

CSconnected: Does CS cluster inward investment improve regional economic prospects?

August 2022

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Table of Contents

Case summary	3
1. Introduction	4
2. Background: the economic role of inward investment	5
3. Wales: A useful lens to examine inward investment and economic development	9
4. The Welsh compound semiconductor cluster	12
5. Conclusions and recommendations	20
6. References	21

Case summary

This case explores the role of firms in the Welsh compound semiconductor cluster as inward investors and agents of regional economic change. A key theme is that compound semiconductor manufacturing firms represent a pattern of inward investment for Wales that is different from that characterising much of the past and with the potential to provide better quality long term regional economic outcomes.

The case reveals that for more disadvantaged local economies that there are challenges to develop conditions for encouraging inward investors to choose their nation or region as a home for knowledge-intensive industries. Here the strategic economic development goal and means of inward investment attraction is based more on the creation of knowledge spill-overs, such as the transfer of new skills, science, and management techniques which in the longer term stimulate local competition and innovation.

This represents a different model from the past. For example, in Wales pull factors for inward investment have been understood in terms of factors such as grants and subsidies, infrastructure access to EU markets, and relatively low unit labour costs. While previous rounds of inward investment have had impacts in terms of creating employment, providing some well-paid jobs and enhancing economic stability, this same inward investment may have restricted the transformative capacity of the Welsh economy towards upgraded developmental pathways. Consequently, Wales might be seen as a good example of where positive public policy action in respect of attracting new investment capital has been quite efficient to resist against and adapt to economic shocks but less effective to transform the economy away from what has been a low productivity trajectory since the 1960s.

The case then explores how far inward investment in the compound semiconductor cluster might be different in its ability to change the regional economic trajectory. The evidence suggests that the CS cluster has characteristics that place it firmly in the knowledge-based- category of inward investment stock in Wales and then potentially better placed to generate local economic transformation.

The case examines the motivations for continued inward investment into the CS cluster in Wales where critical areas are supply side issues in respect of knowledge, technology, skills and institutional support. Inward investment in the CS cluster reveals a willingness to use South Wales's knowledge, expertise and assets across the CS space in terms of research collaboration and specialist facilities. Here the CSconnected initiative has an increasingly important role in highlighting the evolution of the regional CS supply side.

The CS cluster also distinguishes itself in terms of what is produced. While the historical inward investment pattern in Wales has tended to feature more mature commodities towards the end of the product life cycle, the product set of the CS cluster is diverse in terms of wafers, fabrication, packaging, epitaxy and technical solutions and consultancy. These products vary in terms of their technical maturity but tend to be IP intensive and with the overall product and linked services market growing very fast as compound semiconductors are increasingly adopted by a diverse set of industries. Finally, the CS inward investment cluster would also seem to score well in terms of regional embeddedness in relation to elements such as joint research with higher education colleges, intra-firm collaboration to develop new products and processes, and movement towards strategic coupling.

This reveals a case of knowledge intensive inward investment that is comparatively well embedded within the regional economy. Particularly encouraging in an economic development sense is cluster activity to develop new products in Wales and to collaborate with local universities to achieve these aims.

1. Introduction

This is the second in a series of case studies to support the CSconnected Strength in Places Fund (SIPF) project, funded by UK Research and Innovation. While the first case explored the evolution of, and challenges facing, compound semiconductor clusters across Europe, this second case explores the role of firms in the Welsh cluster as inward investors and agents of regional economic change. A key theme is that compound semiconductor manufacturing firms represent a pattern of inward investment for Wales that is different from that characterising much of the past and with the potential to provide better quality long term regional economic outcomes.

Inward investment has a long and varied economic history in Wales. While research has pointed to economic benefits to Wales from exogenous investment in terms of employment, investment and new technology, this has been set beside a series of critiques which have questioned the embeddedness of the externally owned sector in Wales, the underlying quality of employment and investment offered.

Selected critiques have focused attention on factors such as a production-only focus of operations, the low R&D intensity of the externally owned sector, limited local decision-making autonomy and poor long run stability. Critics have also underlined inward investment motivations with much of Welsh success founded on businesses that have seemingly entered the economy to take advantage of favourable factor costs and the advantages of a Welsh location in terms of gaining access to EU markets (Munday and Roberts 2008, 2009).

Generalising on the regional costs and benefits of inward investment is difficult. Investors vary in terms of industry and technological scope. In this second case study we aim to reveal the characteristics of inward investment into the compound semiconductor cluster. The case shows how the CS cluster might work to support a more transformative developmental path for the regional economy, and with the characteristics of the CS cluster quite different from many parts of the inward investment sector of the Welsh economy.

In what follows there are four sections.

- First, we provide some background into debates on the transformative role of inward investment in the regional economy.
- Second, we argue that Wales and the CS cluster is a valuable lens through which to explore the regional transformative benefits of inward investment.
- Third, we highlight selected characteristics of the CS cluster firms which differentiate them from other parts of the inward investment sector in Wales.
- Finally we conclude on how far this group of inward investors might yield transformative change for Wales and how the CSconnected SIPF project might reinforce this role.

2. Background: the economic role of inward investment

The costs and benefits of inward investment

The costs and benefits of attracting inward investment have given rise to an extensive economic geography literature. A strong regional export orientation linked to external firm ownership could contribute positively to regional economic growth and long term resilience (McNabb and Munday, 2017). Some have claimed that foreign plants could be a significant source of employment generation, technology and skill upgrades, regional productivity and export growth (Driffield and Munday, 2000; Feenstra and Hanson, 2000; Bronzini, 2015). However, inward investment can have negative impacts in terms of the employment of unskilled labour and lead to a lower skills equilibrium in the host region (Firn, 1975; Bailey and Driffield, 2007; Rong et al. 2020).

Important here is that externally owned and controlled plants may not embed themselves in the local economy and community and could relocate more easily from the host region when the political or socio-economic environment changes (Bailey and Driffield, 2007; Godart et al., 2012). The relatively footloose nature of inward investment is often associated with times of economic turbulence (McNabb and Munday, 2017). A corollary of low levels of embeddedness can also be a production-only focus of manufacturing activity and with more 'routine' business activities allocated by foreign firms to the region in question. This can result in a lack of skills intensive R&D and engineering activity at the regional level and be a contributor to a low skills equilibrium in the host economy. External control may also pose additional constraints linked to non-local procurement patterns with reduced regional expenditure multiplier effects (Firn, 1975, Munday and Roberts, 2001).

Responses to economic shocks

Yet elements of the above are contested. For example, externally owned plants may actually be better placed to support domestic supply chains through periods of crisis while preserving their own operations and might have the ability to cross subsidise from activity in other places. They may also have wider access to overseas markets which are perhaps not affected by the same economic factors as the domestic host economy and could have easier and cheaper access to external finance compared to domestic firms, with this making them more capable of levelling off recessionary effects and other shocks.

Moreover, evidence from the 2007-08 economic crisis (Soroka et al., 2019) reveals that externally-owned businesses may have access to valuable resources, such as capital and knowledge, that are not available to grounded firms. In this respect the age and experience of the corporations, as well as their well-established routines, might work to strengthen their position for dealing with shocks. Where it can be shown that employment and output in inward investment firms is relatively stable, and associated with relatively higher earnings, then their presence may provide regional stabiliser effects (clearly stability does not necessarily equate to a positive force for regional economic transformation). Moreover, larger externally owned plants may be connected to higher levels of sunk costs and have greater levels of scale which enable them to ride out the economic cycle.

Here it is important to consider wider embeddedness factors which might work to retain inward investment capital in a region. These might include the time and effort involved in developing joint research collaborations within a cluster of interrelated industry activity; the resources used up in developing a regional skills base, and resources employed in developing higher education linkages. Therefore, and also considering their strong influence, externally-owned investors might be better placed to put pressure in terms of favourable government interventions in times of crisis.

Inward investment and knowledge spillovers?

A potential issue with the economic evaluation of inward investment is that where regions are associated with large, non-locally owned branch plants, then evidence for knowledge spillovers and positive innovative impacts is also weak, or at best mixed (Bishop and Wiseman, 1999). This inevitably links through to prospects for resilience and could be a serious problem for smaller economically peripheral regions. In this respect the lack of a local core of decision making in large firms has been a common theme in regional economic development literature since the seminal work of Firm (1975). Here regions where firms are largely externally controlled and owned could gradually lose out to other regions, and with an intraregional swap from 'entrepreneurship' activity towards 'management' activity. Firm noted that this could have longer term developmental implications, and at the very least could impact innovation systems.

Businesses investing overseas have tended to keep the majority of high-technology and knowledge-intensive resources within their indigenous home location. However there is a trend emerging whereby a research presence within the host location is seen to provide additional knowledge transfer benefits, especially access to new sources of technological, organizational, and marketing expertise, and to overseas innovation systems. Knowledge spillovers are now viewed as moving more equitably between the home and host locations (Huggins and Izushi, 2007).

Transforming the local economy?

In light of the above, a region's ability to be innovative is expected to be a critical part of its transformative capacity. For example, Tödtling and Trippl (2005) suggest that regional innovation systems might be described as being organisationally thin or thick. Thin systems might be identified, for example, with 'branch plant' economies where ultimate capital ownership of facilities, even in strong growth high productivity sectors, rests elsewhere. In cases of organisationally thin research and innovation systems, development could be associated more with external expert milieus and technology imports, and with this route providing regional firms with new competences and solutions. In these cases, new development paths are driven by 'solutions' found to be successful in other regions.

Alternatively, in organisationally thick regional innovation systems, development paths might be linked to indigenous spin-offs from knowledge institutions working with the local industry base, and with this resulting in more likelihood of extant regional industries diversifying into new areas. In summary, external to the region capital ownership in industry might typically be linked to 'thinner' regional innovation systems, and a weaker resilient capacity.

Inevitably patterns of capital ownership and inward investment are associated with the nature of the spatial division of labour and with this revealing something of what is produced, where it is produced and what types of jobs are created and where (Massey, 1995). The spatial division of labour links to the capacity of a region to adapt. In this respect adaptation could refer to changing circumstances in the existing regional development path (Pike et al., 2010) and a regional ability to hold-on in the face of change. This 'hold on' strategy contrasts with an adaptability that refers to pro-active economic policies seeking to create new regional growth paths resulting from transformation and reorganisation of internal structures and relations among socio-economic actors (Boschma, 2015).

Inward investors necessarily play a role in regional adaptation. The external control and ownership of capital in a region and the spatial division of labour determine the hierarchical relations among territories, i.e. relations of dominance and subordination. High-skilled jobs and major activities are allocated in the dominant and well-developed regions, with an important position in the international division of labour and global production networks. Low-skilled jobs and routines/minor activities remain in the subordinated and economically disadvantaged regions, with a weak position in the global value chains.

Crucially, economic crises entail important geographical restructuring and changes in the space economy, with different business decisions, policy choices and responses for each region (Kapitsinis, 2018). With recessionary shocks, the closure of a local subsidiary is decided by a parent company typically headquartered in a distant region. For this reason, regional economies with high levels of external ownership with branch plants represent a constant source of vulnerability due to the risk of plant closure and lack of local influence (Leaver and Williams, 2014).

Motivations for investment are important

Given the above, there is a debate on how far inward investment might work to hinder the long term transformation of a local economy. Questions on the lack of transformative potential even go back to the very motivations for inward investment. For example where primary location determinants are related to factor costs and market access, as opposed to strategic asset seeking and developing new products, then more limited demands are placed on local skills and supply infrastructure. In this case, there could be the prospect of investments tending to result in an increase of jobs rather than of higher quality jobs. Other issues link to what is produced. For example, where inward investor products are mature or at the end of their life cycles there may be more limited scope for knowledge spillovers into the local economy, innovative spin-offs or new entrepreneurial behaviour development. There is also a profit contingency here. Subsidiary profits from the sales of more mature end of life cycle goods might simply be returned to head offices elsewhere, as opposed to being reinvested in local operations, which again places limits of what can be achieved in regional subsidiaries.

Much of the above illustrates a fundamental developmental problem with inward investors as potential corporate bed blockers, surviving over a long period and soaking up regional factors doing a limited range of things. With the headquarters located out of the region, the entrepreneurial capacity of the territorial economy declines, alongside its ability to innovate.

Upgrading to Knowledge-Based Investment

In its traditional form, inward investment policy has followed a series of fairly well-trodden and rehearsed rules, encompassing the provision of pragmatic attractions such as financial incentives, ample land availability, and a sound infrastructure with competitively priced labour. As the knowledge economy is prioritising the nurturing of skills and talent, it is also changing how economies attract from overseas the types of investments creating high value-added. Global competition for such investment is increasing, requiring major shifts in policy and strategy.

In particular, those economies that have traditionally attracted high shares of such investment think more innovatively about how they attract and embed knowledge-based external capital. It is important to understand the different approaches required to attract and embed knowledge-based investment compared with more traditional sectors of activity. Traditional areas of inward investment, such as textiles, medium manufacturing and basic consumer electronics and other low value-added manufacturing, have declined within most OECD nations and are being replaced by knowledge-based activities such as financial services and pharmaceuticals. Also, the general size of initial inward investments in developed economies has fallen in recent years, with a switch toward attracting smaller and growing knowledge-intensive businesses, as mainstream and large-scale manufacturing operations relocate to developing nations in Eastern Europe and Asia, particularly in the 2000s, with EU enlargement to the East (Kapitsinis, 2017).

Given the above, the requirement for disadvantaged regional economies is to formulate the correct investment conditions both for retaining home-grown companies and for encouraging inward investors to choose their nation or region as a home for knowledge-intensive industries. In the past, the traditional rules of location marketing involved the provision of an adequate infrastructure, a relatively low-cost labour force and incentives – chiefly in the form of subsidized land and tax breaks. The primary objective of the host location was job creation. In essence, many of the traditional methods of attracting inward investment are cost-based, and this has been particularly relevant and effective where investments have been made in large-scale manufacturing (see for example Hill and Munday 1992).

As indicated above, under the new environment, the primary goal and means of inward investment attraction is based more on the creation of knowledge spillovers, such as the transfer of new skills, science, and management techniques. Viewed by the host economy, such spillovers stimulate local competition and innovation. When knowledge is the key competitive component of investment attraction, land or plant-based policy incentives become less relevant, replaced by opportunities for networking and technology transfer. Chiefly, this has come in the form of fostering local and global relationships and networks between indigenous businesses and inward investors. Since an existing concentration of well-qualified workers is a crucial cog in the building of successful knowledge-based inward investment policies, if the correct mix of skills is present, a knowledge-based company is more likely to gravitate toward a particular region, be it foreign or domestic, whether or not there are tax incentives and investment subsidies on offer. By attracting knowledge workers, companies and investors will follow, allowing further start-up investment to be available and allowing attraction activity and cluster development to occur (Huggins and Izushi, 2007).

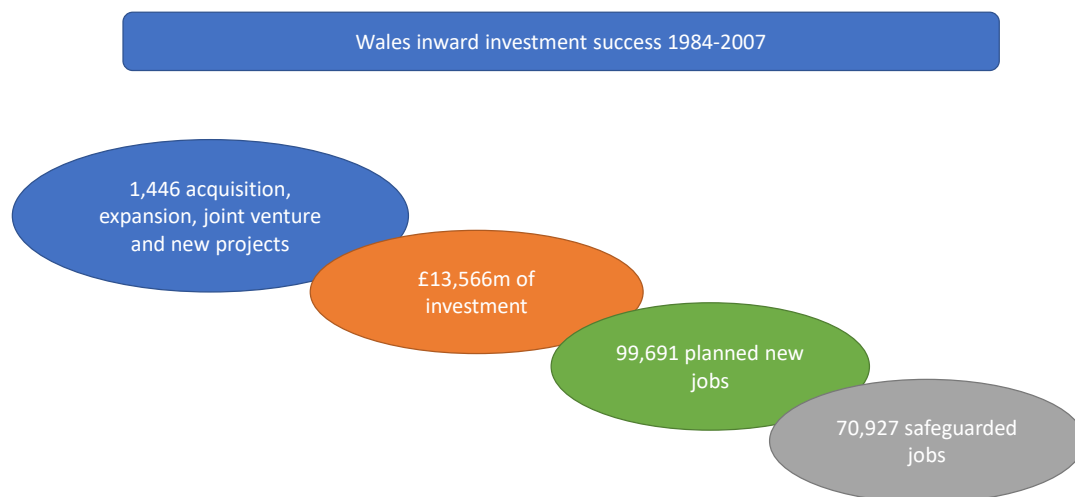
3. Wales: A useful lens to examine inward investment and economic development

Wales' inward investment successes

Wales has long been a useful lens for exploring the impacts and developmental role of inward investment. It is an economy where many of its business head offices are located outside the region, and indeed outside of the UK, with prior work suggesting this has impacts on the quality of underlying business activity and skills (Munday and Roberts, 2008, 2009; Phelps, 2016). Indeed 'one of the most defining characteristics of the Welsh economy when looked at in an evolutionary perspective is its enduring dependence on external and often cost-sensitive investment' (Bristow and Healy, 2015: 248). Figures 1 and 2 reveals something of this, revealing the growing importance of foreign manufacturing in the Welsh economy in the period 1977-2003. Indeed Wales was identified as one of the most successful regions of the UK in attracting inward investment in the 1980s and early 1990s (Hill and Munday, 1992).

Following from the previous section, the main factors that attracted externally owned manufacturing to Wales after 1980 included grants and subsidies, infrastructure access to EU markets, and relatively low unit labour costs. Aside from manufacturing, the movement towards external control has also been noted in services such as banking, financial services, energy and utilities. For example, the 1980s and 1990s saw 'local' control decline in sectors such as utilities, banking, finance as regional offices were moved elsewhere and as a result of privatisation processes (Gripaios and Munday, 2000).

Figure 1 Welsh inward investment success 1984-2007



Source: Derived from IBW Database in Munday et al., 2009.

Figure 2: Plants and Employment by Ownership and Business Structure, Wales, Selected Years

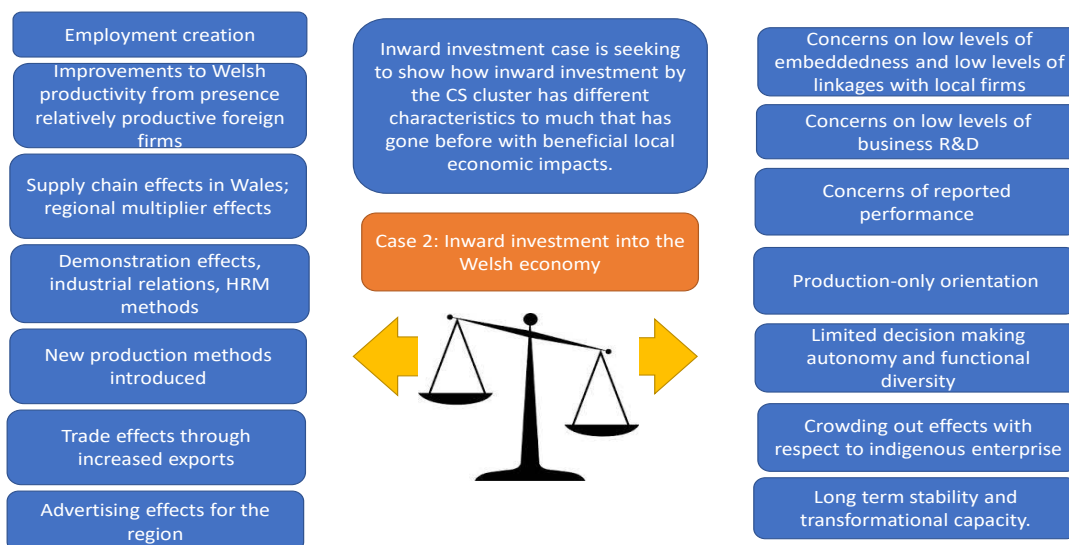
Sample (Ownership / Business Structure Classification)	1977			1986			1997			2003		
	Plants (N)	Emp.	Mean Emp	Plants (N)	Emp.	Mean Emp	Plants (N)	Emp.	Mean Emp	Plants (N)	Emp.	Mean Emp
Domestic plants	2,561	223,685	87.3	2,169	136,721	63.0	1,693	124,756	73.7	1,339	99,042	74.0
E.U.	90	28,557	317.3	128	20,151	157.4	136	20,584	151.4	110	17,421	158.4
Non-E.U. Europe	..	..	..	15	1,525	101.7	20	2,112	105.6	15	1,935	129.0
North America	122	48,216	395.2	150	36,172	241.1	158	33,752	213.6	136	28,849	212.1
Asia	..	..	..	19	7,098	373.6	43	17,391	404.4	39	12,287	315.1
Foreign owned plants	251	85,161	339.3	336	66,341	197.4	375	75,540	201.4	315	62,400	198.1
Foreign/All (%)	8.9	27.6		13.4	32.7		18.1	37.7		18.4	37.7	
All	2,812	308,846	109.8	2,505	203,062	81.1	2,072	200,323	96.7	1,713	165,484	96.6

Source: McNabb and Munday, 2017

Inward investment opportunities and problems

Figure 3 summarises our review of the inward investment literature in Wales over the last three decades. On the left of the Figure are a series of factors that have been drawn out of the regional literature as positives of inward investment. On the right is a summary of the concerns that have been raised in research.

Figure 3: Issues in recent research on inward investment in Wales



Inward investment has been shown to have some positive impacts on the Welsh economy, creating employment, providing some well-paid jobs and enhancing economic stability. Inward investing firms in manufacturing have been shown to be more stable than their domestically owned counterparts, while also tending to feature higher productivity and creating significant numbers of jobs (McNabb and Munday, 2017).

However, in spite of these benefits, inward investment capital in Wales may have restricted the transformative capacity of the Welsh economy towards upgraded developmental pathways. A question is how far this investment has worked to lock Wales into a particular developmental trajectory. Some of these concerns were picked up by Munday and Roberts (2009) in a review of Welsh inward investment policy showing that:

- There was a need to reflect far more on whether the types of assistance offered to firms should be better connected to the expected level of long term economic benefits. It was argued that by examining inward investment motivations, the industry involved, the expected levels of earnings and productivity growth, and the stage of the life cycle reached by industry products that the future embeddedness of the investment in the Welsh economy could be better understood.
- Inward investment policy might be steered more towards inward investors who bring HQ-type functions, and with the lack of higher order management and research functions in Welsh manufacturing working to deepen problems of a low skills equilibrium.

A persistent theme has been the lack of HQs and decision making locally, a possible factor locking Wales into a more dependent development path. In this scenario inward investment capital contributes to a low innovation equilibrium, with low demand and supply, with knowledge and new technology imported and dependent on other national/regional economies.

Public policy and regional transformation

In summary, Wales might be seen as a good example of where positive public policy action in respect of attracting new investment capital has been quite efficient to resist against and adapt to economic shocks but less effective to transform the economy away from what has been a low productivity trajectory since the 1960s. The creation of employment in the inward investment sector has been effective in maintaining a relatively stable economy, but without facilitating its transformation towards upgraded developmental pathways and high growth trajectories. **Then a question we explore in the remainder of this case is how far inward investment in the compound semiconductor cluster might be different in its ability to change regional trajectory.**

4. The Welsh compound semiconductor cluster

CScnnected and local transformation

The UKRI Strength in Places support for the CScnnected cluster is based in part on the need to make individual geographical places more resilient and to place more needy regions on a stronger developmental pathway. How far funded activity will achieve these ends will in part be linked to the trade-off between the positive and negative effects of external ownership of the manufacturing firms in the CScnnected cluster. Figure 4 shows the manufacturing firms and organisations in the cluster, and their incorporation dates in Wales.

Figure 4 CS Cluster Commercial Organisations

<i>Organisation</i>	<i>Area of production/services</i>	<i>Previous names</i>	<i>Date of incorporation</i>
SPTS Technologies Limited (UK), a KLA Company	The design, manufacture and distribution of specialised equipment used by the group's customers to produce semi-conductor related devices.	SPP Process Technology Systems UK Limited	12/10/2009
Microchip Technology Caldicot Limited (US)	Development, manufacture and marketing of semiconductor integrated circuits.	Microsemi Semiconductor; Mitel Plessey Semiconductors	05/10/1961
IQE plc	The manufacture of advanced semiconductor materials. Research, development, manufacture and sale of advanced semiconductor materials and related proprietary technology.	Epitaxial Products International IQE Silicon Epi Limited Filbuk 614 Limited	09/03/1987
Nexperia Newport Limited (PRC)	The development, manufacture, marketing and sale of semiconductor devices for assembly.	Newport Wafer Fab Limited IR Newport Limited Inhoco 2597 Limited	12/12/2001
Rockley Photonics Limited (US)	Photonics supplier of integrated optical chips and modules across multiple markets. Key markets healthcare, wearables, and machine vision.		09/09/2013 in the UK
Microlink Devices (US)	Specializing in the design, development, and manufacture of advance solar arrays for spacecraft, aircraft, and terrestrial applications.		
Compound Semiconductor Applications Catapult Limited (UK)	Independent centre of expertise connecting researchers and the entire compound semiconductor supply chain within the UK with those business that can gain the most from using compound semiconductors in systems and devices in their end products.		28/06/2016

Organisation	Area of production/services	Previous names	Date of incorporation
Compound Semiconductor Centre Limited (UK)	Builds on research undertaken at Cardiff University's Institute for Compound Semiconductors to develop innovative new materials technologies that will enable a wide range of new and emerging applications		9/9/2014

Immediately apparent in Figure 4 is that some of the firms making up the CS cluster in Wales have a long provenance in some cases going back over 20 years. While some of these investments have gone through different ownerships, activity has been maintained in Wales with limited instances of disinvestment from the region.

So how does the CS cluster 'fit' in the regional inward investment context outlined previously?

In what follows we suggest that the CS cluster has characteristics that place it in the knowledge-based- category of inward investment stock in Wales and then potentially better placed to generate local economic transformation.

To begin, Figure 5 provides a summary checklist of the expected effects of inward investment following from Figure 3 and how the businesses in the CS are seen to measure up.

Figure 5 CS cluster local economic effects checklist

Potential effects	Nature of effects	CS cluster in Wales?
General productivity spillovers	Role of inward investment in technical change and progress and domestic sector productivity growth	Potentially strong in terms of involvement in cutting edge technology and shown to be a highly productive sector in Wales.
General competition effects	Inward investment role in breaking down monopolies in host economy, competition effects.	CS cluster has no explicit competition within Wales and markets are international. Limited displacement of any domestic regional capacity.
Trade effects	Impacts on export and imports, more general balance of payments effects.	Strong impact on regional export activity and offers diversity of export locations away from EU.
Buyer-supplier and value chain effects	Issues of embeddedness. Indirect economic impacts on regional supply chains. Demonstration effects to suppliers in terms of operational techniques and links to increased productivity.	Limited backward supply chain links currently into Welsh economy but CSconnected seeking to expedite this issue, particularly in terms of linkages between the investors.
Employment effects	Effects in terms of direct and indirect employment creation, and the employment contribution in different industries.	CS cluster supports jobs directly and indirectly in the Welsh economy (c.2,400 jobs) through wage and procurement effects. Also extensive activity in terms of developing local skills supply side.

Potential effects	Nature of effects	CS cluster in Wales?
Industrial relations effects	Inward investing firms promoting novel IR practices, and extent to which demonstration of new practices spill-over to domestic firms and other institutions	CS cluster firms among industrial leaders in terms of IR practices.
HRM and operational management practice effects	Presence of different operational and HRM practices in the inward investment sector, and extent to which demonstration of practices spills-over to the extant firms in the economy	CS cluster firms strong in terms of application of advanced manufacturing technology and robotics.

In what follows we seek to touch on selected of the above ‘effects’ themes under the headings of investment motivation, production activity, and embeddedness.

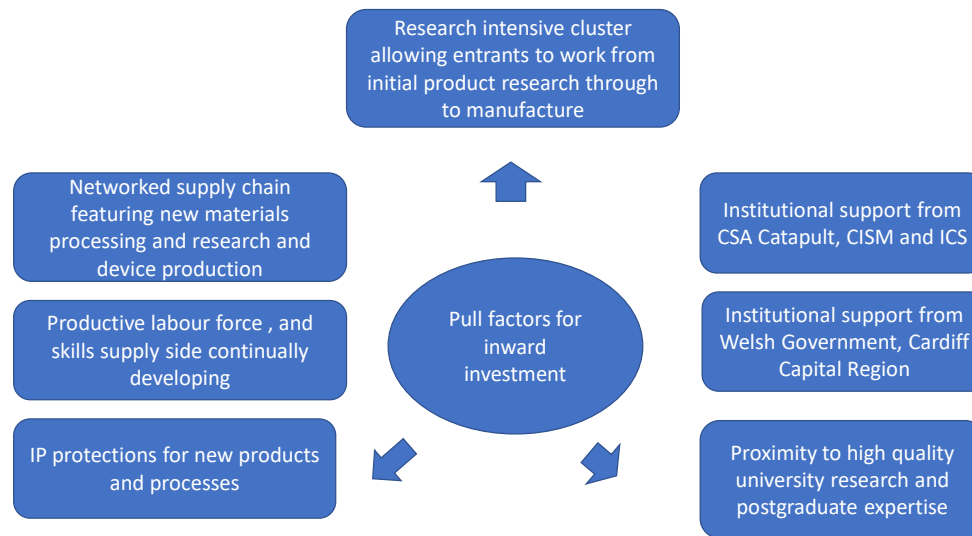
Motivations for investment?

There is a swathe of research into inward investment which suggests that the local impacts of external capital link through to initial location determinants. As outlined above much of Wales earlier inward investment success was founded on a complex menu of pull and push factors. So, for example, much of the Asian inward investment capital that came to Wales in the period after 1982 was subject to pull factors including the size of the EU market for electronics products, national and regional level grants and subsidies available, and the availability of a well skilled and productive workforce (Morris et al., 1993). Critically over much of the 1980s and 1990s, Wales was one of the closest assisted areas to large consumer markets in the South East of England and then close to the new Eurotunnel. On the push side, tariff free access to EU markets for many of Wales’s earlier inward investors necessitated an EU production base. As such there was a sense in which much of Welsh inward investment success from the early 1980s was based on firms that had to be located here to secure market access i.e. had trade constraints not existed they would likely be located elsewhere, or just exported from a domestic base. These complex push and pull motivations then linked through to operations tending to be production-only with more complex functions being retained in home economies. This then might be seen to have limited the impacts of these plants in terms of local economic development gains.

For contemporary firms in the CSconnected cluster investment motivations would seem to be quite different. In the first place issues of factor costs and EU market access are largely secondary, and with markets served more global in nature. It is understood that production costs in Wales for a number of the CS cluster firms would be lower than in some competitor locations such as Singapore and Silicon Valley (fDi Benchmark, 2020).

More important to firms are supply side issues in respect of knowledge, technology, skills and institutional support. For example, Rockley Photonics who moved to Wales in 2018 have argued that the location decision was based on whether or not there was a technology match and the presence of key technology partners. At the time of their location, Newport Wafer-Fab (now Nexperia) was able to assist them and with linkages to a series of UK universities. Rockley also had pre-existing linkages IQE in terms of epitaxy processes.

Figure 6 Pull factors for new inward investment in the CS cluster



In consequence continued inward investment into the CS cluster reflects a willingness to use South Wales’ knowledge, expertise and assets across the CS space in terms of research collaboration and specialist facilities such as the Institute for Compound Semiconductors, Centre for Integrated Semiconductor Materials and Compound Semiconductor Centre. Moreover, the Welsh location provides access to leading higher education institutions. It is estimated that the four universities (Cardiff, Cardiff Met, Swansea and South Wales) produce over 12,000 graduates in subjects commonly used by the CS cluster firms each year (i.e. mathematics, computing and data science, physics, chemistry and engineering). Then a key inward investment motivation relates to the strength of the existing cluster of CS firms in Wales and related supporting institutions. While the predominant business model of inward investment suggests firms enter with exploitable ownership advantages in terms of specific assets and organisational abilities, recent trends in inward investment into the CS cluster in Wales suggest an element of technology and knowledge sourcing investment making full use of the local cluster supply side.

A conclusion here is that where the strength of the existing cluster of firms becomes a location factor, then each additional firm joining the cluster may work to strengthen it further in a dynamic fashion and a path-dependent process. It is also suggested here that issues of motivation suggest that the CS cluster firms are in Wales for the long haul i.e. being ‘stickers’ rather than ‘snatchers’.

Figure 7 Inward investment motivations in Wales: The CS cluster?

Motivation	Historical inward investment 1980-2010	CS Cluster of firms
Resource seeking motivations (i.e. to gain access to primary materials, specific types of labour, or technological expertise);	Medium importance	Higher importance
Market seeking motivations (i.e. to sustain or protect an existing market; to engage in product adaptation; to reduce transactions costs of doing business remotely; to overcome tariff barriers);	Higher importance	Lower importance
Efficiency seeking motivations (i.e. perhaps to gain the advantages of scale and scope economies);	Lower importance	Lower importance
Strategic asset, capability seeking motivations (for example, gaining assets and knowledge that complement the firm's competitive position, or to be close to related firms and resulting knowledge spill-overs).	Lower importance	Higher importance

What is produced?

In terms of a series of stylized facts much of Welsh inward investment after the 1980s has been connected to more mature products that have been developed and researched elsewhere. Typical here are commodities towards the end of the product life cycle where there are limited opportunities for innovation in the production of the good. This connects somewhat with the underlying motivations for inward investment discussed in the previous section i.e., important for inward investors was to overcome trade barriers on an existing and established set of products. Then, for example, in the 'general' Wales inward investment case, developed plants were largely replicas of manufacturing plants elsewhere and the nature of manufactured products were tightly coordinated by head offices elsewhere. As a result, while there was scope for some product development in Wales this rarely involved fundamental research and development or extensive collaboration with the local higher education sector.

It is accepted that there are plenty of Welsh inward investment examples of innovation in terms of process but less so in terms of new product and service development in the externally owned sector (Munday et al., 1995). Overwhelmingly this manufacturing orientation also meant that where surpluses were generated in the Welsh economy they were quickly remitted overseas (Peel and Munday, 1997) and with limited scope for their use in the region to develop new products and services. In part then this regional manufacturing orientation worked to reduce business expenditure on R&D in the Welsh economy, and with this one factor used to explain Wales's poor productivity growth record.

In contrast, activity in the CS cluster appears markedly different. The product set of the CS cluster is diverse in terms of wafers, fabrication, packaging, epitaxy and technical solutions and consultancy. These products vary in terms of their technical maturity but with the overall market growing very fast as compound semiconductors are increasingly adopted by a diverse set of industries (Huggins et al., 2022).

Box 1 New product and process development in Wales

The CS inward investment cluster provides some evidence of products being developed in Wales which have ramifications for international group operations. IQE produced the world's first 6" (150mm) vertical-cavity surface-emitting laser IQE (VCSEL) in 2017 which was one factor leading to the mass adoption of 3D sensing. IQE has now worked in collaboration with Cardiff University on the development of a full fabrication process for 200mm (8") VCSEL epiwafers. Developmental wafer epitaxy has been led out of IQE in Wales and the business is seeking to move to fast full fabrication of this larger wafer. This is a major change in terms of the scale of the wafer and is the first time this size of wafer has been developed for the commercial market. IQE is working closely with Cardiff University to refine the device fabrication process around the wafer. The underlying innovation creates new export opportunities. The innovation led out of Wales on larger wafer diameters, could work to grow other new markets for wireless and photonics applications. Critically the advances being made in Wales also involve other firms within the CS cluster. For example, elements of specific photovoltaic epitaxy involves collaboration between IQE and Microlink Devices. This then is a case of a new product and process developed in Wales providing potential new export markets, but also new opportunities to integrate compound semiconductor cluster activity in the region.

A key factor here is that outputs in the CS sector are IP heavy, meaning that in addition to final goods and services, the CS businesses in Wales produce intermediate knowledge and research outputs. A critical part of the inward investment business case is that investors have the opportunity to research and

innovate, collaborate together on research funding for new products and services, and collaborate with the higher education sector for testing and pure research. For example, currently within the inward investment cluster research is being undertaken into innovative new materials such as Gallium Oxide which is more cost effective than silicon, provides improved energy efficiency, and when applied to devices permits much faster communication speeds. This means that in terms of inward investment characterisation there are CS cluster examples of products, services and technical solutions actually being developed in Wales for international customers (see Box 1).

Indirect evidence for the knowledge and skills intensity of production can be found in the high salaries being offered in the CS cluster in Wales. This reflects the employment of operations staff but also highly qualified engineers and research personnel. For example, it has been estimated that the CS cluster paid out around £71m in wages and salaries in 2021, with the average gross wage being around £52,000 (annual pay in Wales as a whole in 2021 for full time workers was around £32,700 see Welsh Economy Research Unit, 2022). In consequence, gross value added per employee in the CS cluster at an estimated £121,000 in 2021 was well above the Welsh average.

Other indirect evidence is reflected in the wide constituency from which CS cluster members draw skills. For example, in the case of one inward investor into the cluster, the local research and engineering team had developed to over 30 staff and with their Welsh site the largest in Europe. The research and engineering skills used by this investor are reflected in average salaries that topped £80,000 in 2021 and with the workforce derived from a constituency that includes Hong Kong, Europe, Scotland and Italy and embracing postgraduate skills in material science, micro-electronics and chemistry. Indeed, for this inward investor the presence of the cluster of interrelated compound semiconductor activity was critical when trying to attract new talent as they believed that there was "enough going on here to get people's interest". Moreover, it was estimated in 2021, that four manufacturing members of the CS cluster in Wales employing around 1,300 people, and that just over 20% of these staffs were involved in R&D activity.

Following from this is that where new inward investment into the cluster is occurring then research and development capacity is an important issue. For example, SPTS Technologies at Newport which is a key supplier of advanced wafer processing solutions announced in June 2021 that it hoped to develop a new R&D and manufacturing headquarters in Newport; key here was the need to grow local R&D capacity in a fast-growing market.

Embeddedness

The embeddedness of inward investment can embrace a number of factors. In the research literature higher levels of inward investment embeddedness often link to the presence of buyer-supplier linkages in the region; the presence of local decision-making capacity; and then the presence of social and economic network linkages. However, in recent debates it has been argued that when considering embeddedness, it is most important to look at the long-term evolution of the inward investments in the region, and to explore strategic coupling between firms beyond simply purchasing and sales links (Wei, 2015). Overall, however, the literature tends to emphasise that higher levels of embeddedness, however measured, are beneficial, with deeper embedded firms being more capable of making a long-term economic contribution to their regions (Huggins and Izushi, 2007). In Wales this has been exemplified in more policymaker interest in encouraging medium sized independently owned firms and improved business succession from small to medium sized enterprises in Wales (Economic Intelligence Wales, 2020¹).

Through recent periods of inward investment into Wales (from the 1980s to the present), there has been public encouragement to inward investing firms to integrate more into the host region economy particularly through purchasing locally produced goods and services, and with regional agencies seeking to assist local suppliers to meet the needs of incoming inward investors (for

Box 2 The importance of local HQs

A critical development issue for Wales has been an absence of headquarter type functions among manufacturing inward investors. An effective cluster ecosystem is expected to benefit where strategic investment and product decisions are made locally with a full knowledge of local supply side potentials. Inward investment in the compound semiconductor cluster has featured HQ type operations. A good example here is SPTS Technologies at Newport which has maintained a Welsh headquarters function for well over two decades. In June 2021 the firm announced that it was seeking to develop a new R&D and manufacturing HQ site at Imperial Park in Newport which will allow for further expansion.

example, the *Source Wales* and *Sell to Wales* initiatives). Clearly value chain linkages in the local economy can be a means of passing on knowledge and these have been identified as a means through which productivity spill-overs occur in the UK (see Driffield et al., 2005). However, for the CS cluster opportunities to purchase

goods and services locally in Wales are fairly limited. Indeed, analysis of the spending of the CS cluster manufacturing firms in Wales suggests that local economic impact comes as much through the spending of employee wages and salaries as it does through spending with local producers of goods and services². This would be expected in the context of the small open economy of Wales (and it is perhaps the case when exploring value chain effects that an all-UK approach is taken).

¹ See [EIW succession report May 2020 ENG Final.pdf \(developmentbank.wales\)](#)

² See [CSconnected Annual Report - Cardiff University Business School](#)

The CS cluster would seem to score more strongly on other facets of embeddedness. Each of the cluster manufacturing firms maintains a rich functional diversity in terms of staffing with limited resemblance to the production-only branch plant model more common in the 1980s and 1990s. Furthermore, selected of the cluster firms feature headquarter functions in Wales, meaning that

Box 3 Joint research collaboration among inward investors

An evidence of the embeddedness of the CS cluster firms has come in their willingness to work together to overcome challenges facing the whole sector. For example, businesses in the CS cluster in Wales have been working to develop elements of the UK supply chain around silicon and gallium nitride ‘trench’ devices. Compound semiconductor materials being developed in Wales are critical foundations for trench-based devices. These devices help in conducting electrical current from one semiconductor surface to another which improves the capability and efficiency of the devices. Part of the project seeks to develop a UK manufacturing capability in this technology area and with potential markets in new net zero orientated automotive systems. A consortium led by SPTS Technologies at Newport has worked to introduce new trench technologies to the UK and with research support from UKRI. Other local members of the consortium include Nexperia, Swansea University, Compound Semiconductor Centre and CSconnected. The Welsh partners are seeking to deliver industrial processes for trench etching which will significantly support new supply chain development and the development of new human skills in an area where the UK economy was starting to fall behind.

investment decisions with ramifications for the region are taken locally (see Box 2). Critically decisions taken in Wales shape the wider global operations of the cluster firms. For example, in the case of IQE plc all major policy and technological decisions are taken from the Wales

headquarters in shaping the development and operations of their other ‘Fabs’ in North America and Asia. As seen earlier, this has been identified as a critical limitation of the Welsh economy that, in relative terms, so few larger businesses are headquartered here, and with work seeking to link this as one explanation of poor regional productivity performance (Munday et al., 2009).

While value chain links and decision-making capacity are key elements of embeddedness there is

Box 4 Inward investment in the CS cluster has been connected to the development of a collaborative ecosystem involving the regional higher education sector and local and regional government. One example is the development of the Centre for Integrated Semiconductor Manufacturing (CISM) at Swansea University. The centre seeks to undertake research around compound semiconductor materials and processes and develop human capital to benefit the regional industry. The Centre which will open in 2023 has the capacity to offer research services to the inward investors, but also the opportunity to link cluster firms to research undertaken by academic staff. Local collaborative partners in the venture include IQE, SPTS Technologies and Nexperia and with other businesses and institutions in the process of joining. Critical here is that CISM builds upon a process whereby local research teams can use exactly the same equipment used or manufactured locally to test out new ideas. The cluster manufacturing partners in South Wales have had a role in planning a building that will support primary research that leads to new opportunities for the same manufacturers.

a need to go much further. For example, Wei (2015) suggests that there can be a problem where inward investors are ‘thinly embedded with local economies’ because there is an absence of strategic coupling in the technological and institutional as well as the structural and geographical level.

The evolution and future development of the CS cluster speaks very much to these elements of embeddedness. For example, the period since 2018 has seen increasing strategic coupling in Wales between the CS manufacturers particularly in terms of research collaboration, joint research bids, and with the CSconnected project seeking to reinforce such linkages (Box 3). Similarly, there is evidence of evolving linkages between the CS cluster firms and the higher education sector, and local and regional government in terms of skills provision, location marketing, research infrastructure (Box 4) and support for new inward investors.

5. Conclusions and recommendations

Clearly the CS cluster of manufacturing firms in Wales is still evolving. Particularly encouraging has been new inward investment announced even in during the Covid-19 crisis. This case study suggests that the characteristics of the cluster mark it out as quite different from much of the inward investment that has come before. It represents a case of knowledge intensive inward investment that is comparatively well embedded within the regional economy. This does not mean that there are not challenges for the cluster, not least in terms of further building the linkages between the manufacturing firms themselves and with this part and parcel of the CSconnected strategic vision. Particularly encouraging in the case is cluster activity to develop new products in Wales and to collaborate with local universities to achieve these aims.

In terms of the future there are recommendations from the case to carefully monitor:

- The growth of inward investment into the CS cluster resulting from the CSconnected initiative.
- How far growth in inward investment feeds through to new entrepreneurship in Wales in the form of spin-off firms from the main cluster, and how far new business opportunities result from spin-offs from the higher education sector.
- The role of CS inward investment in creating productivity spill-overs in other Welsh industries, particularly those with whom the cluster trades locally.
- The longer-term effects of the inward investment on the supply and demand side for specialised labour in the compound semiconductor space.

A further issue that will need to be examined is the buyer-supplier linkages developed by the CS cluster. In much of the literature covering embeddedness of manufacturing plants the focus has tended to be the extent to which there are purchasing linkages and resulting economic multiplier effects back into the local economy. These purchasing linkages are often channels for knowledge and productivity spillovers. While not discounting the importance of these backward links in the CS cluster case, there is perhaps a greater economic significance in terms of the sectors to whom the CS cluster sells goods. These issues will be developed in the third case study currently being developed.

The UKRI funded CSconnected initiative is certainly creating the conditions to further embed the CS cluster into the local economy while at the same time revealing to national and international audiences the scope and opportunity within this technology area in the Welsh economy. There are still challenges for the cluster in terms of the human capital supply side in Wales, and in encouraging more students towards these industries. There are also challenges for the cluster in terms of more general local purchasing. However, more generally for Wales the CS cluster case appears to stand out as an instance of a more disadvantaged regional economy starting on the process of strengthening the conditions to support manufacturing investors to choose a location for knowledge and technology reasons over and above more basic reasons of factor costs and market access.

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