has taken the leading role. Wind and solar power technologies have been the fruit of major government investments that catalysed their historical development around the world.

While the US and China possesses the largest quantity of wind capacity deployed worldwide, Denmark produced the leading manufacturer of wind turbines (Morales, 2014) decades ago: Vestas. In the US, leading manufacturers also emerged during the 1980s, but each was lost through acquisition or bankruptcy. Germany's solar resources are inferior to those of the United States, yet it remains the world leader of deployed solar PV power. China has emerged as the world's major solar PV manufacturing region, successfully out-competing US, Japanese and European rivals that led in prior decades (Zhang et al, 2014, p904).

What must be explained is how a country like the US can become a leading market, but fail to produce a leading manufacturer, and conversely, how a country like China can produce a leading manufacturer in the absence (until recently) of a domestic market. What distinguishes these nations has nothing to do with their 'comparative advantages' as producers of wind turbines or solar PV panels, and it has nothing to do with a natural abundance of wind or sun. Historically, the development of wind and solar power has reflected differences in government policies meant to foster these power sources. For some countries, this is a process that has unfolded over many decades. For others, it is a process of 'catching-up' – but no matter the case, it is the tools deployed by the State that have supported and attempted to

drive outcomes. The international histories of wind power technology development and of leading wind and solar companies provide examples of the extent to which those industries have benefitted directly (and indirectly) from different kinds of public funding and support.

Wind

The importance of government support is seen most starkly through the consequences of its withdrawal: when the United States government abandoned subsidies for wind power development in the mid-1980s, and slashed the Department of Energy's (DOE) R&D budget in a backlash against attempts to promote energy innovation, the domestic market stagnated and momentum for the industry shifted to Europe, or, more accurately, to Germany. Germany's federal Ministry for Research and Technology launched a programme to develop 100 MWs of wind power in 1989. Combined with a FIT programme, which provided above-market prices for wind power and a 70 per cent tax credit to small producers, Germany began its reign as the hottest market for wind power development in the world (Lauber and Mez, 2006, p106).

Combined with GHG reduction targets, and the intention of meeting renewable energy development goals with domestic manufacturing, in 2009 Germany also set aside national and state funding of approximately US$2.2 billion to support continued wind energy R&D. Germany's long-term approach to wind energy development gained momentum in the 1990s and continues today, enabling the emergence of leading manufacturers while providing stable annual growth in deployed wind capacity. Since the Fukushima Daiichi nuclear disaster, Germany decided to phase out its nuclear installations and develop its Energy Transition (*'Energiewende'*) strategy, whereby renewable energies such as wind will receive further push from the State (Smith Stegen and Seel, 2013). The 20-year investment horizons

provided by government incentives are twice as long as those in the US, reducing market uncertainty and boosting investor confidence. Furthermore, KfW has been enlisted as the key source of finance for the *Energiewende* initiative.

China was a relative latecomer to wind power technology, despite having pushed investment in renewable energy in the 1980s as a technical solution for rural electric infrastructure development (Ma et al, 2010, p440). China's partially State-owned Goldwind, a major wind turbine manufacturer, was established in 1998, and initially licensed German technology from Jacobs (a company later purchased by REpower) and Vensys Energiesysteme GmbH (Lewis, 2007, p15). Goldwind turbines benefitted from aggressive Chinese domestic content rules, which were enacted in 2003 to require 70 per cent local content in all wind turbines sold in China (Martinot, 2010). This effectively shut the door on foreign capital in the country; while China's dominant wind manufacturers strengthened their domestic supply chain and presence.

Chinese wind power developers also received 25-year fixed price contracts that were set through a 'concession' programme (competitive bidding). Wind projects had access to low-cost financing, and after 2005, China began to publicly fund R&D and projects with grants or favourable loan terms. China has also prioritized reducing its overall energy intensity (the relationship between energy consumption and GDP), and established goals for renewable energy development (Martinot, 2010).

Solar

Many examples of innovative emerging firms focusing on solar PV can be found in the US, where First Solar, Solyndra, Sunpower and Evergreen, for example, each developed state-of-

the-art C-Si or thin-film solar technologies (Perlin, 1999). First Solar emerged out of the search for commercialized cadmium telluride (CdTe) thin-film solar PV panels and became a major US-based CdTe thin-film producer. First Solar dominates the US market for thin-film solar PV panels, and has produced record-setting technology and low-cost manufacturing, which have enabled the company to generate over US$2 billion in revenue each year since 2009. First Solar's patents have 'extensive links' to prior DOE research (Ruegg and Thomas, 2011, pp4–11). The success of companies like First Solar was built over several decades, during which VCs entered at a relatively late stage and exited soon after the IPO was completed. Much of the risk of investing in First Solar was taken on by the US government, which actively promoted their solar technology through to commercialization. Subsidies supporting a domestic market and a market in Europe, coupled to First Solar's position as a dominant thin-film producer make it hard to imagine how such a company could fail. Yet the value extraction provided, and even promoted, by equity-driven investment and compensation methods ensures that VCs, executives and top managers of firms can reap massive gains from stock performance, whether short lived or not. This perverse incentive not only redistributes the investment in innovation away from its other core stakeholders (governments, schools, workers), but it risks undermining firm performance. Rather than make the risky investment in future innovation, those in positions of strategic control squander resources in a search for financial returns (Hopkins and Lazonick, 2012).

The story of another solar power technology company – Solyndra – provides an important example of what happens if venture capital suddenly withdraws their financial support. In 2009, Solyndra received a US$527 million loan guarantee from the US DOE, as part of the *American Recovery and Reinvestment Act*, in order to develop copper indium gallium (di)selenide (CIGS) solar panels. With the price of raw silicon soaring (silicon is the primary

ingredient of standard solar panels), investing in high-tech CIGS made economic sense. Yet, a couple of years later, the price of silicon collapsed, before Solyndra could capitalize on its investments. Solyndra VC backers, who had invested US$1.1 billion in the company, were the first to jump ship. Even though all of Solyndra's (public and private) stakeholders were betting on the company's success – not failure – for the critics, the company has become the most recent symbol of government's inability to invest competently in risky technology and to 'pick winners'.

And yet the nearly the same amount of money that was lent to Solyndra was lent to another company: Tesla Motors. Tesla received a US$465 million guaranteed loan for its S car. Unlike the Solyndra investment, this one fared very well and Elon Musk, its founder, is today treated as the new hero of Silicon Valley. As is the case with all innovations, for every success there are many more failures. The problem is that by not admitting that the State provided the high risk investment, and that it is subject to the same high failure rates as private venture capital, innovation policy ends up socializing only the risks and not the rewards (Mazzucato, 2013b, Lazonick and Mazzucato, 2013). Instead of worrying about picking winners or losers the real question should be why the 'entrepreneurial state' does not insist that a small per cent of Tesla's profit come back to the state coffers that provided the high risk finance so that the Solyndra loss could be shouldered not only by the tax payers but the entire innovation 'eco-system' that benefits from such public risk taking.

The role of an active private sector

There is nothing 'accidental' about clean technology development or the formation of markets for renewable energy. Rather, clean technology firms are leveraging technologies and cashing in on the prior investments of an active public sector, and responding to clear

market signals proclaimed by progressive government policies about the desired change, and to the availability of support for clean technology industrial growth. The hope is that innovation will produce economic wealth, employment opportunities as well as a solution for climate change.

While the performance of countries has varied tremendously over the decades, it is obvious that Germany has provided a glimpse of the value of long-term support, China has demonstrated that a rapid scale-up of manufacturing and deployment is possible, and the United States has shown the value of R&D, but also the folly of permitting uncertainty, shifting political priorities and speculative finance to set the clean technology development agenda. Governments leading the charge into clean technology do not have to allow themselves to be cheated when investments go sour. Nor should they expect that taxpayers will happily bear the full risks of investing in these technologies and establishing markets without a clear future reward to be gained.

The challenge is to create, maintain and fund a long-term policy framework which sustains momentum in the clean energy sector building up over the last decade. Without such long-term commitments, it is likely that clean technology will become a missed opportunity for many nations. Such a framework would include demand-side policies to promote increased consumption of solar and wind energy, as well as supply-side policies that promote manufacture of the technologies with ‘patient’ capital.

R&D contributing to clean technologies like wind and solar power has occurred on a global scale for decades, as a result of significant public investments and learning, and the leveraging of a broad community that has been inclusive of educational and business

knowledge networks. The technology works as a result, and improvements in cost and efficiency have proceeded despite the unequal commitments of governments and businesses over time. The cost of energy they produce has also fallen over the long-term, while fossil fuel prices continue to be volatile and rise over time.

Some firms may conduct important R&D for decades and remain money losers without a clear commercial prospect in the pipeline. As shown by the history of First Solar, the government's role in pushing innovations out of the lab and into markets does not end with R&D, but can include a role in overcoming commercialization barriers, such as a lack of production capabilities. Likewise, First Solar's VCs needed to endure challenges and an investment horizon which stretched their commitment.

How can firms of different scales interact in generating green transformations? We should not underestimate the role of small firms nor assume that only big firms have the right resources at their disposal. Small firms that grow into big firms are active promoters of their own business models, often to the frustration of 'legacy' industries that one could argue would never have taken the same technologies so far, so fast. The willingness to disrupt existing market models is needed in order to manifest a real green industrial revolution, and it is possible that start-ups, lacking the disadvantage of sunk costs, are the right actors for the job. Many large firms involved in clean technologies look to smaller start-ups and have themselves in the past, relied on the State.

For example, General Electric (GE) 'inherited' the prior investments of the State and innovative firms in its rise as a major wind turbine manufacturer. GE's own resources are vastly superior to those of small start-ups, which include billion dollar R&D budgets, billions

in annual profit available to reinvest in core technologies, complementary assets such as a vast global network, and, as with the wind industry, significant rapport and reputation that reduce its 'risk' to investors. For renewable energy, scale matters, and larger firms can more easily supply enormous energy grids spanning the continents. Perhaps most importantly, large firms like GE more easily win the confidence of investors and utilities, given their extensive operating history, financial resources, debt rating, experience with electricity infrastructure and vast social networks. It is not so coincidental that wind projects picked up to a feverish pace following GE's entry to the wind energy business.

The political challenges of green transformations

The challenges faced by clean technologies are therefore seldom just technical; they are political (and social) and include a need for greater commitments of patient capital by governments and businesses around the world. R&D works, but it is not enough. Nurturing risky new industries requires support, subsidy and long-term commitments to manufacturing and markets as well. Governments must also confront the reality that for most developed nations, the deployment of clean technologies is occurring within a well-developed infrastructure. The clean slate approach is not possible, meaning that investment is intended to manage a transition to clean technology, a transition that threatens fossil and other energy industries that have the benefit of a longer development period and significant sunk costs. Not all in the business community are shy about calling for an active government role in clean technology. The time is overdue to begin discussing what the real role of business is in technological development beyond funding R&D. The clean technology revolution is at a crossroads. Contrary to conventional wisdom: R&D is not enough; VC is not so risk loving; and small is not necessarily always beautiful. In order for the crossroads to be decided and green transformations to be generated, government policies must overcome these naïve

perspectives.

Innovation cannot be pushed without the efforts of many, and it cannot proceed without a long-term vision that sets the direction and clarifies objectives. When government policies fail, public dollars can be wasted and promising technologies may fail to meet their potential, because politicians or taxpayers refuse to commit more resources. When businesses fail, thousands of jobs can disappear, investors lose confidence and the reputations of the technologies are scarred. Uncertainty and stagnation can prevail, while the potential for promising new solutions vanishes. With government and business activities so intimately linked, it is often impossible to point blame accurately. At the root of it, there is only collective failure.

What should be clear is that the green energy revolution that has been experienced so far is a result of a complex long-term, multi-decade-long technological development and diffusion process that unfolded on a global scale. The process has benefitted from major government investments that encouraged the establishment of new firms and supported their growth by creating market opportunities. The variety of policies was meant to produce technological development, market efficiency, scale and efficient regulation. Overarching this process is a broad call to accelerate economic growth through innovation in clean technologies that mitigate climate change and promote energy diversity. The long-term vision is to transform our current productive system into a sustainable green industrial system. That is a mission set on producing long-lasting benefits to the public while delivering on a promise of superior economic performance. Key to future green transformations taking off will be the building of innovation ecosystems that result in symbiotic public–private partnerships rather than parasitic ones. That is, increased investments by the State in the ecosystem should not cause

the private sector to invest less, and focus its retained earnings on areas like boosting its stock prices rather than on human capital formation and R&D.

The challenges of developing clean technologies go far beyond establishing risky public sector energy 'innovation hubs'. Governments must reduce the risk of commercializing energy innovations while establishing and managing the risks of competing in diversified and global energy markets. When difficulty has arisen in the past, such as when wind or solar markets faltered following retraction of US support for renewables in the late 1980s, the tendency has been to focus on how government investment is flawed, while the role of business in contributing to that failure is ignored, or written off as part of the 'natural' behaviour of competitive markets. Worse, some interpret difficulties as proof that a technology 'can't compete' or will never compete with incumbent technology and should be shelved rather than exploited. This would go against the historical record, which suggests that all energy technologies have needed and benefitted from lengthy development periods and long-term government support. What matters more is that the effort continues as if the future of the planet depended on it – because it does.

Conclusion

In seeking to promote innovation-led green transformations, it is fundamental to understand the important roles that both the public and private sector can play and the political dynamics involved. This requires not only understanding the importance of the innovation 'ecosystem' but especially what it is that each actor brings. The assumption that the public sector can at best incentivize private sector-led innovation (through subsidies, tax reductions, carbon pricing, technical standards and so on) fails to account for the many examples in which the leading entrepreneurial force came from the State rather than from the private sector.

Ignoring this role has had an impact on the types of public-private partnerships that are created, and has wasted money on ineffective incentives that could have been spent more effectively.

To understand the fundamental role of the State in taking on the risks present in modern capitalism, it is important to recognize the 'collective' character of innovation. Different types of firms (large and small), different types of finance and different types of State policies, institutions and departments interact sometimes in unpredictable ways – but surely in ways we can help shape to meet the desired ends. For years we have known that innovation is not just a result of R&D spending, but about the set of institutions that allow new knowledge to diffuse throughout the economy.

What distinguishes the State is of course not only its mission but also the different tools and means that it has to deploy the mission. Polanyi argued that the State created – pushing, not only nudging – the most 'capitalist' of all markets, the 'national market', while local and international ones have predated capitalism. The capitalist economy will always be embedded in social, cultural and political institutions and therefore subordinate to the State and subject to its changes (Evans, 1995). Such embeddedness in fact renders meaningless the usual static state vs. market juxtaposition, because, as Polanyi (2001 [1944], 144) has demonstrated, the State *shapes* and *creates*: *'[t]he road to the free market was opened and kept open by an enormous increase in continuous, centrally organized and controlled interventionism'*. Thus, rather than relying on the false dream that 'markets' will run the world optimally for us 'if only we just leave them alone', policy-makers must better learn how to use efficiently the tools and means to shape and create markets – making things happen that otherwise would not. And making sure those things are things we need. Increasingly this requires growth to be

not only ‘smart’ but also ‘inclusive’ and ‘sustainable’.

It is of course important not to romanticize the State’s capacity. The State can leverage a massive national social network of knowledge and business acumen, but we must make sure its power is controlled and directed through a variety of accountability measures and diverse democratic processes. However, when organized effectively, the State’s visible hand is firm but not heavy, providing the vision and the dynamic push (as well as some ‘nudges’) to make things happen that otherwise would not have. Such actions are meant to increase the courage of private business. This requires understanding the State as neither a ‘meddler’ nor a simple ‘facilitator’ of economic growth. It is a key partner of the private sector – and often a more daring one, willing to take the risks that business won’t. The State cannot and should not bow down easily to interest groups who approach it to seek handouts, rents and unnecessary privileges like tax cuts. It should seek instead for those interest groups to work dynamically with it in its search for green growth and technological change.

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[1] ‘Development banks’ and ‘State investment banks’ are used as synonyms throughout this paper.
[2] In a Pareto equilibrium, no person can be make better off without another person being made worse off.
[3] Data on development bank investment in clean energy for 2013 was not available as of the time of writing this paper (May 2014), but they ‘are likely to have increased their investment in clean energy in 2013’ (FS-UNEP/BNEF, 2014), *despite* a 14 per cent decrease in the overall clean energy investments (i.e. including all sources of funding) between 2012 and 2013.
[4] Some green energy subsectors, such as on-shore wind power, are more technological mature than others, such as off-shore wind power.
[5] Online interview, available at https://www.youtube.com/watch?v=x54bVuduggU, accessed 24 June 2014.
[6] The 2009 ‘Cash for Clunkers’ scheme – officially the *Car Allowance Rebate System* (CARS) - was US$3 billion car-scrappage program that offered consumers a credit of US$3500-US$4500 toward the purchase of a new, more fuel-efficient vehicles. Throughout the programme, 700,000 cars had been traded in, with Toyota being the biggest ‘winner’, as it accounted for 19.4 per cent of all trade-in sales (USDOT, 2009).

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