

UCJC Business and Society Review

(Formerly known as Universia Business Review)

Divergent Opportunities of Innovation: When Time and Situation matter
Oportunidades Divergentes de Innovación: Cuando tanto el momento como la situación importan

Ulrich Hilpert

Nº 65

Primer trimestre /
First Quarter

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How “General purpose technologies” trigger long waves of economic development and thereby generate diversities of innovation

Como “las Tecnologías de Uso General” desencadenan ondas largas de desarrollo económico y por tanto generan diversidades de innovación

Walter Scherrer

Diversities of Innovation in Advanced Manufacturing – the aerospace and automotive industries

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CARTA DEL DIRECTOR

NÚMERO 65 BUSINESS AND SOCIETY REVIEW

Estimados lectores, les presento el número 65 (primer trimestre de 2020) de la revista UCJC Business & Society Review.

El mundo avanza hacia una profunda recesión provocada por la crisis sanitaria desencadenada por la propagación del Covid-19. La capacidad de innovación del tejido empresarial será una de las principales base de la recuperación económica. Las medidas de fortalecimiento de esta capacidad de innovación deberán tener en cuenta que no existe un único proceso de innovación, sino que la innovación es un proceso diverso y contingente a lugares y momentos determinados.

Los dos próximos números de UCJC Business & Society Review se centrarán sobre la diversidad de la innovación. La innovación se aborda con frecuencia desde una perspectiva muy monolítica que hace que con frecuencia se olvide los distintos contextos en los que se producen los procesos de innovación. Contrariamente al enfoque de muchos académicos y empresas, no existe un único proceso de innovación, sino que realmente la innovación se desarrolla sobre la base de recursos, culturas, sistemas políticos, procesos y tareas muy heterogéneos que hacen que un proceso de innovación en un lugar y momento sea difícilmente replicable en otro lugar y momento diferente.

Esta visión contingente de la innovación se desarrolla en los números 65 y 66 de UCJC Business & Society Review. En este número, el profesor Hilpert plantea los elementos sobre los que se debe centrar el estudio de la diversidad de la innovación como son los productos, los mercados de dichos productos, la mano de obra, la estructura de la cadena de suministro, la reputación y el proceso de cambio de competencias existentes y la duración de dichos procesos. El profesor Scherrer describe la naturaleza y fases de los procesos de onda larga de la innovación y cómo las economías desarrolladas se encuentran a las puertas de la sexta onda larga de innovación. En su artículo, el profesor Scherrer explica las implicaciones de esta nueva onda larga, protagonizada por las tecnologías relacionadas con la Industria 4.0, y sus complementariedades y divergencias con la onda anterior caracterizada por las tecnologías de la información y la comunicación. El profesor Hickie aborda la innovación dentro de las cadenas de suministro a través del estudio de las industrias de la automoción y aeroespacial. La investigación aborda el problema de en qué parte de la cadena de suministro innovar y el momento en el que se debe promover dicha innovación para optimizar la relación entre riesgo y capacidad de innovación. Finalmente, Vassiliadis y Hilpert afrontan el reto de la heterogénea distribución de habilidades y discuten alternativas para promover un encaje entre habilidades de los trabajadores y estructuras productivas que sin embargo supere el problema de la aglomeración regional de habilidades en lugares muy concretos.

Quiero terminar esta carta expresando un sincero y profundo reconocimiento del equipo editorial de UCJC Business Society Review hacia todos los colectivos profesionales que están trabajando de forma incansable para superar la actual crisis sanitaria a nivel mundial: Gracias!

Francesco Sandulli,
Director UCJC Business & Society Review,
31 de marzo 2020

LETTER FROM THE EDITOR IN CHIEF NUMBER 65 BUSINESS AND SOCIETY REVIEW

Dear readers, I present to you the 65th (first quarter of 2020) number of UCJC Business & Society Review.

The world is moving into a deep recession caused by the health crisis triggered by the spread of Covid-19. The innovation capacity of the industrial structure will be one of the main foundations of the future economic recovery. Measures to strengthen this innovation capacity should take into account that there is no a single innovation process, but innovation is a diverse and contingent process to specific places and times.

The next two issues of UCJC Business & Society Review will focus on the diversity of innovation. Innovation is often addressed from a very monolithic perspective that forgets the different contexts in which innovation processes occur. Contrary to the approach of many academics and corporations, there is not a single process of innovation, but innovation actually develops on the basis of very heterogeneous resources, cultures, political systems, processes and tasks that make a process of innovation in one place and time hardly replicable in another different place and time.

This contingent vision of innovation will be studied in numbers 65 and 66 of UCJC Business & Society Review. In this issue, Professor Hilpert raises the elements on which the study of the diversities of innovation should focus such as products, markets for such products, workforce and skills, the structure of the supply chain, the branding of innovation locations and the process of change of existing skills and the duration of such processes. Professor Scherrer describes the nature and phases of innovation's long-wave processes and how developed economies are at the gates of the sixth long wave of innovation. In his article, Professor Scherrer explains the implications of this new long wave, starring technologies related to Industry 4.0, and its complementarities and divergences with the earlier wave characterized by the technologies of the information and communication. Professor Hickey addresses innovation within supply chains through the study of the automotive and aerospace industries. This research addresses the problem of where in the supply chain to innovate and when innovation should be promoted to optimize the relationship between risk and innovation capacity. Finally, Vassiliadis and Hilpert face the challenge of heterogeneous skill-sharing and discuss alternatives to promote a matching between workers' skills and productive structures that nonetheless overcome the problem of agglomeration skills in very specific locations.

I would like to end this letter by expressing a sincere and deep appreciation of UCJC Business Society Review's editorial team to all professional groups that are working tirelessly to overcome the current global health crisis: Thank you!

Francesco Sandulli,
UCJC Business & Society Review Director,
31 March 2020

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MISIÓN

UCJC Business and Society Review (Formerly known as Universia Business Review) no es una publicación exclusiva del mundo académico en sentido estricto, sino que su misión principal **es trasladar a quienes tienen la responsabilidad de dirigir empresas y negocios las ideas y desarrollos más innovadores que el ámbito científico y académico sea capaz de generar.**

Por otro lado, *UCJC Business and Society Review (Formerly known as Universia Business Review)* no renuncia a dar servicio a la comunidad universitaria y científica como la publicación de referencia, en la que los especialistas puedan efectuar un seguimiento sistemático de las aportaciones novedosas de los colegas de su misma especialidad. En particular, esta revista pretende ser un vehículo de unión y comunicación de las comunidades universitarias de habla latinoamericana dedicadas al estudio de la Empresa.

PROCEDIMIENTO EDITORIAL

Los originales recibidos y admitidos por el Comité de Dirección, serán enviados al Editor del área correspondiente para que analice si el trabajo debe continuar el proceso editorial y ser remitido a dos evaluadores anónimos (expertos ajenos a la entidad editora), de reconocido prestigio en el campo de estudio. Para desarrollar su labor se le envía el listado de evaluadores de los últimos años, pudiendo seleccionar e incluir aquellos nuevos revisores que el Editor de Área considere más acorde con el trabajo para su evaluación.

Una vez recibidas las dos evaluaciones el Editor de Área elevará al Comité de Dirección su propuesta de aceptar o rechazar el artículo para su publicación en UCJC BSR. Se pretende que, mediante la implantación de sucesivos “filtros” de calidad, el lector obtenga garantías de que la revista publica sólo aportaciones de nivel y de actualidad.

NORMAS PARA LOS ARTÍCULOS

UCJC BSR está abierta a la recepción para su publicación de originales preparados por miembros del mundo universitario, escuelas de negocios de todo el mundo, directivos y empresarios. Para que los trabajos puedan ser publicados los autores deberán atenerse a las siguientes normas:

- **Los artículos, que serán inéditos**, tendrán una extensión alrededor de 5.000 palabras, incluyendo notas a pie de página y bibliografía. **No deberá utilizarse un número excesivo de referencias bibliográficas.** Se considera que no deben superar las veinticinco.

- El artículo debe estar redactado de forma que facilite la lectura y comprensión de los contenidos a un público no académico. Se **debe evitar utilizar un lenguaje de corte excesivamente especializado**, en beneficio de una más fácil comprensión de las ideas expuestas y en la medida de lo posible, el abuso de términos muy académicos (metodología, hipótesis, etc.) y funciones matemáticas, aunque esto haya podido servir para que los evaluadores analicen el alcance de su investigación. Las **conclusiones no deben ser un resumen del trabajo**, sino una aplicación, una lección que se está trasladando a los responsables de las empresas para que estos la puedan considerar como un “buen consejo”, y lo que es más importante, que lo puedan entender y aplicar.

Si es necesario, o el evaluador lo requiere, se puede adjuntar como un fichero complementario (o anexo) todos los datos, técnicas econométricas, etc..., que hayan podido utilizar los autores para alcanzar las conclusiones de su investigación.

Una vez dado el visto bueno al trabajo, dicho fichero (o anexo) no se incorporaría en el artículo editado. Los autores deben hacer un esfuerzo para adaptar su trabajo a nuestros lectores, a los empresarios y directivos, no sólo al mundo académico.

• Los autores deberán subir un **fichero adicional “Archivo complementario” respondiendo a las siguientes preguntas:**

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2. ¿por qué cree que los directivos deben conocer su artículo? ¿para qué tipo de empresas serviría y para qué tipo no?
3. ¿qué investigación se ha llevado a cabo para argumentar su propuesta? ¿sobre qué trabajos (artículos, teorías, etc...) fundamenta su propuesta?.
4. ¿cuál es su experiencia personal, académica y/o profesional que avale sus conocimientos sobre el tema?

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• Los **artículos se publicarán en inglés y castellano**. Los autores pueden enviar el artículo en castellano, pero una vez finalizado el proceso editorial y antes de su aceptación definitiva, los autores se comprometen a enviar la versión íntegra en inglés para publicarse en los dos idiomas.

• **No deberá aparecer el nombre del autor/es en ninguna hoja**, con el fin de facilitar el proceso de evaluación, ya que los datos se incorporarán en el formulario digital.

• Los originales, que deberán incorporar el título del trabajo, estarán editados electrónicamente en formato requerido en la aplicación, y se **enviarán por vía electrónica mediante acceso a la siguiente dirección: ubr.universia.net**. Los autores deberán rellenar sus datos en la ficha electrónica.

• Las **referencias bibliográficas** se incluirán en el texto indicando el nombre del autor, fecha de publicación, letra y página. La letra, a continuación del año, sólo se utilizará en caso de que se citen obras de un autor pertenecientes a un mismo año. Se incluirán, al final del trabajo, las obras citadas en el texto según lo previsto en las normas **APA style guide**:

- o Takeuchi, H. (2013). “Knowledge-Based View of Strategy”. *Universia Business Review*, 40, 68-79.
- o Guillén, M., García-Canal, E. (2012). “*Emerging markets rule*”. New York: McGraw-Hill.

• Una vez recibido el artículo, **UCJC BSR acusará recibo**, por correo electrónico, e iniciará el proceso de selección anteriormente mencionado. Finalizado el mismo se comunicará al autor de contacto la decisión sobre su aceptación o rechazo por parte del Comité de Dirección.

• La revista se reserva la **posibilidad de editar y corregir los artículos**, incluso de separar y recuadrar determinadas porciones del texto particularmente relevantes o llamativas, respetando siempre el espíritu del original.

• Los autores deberán estar en disposición de ceder a UCJC Business and Society Review (Formerly known as Universia Business Review) los **derechos de publicación de los artículos**.

MISSION

As stated in our mission, *UCJC Business and Society Review* (Formerly known as *Universia Business Review*) is not a publication dedicated strictly and exclusively to the academic world; its primary mission is **to transmit the most innovative ideas and developments generated by the scientific and academic communities to business leaders.**

Nevertheless, UCJC BSR does not neglect to provide a service to the university and scientific community, as a publication of reference through which specialists can systematically follow the latest contributions made by colleagues in their field. In particular, the journal seeks to be a vehicle of communication and union among university communities that speak Latin American languages and are dedicated to the study of Business.

EDITORIAL PROCEDURE

The originals received and accepted by the Management Board will be sent to the Associate Editor for the relevant area who will determine whether the work should proceed through the editorial process and be forwarded to two anonymous evaluators (experts external to the publishing entity), renowned for their work in the field. The list of evaluators from the last few years is provided to support their work by enabling them to select and include new reviewers that the Associate Editor considers most appropriate for evaluation of the work.

Once the Associate Editor receives the two evaluations, they will submit a proposal to the Management Board to accept or reject the article for publication in UCJC BSR. It is intended that, through the implementation of successive quality "filters", the reader will be assured that the magazine only publishes contributions that are high quality and current.

STANDARDS FOR ARTICLES

UCJC BSR is open to receiving original documents for publication prepared by members of universities, business schools from around the world, and business owners and executives. To ensure that the work is suitable for publication authors must abide by the following rules:

- Check that **the articles, which must be unpublished**, are limited to around 5,000 words, including footnotes and bibliography. **There should not be an excessive number of bibliographical references**, which must not exceed twenty-five.

- Particular attention should be paid to the fact that the article must be worded in a way that enables the content to be read and understood by a non-academic audience. **The use of very specialised language should be avoided** in order to make the ideas presented more easily understood, as should the overuse of very academic terms (methodology, hypothesis, etc.) and mathematical functions as far as possible, even if that may have helped evaluators to analyse the scope of the research. **Conclusions should not be a summary of the work**, but an application: learning that is transferred to business leaders so that they will consider it "good advice" and, more importantly, something they can understand and apply.

If necessary or required by the evaluator, all of the data, econometric techniques, etc. that may have been used by the authors to reach the conclusions of their research may be attached as a supplementary file (or annex).

Once the work has been approved, the file (or annex) will not be incorporated as part of the edited article. The authors must make an effort to adapt their work to our readers –business owners and executives– not just the academic world.

- The authors must upload an **additional “Supplementary file”, responding to the following questions:**

1. What is the primary message or idea in your article? Can business owners and executives apply it?
2. Why do you think executives should see your article? Which kinds of companies would it be of use to, and which not?
3. What research have you undertaken in order to argue your proposal? What pieces of work (articles, theories, etc.) is your proposal based on?
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- Each article must be preceded by the title, a short summary in Spanish and English of approximately 80 words in each case, and five key words in both languages. It should also incorporate a classification of the work according to the descriptors used by the Journal of Economic Literature.

- **Articles will be published in English and Spanish.** Authors can send the article in Spanish, but once the editorial process is completed and before it is finally accepted, the authors must undertake to send the full version in English for publication in both languages.

- **The author's name should not appear on any page** in order to simplify the process of evaluation, since the data will be incorporated into the digital form.

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- **Índice H de las Revistas Científicas Españolas según Google Scholar Metrics** (2011-2015). H:13. Posición UBR: 1/87 revistas del área de Economía y Empresa (Julio 2016).H:12.
- **IN-RECS** (Índice de Impacto de Revistas Españolas de Ciencias Sociales). Categoría: Economía. Índice de impacto 2011: 0,268; Q1; posición 15 de 133 revistas. UBR es revista fuente.
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UCJC BSR ha estado indexada durante el período 2008-2012 en el Journal Citation Report-Social Sciences Citation Index (Category: Business). 2010 Factor de impacto: 0,228; 2011 Factor de Impacto: 0,150; 2012 Factor de impacto: 0,138 (actualizado junio de 2013).

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- **SCOPUS** (Elsevier Bibliographic Databases). Scimago Journal Rank 2015 (SJR) : 0,219 Q2; Category: Business, Management and Accounting (miscellaneous). Position 136/285.
- **Web of Science, Emerging Sources Citation Index (ESCI)** January 2016. Universia Business Review has been indexed, 2008-12, in the Journal Citation Report-Social Sciences Citation Index (Category: Business). 2010 Impact Factor: 0,228; 2011 Impact Factor: 0,150; 2012 Impact Factor: 0,138 (June 2013).
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Divergent Opportunities of Innovation: When Time and Situation matter

Oportunidades Divergentes de Innovación: Cuando tanto el momento como la situación importan

I. INTRODUCTION

New technologies have a fundamental impact on society and economy. No matter whether one might think about new products based on biotechnology and genetic engineering or the most recently discussed the changes, which will emerge because of digitisation and industry 4.0. The example of artificial intelligence also indicates that innovation is more than just technology; it is also organisation, skills and education (see the contributions by Vassiliadis & Hilpert, and Hickie to this special issue). In the light of impressive technological change and because of a concentration of the discussion on gifted researchers and outstanding entrepreneurs the full picture of innovation widely escapes from view. The assistance of robots in manufacturing, the introduction of personal computers in offices, the reorganisation of assembly lines, or the increasing importance of suppliers and supply chains etc. clearly refer to the organisational dimension of innovation.

When paying reference to the innovative potential of new materials (e.g. in automotive industries and aircraft), biotechnology and genetic engineering (e.g. in crops, pharmaceuticals and medical treatment), and artificial intelligence and digitisation (e.g. in manufacturing, servicing and improving traffic) it is immediately obvious that the processes of innovation are highly divergent. They



EXECUTIVE SUMMARY

This paper investigates the rich diversities of innovation which are characterised not only by location or country and regional context of an enterprise but also by a wider context which can even be defined globally. The research argues that these diversities of innovation demand appropriate strategies and a concertation of capabilities in given situations. The paper shows how the opportunities emerge from technologies, organisation of manufacturing and research and how they are associated with constant changes of skills, products and demand. Moreover, the process describes how processes of innovation have become highly collaborative in R&D and also with regard to the supply of high-quality parts to international chains of innovation. These situations have also become important opportunities to contribute and participate based on specialised competences to take advantage of highly diverse processes of innovation and embeddedness in global division of labour. Finally, synergy with traditional competences may help to exploit opportunities in a unique way that create sustainable differentiation.

RESUMEN DEL ARTÍCULO

Este trabajo investiga la diversidad de la innovación que se caracteriza no sólo por la ubicación o el contexto nacional y regional de una empresa, sino también por un contexto más amplio que incluso puede definirse a nivel mundial. La investigación argumenta que estas diversidades de innovación exigen estrategias adecuadas y una concertación de capacidades en determinadas situaciones. El trabajo investiga como las oportunidades surgen de las tecnologías, la organización de la fabricación y la I+D y cómo se asocian con cambios constantes de habilidades, productos y demanda. Además, el proceso describe cómo los procesos de innovación se han vuelto altamente colaborativos en I+D y también con respecto al suministro de piezas de alta calidad en cadenas internacionales de innovación. Estas situaciones también se han convertido en importantes oportunidades para contribuir y participar sobre la base de competencias especializadas para aprovechar procesos muy diversos de innovación e integración en la división global del trabajo. Finalmente, la sinergia con las competencias tradicionales puede ayudar a explotar las oportunidades de una manera única que cree una diferenciación sostenible.

are based on different progress in technologies, demand divergent adjustments in manufacturing, and suppliers change their position and importance in the value chains. And since some technologies (e.g. robots and steering based on artificial intelligence) provide a constant replication of quality of products they can replace simple work and those who do the work - plus they may allow for a combination of new and modern technologies with unskilled or semiskilled labour in countries with low labour costs and weak regulations (Hilpert 2019). Thus, societies which are characterised by skills and education may perform differently and their economies and enterprises may take advantage of innovative opportunities differently.

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Consequently, locations are faced with highly divergent situations at different points in time. Different technologies emerge at different times, industries are characterised by divergent opportunities and challenges, and educated and skilled labour is demanded at different levels and for divergent purposes along the organisation of the process of innovation (Scherrer 2019). One could easily find even more dimensions which are influenced and it is important to see how these are interrelated. Finally, it is, of course, important to see this in relation with capabilities of scientific research, the development of technologies which suit the industries at the place and universities which are the home of outstanding research as well as being ready to educate knowledge workers and academic researchers (Hilpert & Lawton Smith 2014, and the contribution by Lawton Smith & Assimakopoulos in these special issues). Although the individual situation already provides for highly divergent situations, in addition, the context of a global economy and the globalisation of supply chains and value chains point to the importance of the context (Hickie 2019, and Hickie to these special issues). When turning to tariffs and trades which may protect a national industry or which may help to avoid unfair trade, it becomes immediately obvious, how critical the context is. The current example of the BREXIT indicates that an unchanged regional situation in a previously open economy can be become exposed to a situation characterised by tariffs and different trade – facing a new international context. Thus, there are rich diversities of innovation which are characterised not only by location or country and regional context of an enterprise but also by a wider context which can even

be defined globally – and thus provide for talent of labour from blue collar to academically educated labour. The diversities of innovation demand appropriate strategies and a concertation of capabilities in given situations.

2. REGIONS AND BRANDING

When paying attention to processes of innovation there is immediately a relationship with geography is to be identified. Regions do not equally participate in innovation. This is, of course, self-explaining in areas where no industries or research facilities are located (see the contribution by Sandulli to these special issues). It is very interesting how diverse the situation is, when more developed regions are taken into consideration. During industrialisation of the 18th and 19th century regions have transformed from rural areas into highly industrialised locations. This is most notable when it comes to iron and coal. These were basic materials to produce steel as a general basis for many other mass products which were developed and were introduced during this period in history. Steam engines, locomotives as well as rails, ships or cars were dependant on steel. Such regions – today called *old industrial regions* – were well known for the products and the use of steel made other regions well known. The automobile industry of Detroit made this region a world centre of cars and one expected to be among the highest competence of cars to be found. Shipbuilding even found its centres at harbours of particular countries which were in strong demand for ships for commercial use transporting goods or armed as navy equipment. Thus, as the shipbuilding indicates, even before the strong industrialisation locations were well known for the competence which was located there. Musical instruments, jewellery or precious textiles are further examples which refer to such underlying geographical information. Regions or even countries were experiencing a particular reputation which meant that whenever one would like to have a particularly high quality product or a technical problem solved one would search at such places. When more modern industries emerged (e.g. chemical industries, mechanical engineering, precision engineering, apparatus building) which did demand for scientific research or highly advanced engineering the role of knowledge and particular expertise increased. Regions which were not privileged by nature to have coal or iron ore were

KEY WORDS

R&D, Skills,
Innovation,
Globalization.

PALABRAS CLAVE

I+D, Habilidades,
Innovación,
Globalización.



put into a situation to manufacture industrial products based on knowledge and high competence. Skills, education, development of new products and leading edge research became fundamental for such processes of industrialisation which related to high value added during R&D and manufacturing. Consequently these regions, locations or even countries were known and branded for such products and competences (Bellini and Pasquinelli 2016). The more such knowledge became important for modern industries as compared with traditional “old” industries, the more such competences from research and engineering became demanded to find the best products adding to the already existing branding and reputation – and thus building synergy with competences from industrial history (see the contribution by Vassiliadis & Hilpert to this special issue).

This refers to competences in research and manufacturing of certain products but it also indicates capabilities to provide high-quality parts or semi-fabricated products which are demanded by other industries or enterprises. Electronic steering equipment or measurement instruments are easy to imagine as manufactured at one place and implemented into a different product (e.g. machines, industrial plants, automobiles, aircraft or pollution control) at a different location. But it may also be that the final products require for a constant high quality, reliability of supply or particular improvements (see the contribution by Hickie in this special issue).

Regional concentration of enterprises and leading edge research or engineering may help to develop particular visibility and to strengthen the position in trade of innovative products. Locations and companies of outstanding competence can take advantage of demand from other dynamic processes and related business (see the contribution by O’Gorman & Donnelly to these special issues). The success of Tesla cars creates a demand for parts which are assembled by Tesla. About 60 to 70 per cent of the parts used by Tesla are said to be bought in Germany, predominantly from Bosch (Hilpert 2019). Consequently, it is no more a hierarchy between OEM and suppliers rather than an interdependency and divergent contributions to innovative processes - and hence the branding and the continuously increasing competence of enterprises and at particular locations which take advantage of divergent situations and capabilities. The diversities help, benefitting such enterprises and

locations and indicate divergent competences, global value chains and a continuing participation in leading edge innovation.

3. INDUSTRIES AND SIZE OF ENTERPRISES

Geographic concentration and branding of competences relates closely with certain industrial profiles and expertise of enterprises. The emergence and identification of innovative clusters clearly refer to such agglomerations (see the contributions by Lawton Smith & Assimakopoulos and by O’Gorman & Donnelly in this special issues). Although their composition can be highly divergent it allows for recognition, employment and economic development. During earlier periods of industrialisation larger enterprises did characterise such geographic concentrations. When vertical integration was very low there was a concentration at particular locations because they did provide some advantages (e.g. traffic and transportation, raw materials). Old industrial regions did emerge where coal was accessible and where transportation by ship or railway could provide for iron ore. Similarly, chemical industries developed where river water could be used for processes. When the management of manufacturing changed by reducing vertical integration and smaller enterprises developed to supply the dominant ones such locations continued, but new enterprises with an interest in marketing their expertise and products complemented existing structures. During long periods of industrialisation the existence of large firms was a strong advantage for regional development and also for smaller firms as these did have local customers for their specialised products.

Already during such early periods of industrialisation technological progress and efficient equipment became highly important (see the contribution by Scherrer to this special issue). It did increase productivity and security. In mining new machines were developed and introduced and safety of mining was improved. Consequently, mining equipment was produced and exported also to customers at other locations. These new competences emerged and industries based on new knowledge and application of research were the basis for mechanical engineering, precision engineering or measurement instruments. Such lead industries were characterising the suppliers and the competences which were developed. The competences, of course, are not limited to these products to match existing customers



demand. Applying materials, constructing powerful machines etc. can be used in other contexts and for other purposes. The more heterogeneous such clusters become and the less dependant on a particular lead industry they were, consequently, the better these regions, countries or locations can adapt to changes because of declining industrial sectors. The development of knowledge-based enterprises, industries and products allow for application of such competences to new and other areas and products. The more advanced and marketable such competences are, the more demanded were these applications.

While lead industries were dominant and usually characterised by large firms producing large quantities, the suppliers were small and highly specialised. The demanded products were related to higher competences in manufacturing and smaller series or even specialised or adjusted products. An increasing number of suppliers also spread the development of competences over many more enterprises and provided a basis for further synergies of competences and knowledge. Divergent areas of specialisation of firms allowed the entering different markets and approaching different customers. As small and medium sized enterprises, these were both more flexible and could also take advantage of smaller market niches. The orientation in particular supplies was usually related to a specific competence. Consequently, the higher competence in selected areas allowed for change or additional products. The existence of other firms with specific competences, in addition, provided for the opportunity to merge when the specific demands of new customers emerged.

The change of industrial structures because of new competitors and the disappearance of traditional industries and enterprises based on mass-production weakened regions and clusters which were characterised by their orientation in such large firms. Simultaneously, emerging market niches because of increasingly free international trade allowed for smaller firms to find new economic opportunities for their competences. While such small and medium sized enterprises (SMEs) from old industrial regions had to pass through restructuring and to rearrange their strategies, SMEs from other regions which were not dominated by single firms or industries of a small range of products immediately could reorient towards these new and changing opportunities.



4. PRODUCTS AND MARKETS

When international trade and dislocation of plants for mass-production and less complex products towards newly industrialising countries became more intensive, this fundamental structural change did also introduce a change of products and markets. New technological opportunities allowed for more specific solutions of customer demands and introduced small series or products which were highly oriented to the demands of individual customers. The specificity of individual situations which demanded adjusted products and the application of new technologies increased the knowledge and competences required for both design and manufacturing of the products (see the contribution by O’Gorman & Donnelly to these special issues). Profits increasingly emerged from higher quality and from values added rather than from lowering costs through large series production. Plant construction, mechanical engineering, precision engineering, medical instruments, apparatus engineering or measurement instruments are examples of industries of increasing knowledge intensity which meet the changing and growing demand.

While global trade grew dynamically, transportation of goods and people increased also. Rapid train systems as well as aircraft created a strong demand for a higher quality of materials and for new materials. Environmental problems and regulations to reduce environmental impact in addition created a strong demand for research and new technological opportunities based on new research findings. Products, as a consequence, required a constantly increasing contribution from research and development. Electronics, biotechnology, new materials and informatics became driving forces of innovation and allowed for a rich combination with already existing industrial competences. The advancement in electronics and software allowed for fundamental innovation in mechanical engineering, robotics, measure instruments, control of plants etc. Current processes in digitisation and Industry 4.0 again reach out much further and induce processes of innovation in relation to the industrial opportunities or capabilities of a region (see the contribution by Gaddi, Garbellini & Garibaldo to these special issues). New materials allow for widespread innovation and are also addressed in many industries. Aircraft manufacturers and automobile industries both benefit from such new technological opportunities but some materials are also applied in many other products such



as machines, instruments or apparatus because of durability, hygiene or advantages when compared with traditional materials. Biotechnology and genetic engineering as a further example allow for changes in the process of producing pharmaceuticals, replacing traditional chemicals, allowing for modified plants, merging with medical instruments improving their precision as well as some genetic intervention helping to treat diseases.

Consequently, innovation is also oriented in traditional industries and products which allow for improvement when merging with new technological opportunities. Energy efficient cars and aircraft, improvement of health, precise measurements and dosing, or information for pollution control of air, water or soil, such innovation is build upon already existing competences and improves the quality of the products. This provides the basis for processes of innovation, which are already highly divergent because of the different industries, specific products and capabilities of the regions and locations. Those are divergent due to their effect on economic development, concerning the relationship with skilled and educated labour and because of opportunities to link up with techno-scientific research. Close linkages between techno-scientific research and industries ready to apply new opportunities provide for situations that are widely beneficial (see the contribution by Vassiliadis & Hilpert to this special issue). These situations also indicate the divergent arrangements which are fundamental to the processes of innovation to be identified in the individual region, location or metropolis.

Industries which are characterised by large enterprises, simultaneously, provide markets for suppliers and further business opportunities (see the contribution by O’Gorman & Donnelly to these special issues) - and benefit from the innovation which is realised by suppliers. Aircraft industries and automobile industries have developed a vertical range of manufacturers which give particular importance to suppliers and their level of innovation (see the contribution by Hickie to this special issue). Thus supply chains also turn into markets which demand for innovative goods and continue as long as such components of final products are delivered. While this indicates the role of advanced management in complex manufacturing processes, other industries and products can readily approach other markets more directly. Although these can be final products or original equipment manufacturers (OEMs) which also are often related indirectly with certain industries or multi-



national enterprises (MNEs), these firms enter markets not in the rather defined situation of suppliers. Demands of customers and capabilities of innovative firms as well as their innovative products can create a positive socio-economic effect only when markets are available and size of the market is sufficient. Because of the strong demand for innovative products and solutions from customers, for all participants in such a market free trade regulations are important. Producers as well as customers depend on the supply of markets. Thus, a highly diverse process of innovation is indicated by specific situations of regions, locations and metropolises but it can be realised only on the basis of a context in such situations which is formed through available markets where firms and their products may be competitively successful.

5. TECHNOLOGY AND LABOUR-FORCE

Such relationships between innovative enterprises and value chains which inhibit the application or development of new technologies also refer to divergent geographic opportunities. Products need to be manufactured and contributed along the supply chain. Thus, competences in technologies, leading edge engineering and research and transportation match and allow for merging within the chain, based on collaboration and are ready to contribute to the final product. Thus, developers of technologies and manufacturers of high quality products find their position within the value chain at similar, often converging locations. Public research institutes and private enterprises of outstanding technological competence or being well known for particular areas of manufacturing contribute to such processes. A close relationship between those who are engaged in techno-scientific research and enterprises engaged in high value products for dynamic markets allows for an economic orientation early on in periods of technology development and product design.

As diverse as the locations and the individual structures are, similarly diverse are the areas of innovation and the opportunities to participate in innovation. Although frequently certain countries are identified as drivers of innovation or considered to be particularly strong in some areas of research and technology, one needs to take into account that these capabilities are not evenly distributed over the country. Regions, locations and metropolises differ (Hilpert



2016). They allow for diversities of innovation across countries but also within countries – and even in countries which are considered to be strong in new technologies, scientific research and innovation, often, there are significant diversities. Such diversities emerge because of the agglomeration of institutes, knowledge workers and advanced industries, but, in addition, the individual profiles indicate diversities concerning the area of expertise.

Consequently, there are highly specific constellations based on different areas of leading edge research and demanding different education and skills of the labour-force (see the contribution by Vassiliadis & Hilpert to this special issue). Biotechnology is based on research in life sciences and Industry 4.0 or digitisation refers strongly to top research in electronics and computing. Similarly, progress on new materials or medical treatments as well as the development of new pharmaceuticals refers to outstanding competences and established capabilities in a region or at a location or metropolis. Increasingly the importance of cross-disciplinary collaboration, or even interdisciplinary research teams, and the agglomeration of capabilities, competences and labour-force provides a competitive advantage – and in many cases it is the basis of break-throughs which can be geographically localised.

It is the exchange and collaboration of expertise which creates synergy and indicates Islands of Innovation which are outstanding because of such situations and, in addition, these particular locations are building specific continental and trans-continental networks of collaboration. They exchange knowledge while carrying out joint research processes and they exchange knowledge-workers, academics and outstanding scientists as basis of further leading edge research (Hilpert and Lawton Smith 2013). Nevertheless, such networks, locations and opportunities address particular areas of research and expertise as a basis for exchange and synergy. The diversities of innovative locations are reproduced within wide networks among Islands of Innovation – the areas of expertise, research and competences provide the basis for such highly diverse processes.

While Islands of Innovation are centres of excellence in leading edge research and technology development, locations which are less central hardly have opportunities to participate in such processes of innovation in a similar way (see the contribution by Sandulli to these special issues). Once new technological opportunities are ready for



application there are opportunities for synergy when applying them in traditional products or to supply parts on a higher technological level. The examples of aircraft industries or automobile industries indicate the importance of innovation at the level of suppliers (see the contribution by Hickie to this special issue). Reducing the weight by the application of new materials or improving the energy efficiency of motors and machines is also based on design and improvement along the supply chain. This requires a lot of competences built through experience which needs to be merged with tradition. This does not demand links at central locations but for competences to constantly advance the products based on new technological opportunities and to be able to implement those in high quality manufacturing. Such processes of innovation allow for opportunities to continue and constantly modernise existing firms and industries.

While Islands of Innovation create a wide range of jobs for highly educated personnel who frequently hold higher university degrees such as Masters degrees or PhDs, on the other hand, manufacturing firms outside of such highly innovative regions strongly demand highly skilled blue collar workers to match the demands for innovation in quality of the products – and thus indicate that localities for talents vary with the industries and products manufactured. Such skilled labour is fundamental for regional development which takes advantage through application of new technologies without generating leading-edge technoscientific research (see the contributions by Vassiliadis & Hilpert and by Gaddi, Garbellini & Garibaldo to these special issues). The capability in manufacturing and a strong basis in engineering and design to match consumer demands provides for international champions in selected areas although the firms are not based in Islands of Innovation. It needs to be considered that innovation is socio-economically effective only if it is related with manufacturing and higher values added. Thus, the capability to manufacture such high levels of technology-based products creates further Diversities of Innovation by constantly improving capabilities in manufacturing. Consequently, the availability of labour and the skills and education are fundamental for making innovation socio-economically effective. The awareness of the relationship between manufacturing and innovation is also important when searching for a particular strategy of development. While the capabilities and areas of



research are creating clear diversities, in addition, industries are important for identifying the potential for manufacturing. Continuing and constantly strengthening the research basis of Islands of Innovation this provides for a wide area of opportunities realised at different regions, locations and metropolises. On the other hand, continuously increasing and modernising skills of the labour-force are fundamental to participate in innovation from locations in less central regions. Flexible response towards customer demands and the application of new technologies are based on organisation and management of firms: Skills, positive attitudes towards work and the modernisation of the products manufactured provide for the realisation of such processes.



6. CHANGE AND DURATION

Processes of innovation clearly are referring to changing and new needs and demands which may be matched differently than previously by new technologies or new products applying new technological opportunities. The process itself may also require changes in organisation, management, skills and education. Thus, technological innovation is not enough in its own. The realisation of innovation is also based on change which includes firms, societies, economies and government policies (see the contributions by Vassiliadis & Hilpert and by O'Gorman & Donnelly to these special issues). It is already frequently discussed, how widely new information and communication technologies, social media using the internet, new materials applied in cars and aircraft, new pharmaceuticals and the biotechnology and genetic engineering have both impacted and changed everyday life. Whereas the changes which were fundamental to allow for such processes of innovation – frequently associated with noticeable effects from new technologies – are rarely considered. Economic change, modernisation of industrial structures or the demand for new skills or educated labour is discussed in general from a perspective which either asks what is necessary to implement such new technological opportunities or how much such innovation affects existing situations, challenging the established processes and individuals associated with them.

Diversities of Innovation are taken into account implicitly only by empirical studies which refer to certain technologies, industries

or services. Clearly, divergences in technologies, size and scope of firms and their products, markets approached and research required for application indicate specific situations which are usually different from one another. Nevertheless, certain systematics of innovative processes converge but the divergences emerge because of the changing situations based on alteration of elements although individually such changes may be small. During processes of Industry 4.0 firms may find new market niches for specifically modified products, some alterations in the production chain, additional or new skills, and opportunities for transportation of products which individually are rather limited, but are matched to major changes of organisation and requirements which need to be met in the societal, industrial and research environment. One needs to bear in mind that within such constellations of innovative development even minor changes (such as five per cent in each of the areas mentioned) may add up to a significantly changed situation (it adds up to changes of about a quarter of the existing arrangements) - and thus even similarly innovative situations require one to take into account the Diversities of Innovation. This requires adjusted actions and strategies which are based on an understanding of diversification of processes on the firm level which mount up to challenging situations of industries, regions, countries and metropolises.

While this indicates the effect of combination of even slight changes, it needs to be taken into account that in practice certain core competences (e.g. industrial capabilities or particular products) are continued while other elements such as new or changing markets, new technologies or customers demands, may change much more widely. This may indicate even more, that in relation to certain established structures (such as industries or enterprises of outstanding reputation), opportunities for innovation are highly divergent but empirically are concentrated on particular situations and core competences (see the contribution by Lawton Smith & Assimakopoulos to these special issues).

A realisation of changes and adjustments take time. The application of new technological opportunities with traditional products usually take five to seven years until these are standard of an industry. In doing so synergy between traditional competences, updated skills, advanced education and modernised products to meet customers' demands is to be found. Such changes frequently follow from



longer lasting research which takes influences on new product opportunities. Long waves of innovation indicate the periods and changes which emerge during development, introduction and maturation of technologies (see the contribution by Scherrer to these special issues). This also indicates the changes required at different periods of innovation and how divergent the processes are which enterprises and industries have to cope with. Thus, time and duration are important dimensions to understand and to plan for such processes. Consequently, there are Diversities of Innovation according to the period of the process in which enterprises are engaging.

Even in cases when enterprises are in similar industries manufacturing similar products the different periods matter a lot. In particular at the forefront of innovation there might be a strong demand for new technologies and new products applying new technological opportunities. This confronts labour markets which usually are not prepared to supply such new and unique skilled labour. Systems of education and blue-collar skills need to be ready to adjust quickly or to provide such labour which is flexible to adjust to new challenges, and to match the newly emerging demand and manufacturing innovative products (see the contribution by Vassiliadis & Hilpert to this special issue). Nevertheless, a fast developing innovative sector may move faster than the opportunities provided by regional or national labour markets - and in some areas of skills and education even labour migration may neither be available nor ready to meet the new and dynamically emerging demand.

Thus understanding innovation requires analysing processes which begin long before the precise phenomena are identified. In contrast, a concentration on the new phenomena is only a kind of coping with techno-industrial change. To be prepared for innovation there needs to be a supply of labour, research and management of enterprises which are ready to adjust to the changing situation – and these processes need to be rather corresponding. These contributions, required to realise the socio-economic effects of innovation, are constantly changing and are characterised by on-going improvement. Thus change over time plays an important role and creates divergent opportunities of innovation which emerge in different periods and maturities of technologies.



7. CONCLUSIONS: SPECIFIC OPPORTUNITIES DURING CONSTANT CHANGE

Global development and export markets indicate a constant need for advancement and change. While there is much thinking about start-up enterprises, new technologies and break-throughs in research, in fact, existing situations and capabilities of industries, research and workforce are important conditions of innovation. Although some areas of innovation or niches to supply particular markets can be developed, in general, these structures are important to identify appropriate areas and opportunities for such processes in a country, region or metropolis. Industrial structures can provide a basis for application or are critical to both to participate generally in innovation processes and to have an impact on such processes. But, even where there might not be the core capabilities to develop new opportunities, international networks provide opportunities to participate in such processes, which generate the demand for specialised contributions to the entire process (see the contribution by Hickie to this special issue). Consequently, this creates highly diverse opportunities which are to be understood not merely on the basis of technologies but in particular with regard to potential socio-economic opportunities in the light of existing situations (see the contribution by O’Gorman to these special issues).

Participation in divergent areas of innovation is strengthening and modernising regional or metropolitan innovative potential and can also provide cross-sectoral opportunities by merging existing and new capabilities for new processes, products and services. As this strengthens and modernises a regional or metropolitan socio-economic capability it can also help a business which is not related to the innovation itself. Increasing incomes and increasing numbers of people with higher incomes will provide a purchasing power which has positive impact on supermarkets, shops restaurant, services, housing etc.. In addition, such customers demand products and services of higher value and are both capable and willing to pay higher prices. Consequently, processes of innovation are in the interest of inhabitants, employees and employers, shop owners and service suppliers in a region or metropolis. Public policies addressing such processes of constant innovation and modernisation, as well as supporting skill strategies of enterprises and continuous modernisation of the workforce, are clearly oriented





in a strategically important part of the socio-economic structure providing for processes oriented towards a prosperous future.

While doing so, research capabilities and a skilled workforce are fundamentally important to realise such processes and to attract innovative enterprises to come to the region or to stay at the location (see the contribution by Vassiliadis & Hilpert to this special issue).

While Islands of Innovation are usually located at metropolises they also indicate a growth of population. Highly skilled and university educated personnel increasingly are concentrated at highly innovative agglomerations while peripheral or rural regions have to face outward migration (see the contribution by Sandulli to these special issues). When preparing for the innovative processes addressed here, there is a need for a labour-force ready to manufacture or to design higher value-added products, and for research capabilities ready to provide competences and results which suit the industrial structures and are related to the high-quality services of a region.

Hence, government programmes which support such initiatives and help to build sustainable structures of skills and R&D underpin the need to serve the public interest in constant innovation and socio-economic development. Since the structures vary a lot across regions, consequently, the programmes and support required need to address different issues. A clear knowledge about innovative opportunities of the regional or metropolitan structures can help to select the appropriate policies and to allow innovative specialisation to blossom.

Such opportunities emerge based on technologies, organisation of manufacturing and research and, in addition, they are associated with constant changes of skills, products and demand. Since processes of innovation have become highly collaborative in R&D and also with regard to the supply of high-quality parts to international chains of innovation. These situations have also become important opportunities to contribute and participate based on specialised competences. Building specialised competences may help to take advantage of highly diverse processes of innovation and embeddedness in global division of labour. Such Diversities of Innovation are to be identified during constant change processes and in matching with new opportunities. Thus, synergy with traditional competences may help to make opportunities unique and to allow for a continuation of specific contributions to innovation processes which are based on diverse competences.

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How “General purpose technologies” trigger long waves of economic development and thereby generate diversities of innovation

Como “las Tecnologías de Uso General” desencadenan ondas largas de desarrollo económico y por tanto generan diversidades de innovación

I. INTRODUCTION

“General purpose technologies” (GPT) that can be applied to a multitude of economic activities and sectors cause fundamental structural changes in the whole economy and in the way how economic life is organized. They allow for developing new markets and introducing new products, processes and organization principles to the market and thereby triggering fundamental changes in all parts of the economy and society. Because of this impact on all sectors of the economy GPTs generate “long waves” (Kondratieff 1935, in German: 1926) representing long-term surges of economic development. The internet as the major outcome of the fusion of modern information and communication technologies is the dominant GPT in the current long wave that followed the Fordist mass production which was the preceding long wave’s GPT. This paper shows that long-term structural change is influenced by the emergence and dissemination of GPTs and that the behavior of economic agents and activities of economic policy makers exert a strong influence on a country’s possibilities to benefit from applying the new technologies. It is shown that during the unfolding of a long



EXECUTIVE SUMMARY

Long-term structural change is influenced by the emergence and dissemination of general purpose technologies (GPT) that generate "long waves" of economic development. The paper shows that the long-wave dynamics is characterized by major diversities of innovation and that economic agents and policy makers strongly influence an economy's ability to benefit from new technologies. Information and communication technology as the dominant GPT of the current long wave and other, emerging technologies that possibly act as a GPT of the next long wave (e.g. Industry 4.0) are put into the long wave-context.

RESUMEN DEL ARTÍCULO

El cambio estructural a largo plazo se explica por la aparición y la difusión de tecnologías de propósito general (GPT) que generan "ondas largas" de desarrollo económico. El trabajo muestra que la dinámica de las olas de larga duración se caracteriza por marcadas diversidades de la innovación y que los agentes económicos y los responsables políticos influyen de manera significativa en la capacidad de una economía para beneficiarse de las nuevas tecnologías. La tecnología de la información y la comunicación como actual paradigma dominante de la actual onda larga de cambio tecnológico y otras tecnologías emergentes que posiblemente actúan como tecnologías de propósito general de la próxima oleada de cambio tecnológico (por ejemplo, la Industria 4.0) se ponen en el contexto de la teoría de las ondas largas de cambio tecnológico.

wave, typically, different diversities of innovation (Hilpert 2019) emerge and predominate.

In the next section a model of long waves of economic development will be presented in a nutshell. This is followed by an analysis of the phases that a long wave consists of and a discussion of the diversities of innovation that are typical for the specific phases. Then information and communication technology as the dominant GPT of the current long wave and other, emerging technologies that could possibly act as a GPT of the next long wave (e.g. “Industry 4.0”) are put into the context of the model. The final section concludes with insights from the long wave model for understanding diversities of

innovation. This article builds on the author’s contributions to the Handbook of Politics and Technology (Scherrer 2016) and to the edited volume “Diversities of Innovation” (Scherrer 2019); both books were edited by Ulrich Hilpert and published by Routledge.

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*...long-term structural
change is influenced
by the emergence
and dissemination of
GPTs...*

**2. “LONG WAVES” OF ECONOMIC DEVELOPMENT –
A BRIEF INTRODUCTION¹**

Based on empirical research of long economic time series Kondratieff (1935) detected that the era of industrialisation is characterized by long waves/surges of economic development of 40 to 60 years duration. While he already suggested that technological change would play a major role for understanding long-term economic development and its cyclical nature, Schumpeter (1939) embedded Kondratieff’s idea into a theoretical framework of innovation. Neo-Schumpeterian and evolutionary economists like Freeman and Perez have focussed on newly emerging GPTs (“core technologies”) that have an impact on all sectors of the economy and unleash “technological revolutions”. The key factors or key inputs are characterized by clearly perceived and rapidly falling relative cost, an almost unlimited availability of supply over long periods, and a clear potential for use or incorporation of new key factors in many products and processes throughout the whole economic system.

The literally path-breaking new GPTs fundamentally change the structure of existing markets and make it possible to develop new markets and to apply new modes of organising economic activity and relations between economic agents. They can be combined with already known technologies which facilitates their roll-out out

over the whole economy. In order to capture the potential benefits of these technologies, major investment in new infrastructure and skills is required, the rules – formal and informal – in economy and society need to be adjusted, and attitudes and behaviour of individuals, firms and public entities need to allow for such fundamental change to unfold. This process of re-structuring is time consuming (therefore: long waves) and provides huge opportunities for entrepreneurs.

A model that generates such long surges through endogenous technological change needs to answer four questions (Rosenberg and Frischak 1983):

- What are the necessary and sufficient changes in the environment that can bring out a bandwagon-like diffusion of basic innovations”?
- Why do technological innovations lead to long periods of economic expansion followed by similarly long periods of stagnation spanning two to three decades, each?
- Is the impact of innovations or clusters of innovations strong enough to cause a sizeable macroeconomic impact?
- Are there mechanisms endogenous to the economic process to make the waves repeat themselves?

The Perez model of long waves (Perez 2002) can answer these four questions. It is the most often used model of technology-driven long waves (Gallegati 2019), and henceforth it will be used as vehicle of analysis. At the model’s core there are interrelated radical breakthroughs (“technological revolutions”) that lead to the emergence of a new GPT that has the capacity to profoundly transform the economy by establishing a new “techno-economic paradigm” (Perez 1983). In this setting, innovations that are driven by a new GPT are not only considered as technological phenomena, but innovations are complemented by socio-economic change. This can be illustrated with the dissemination of automation and computerisation that first endangered jobs of blue-collar workers, and since these tendencies progressed white-collar jobs have also been at risk (O’Gorman and Donnelly 2019) and the resultant underemployment of medium skilled workers might undermine innovative capacities (Sandulli and Gimenez Fernandez 2019). Strengthening innovation systems by combining vocational and academic qualifications (Vassiliadis 2019) could be a possible response to such a socio-economic change that is initiated by applications of a new GPT.

KEY WORDS

Technological Change, Information Technology, Techno-economic Paradigm

PALABRAS CLAVE

Cambio Tecnológico, Tecnologías de la Información, Paradigma Tecnológico-Económico.

Therefore, the absorptive capacity of society and adapting to the required changes become most relevant for implementing a new GPT² and for mobilizing its potential economic benefits. A “set of ‘best practice’ principles, that break the existing organisational habits in technology, the economy, management and social institutions” (Perez 2002, 7) emerges and thereby establishes a new “techno-economic paradigm” (TEP). The TEP disseminates to all sectors of the economy and all realms of society and thereby drives a long development surge that typically goes through several phases. The concept is not deterministic because economic agents and policy makers can choose on how to adapt to the newly emerging TEP and on different time paths of adaptation. By implication, strategic choices of society determine the economic benefits that can be derived from a new GPT and its related TEP and explain why these benefits differ across economies/societies.

3. DIVERSITIES OF INNOVATION DURING THE PHASES OF A LONG DEVELOPMENT SURGE

A development surge starts with the “*Irruption*” of a new set of technologies from a small industrial base that allow a step change in potential productivity in practically all economic activities (Perez 2002, 8). Initial technological or scientific breakthroughs in the new TEP have regularly occurred long before, but do not yet have an encompassing economic impact in this phase because much experimentation with the new technologies is still needed as the road to fully exploiting the economic potential of the new GPT is not yet clear. While some firms already successfully innovated and invested in the new GPT, uncertainties and economic risks of applying the new technologies in many sectors are still high.

Given the high degree of uncertainty concerning how to make concrete use of the new GPT, the prevailing “old” TEP is still attractive for many economic agents. The benefactors of the old TEP still defend their business model although gains from investment tend to diminish, and the big bulk of investment in this phase, therefore, is about incremental improvements within the prevailing paradigm. While proponents of the new GPT feel themselves restrained by the existing institutions, investment in the new GPT increases fast, but only from a low level, in industries that develop the new technologies and in a small number of industries that make intensive use of it.



Innovation in the irruption phase is mostly considered a technological phenomenon, the socio-economic foundation of the prevailing “old” TEP is not seriously challenged, yet.

Diminishing gains from investment within the “old” TEP and an increasing number of successful applications of the new GPT shift the perception of the economic potential of the new technologies. This marks the begin of the second phase of a long development surge, the “*Frenzy*” phase (Perez 2002) when the interplay between real economy innovators and financial investors becomes most visible. The former ones see the time come for creating new markets and introducing new products, while the latter ones gradually shift from less risky but poorly rewarded investments within the old paradigm to investing in more risky investment projects that promise higher profitability. This can be achieved either by redirecting investment that is mostly based on the old TEP to developing countries that benefit from lower labor cost and lower regulatory standards, or by investing in the new GPT that becomes increasingly attractive. Both alternatives have in common that they involve higher risk and promise high returns, and that after a while very likely a speculative bubble builds up.

It is difficult to judge in advance which of the new business models based on the new GPT would work in the future (and which ones would not work) and therefore much speculation and tricky business gestation is involved (it is a time of “irrational exuberance”). Investment in stocks of companies that develop and apply the new GPT and establish new business models based on these technologies is huge and results in the build-up of a speculative bubble on the stock market. Ultimately a bandwagon-like development is released because many investors do not want to forgo this potential for earning high profit. Therefore, from a long-wave perspective the build-up of a speculative bubble is not an accident of capitalism but is part of the dissemination of a new TEP. Its bubble’s burst (like in 2001) marks the end of the Frenzy phase.

The *diversity of innovation* in this phase is dominated by three drivers of innovation and related investment. *First*, the technological core of the new GPT is improved and further developed. In the current long wave, the enormous increase of computing power and its cost decline (“Moore’s Law”) is a good example for the improvement of the core production factor over a rather long period. *Second*, in this phase there is still experimenting with applications of the new GPT going



on, with combining the new GPT with existing technologies, and with creating and refining business models that are based on the new TEP. Innovation and related investment rooted in the new paradigm disseminate to an increasing number of firms in various industries. *Third*, particularly but not exclusively in this phase the dissemination of a new TEP requires much investment in new infrastructure which is an innovation activity itself.

At the “*turning point*” of a development surge a mismatch becomes apparent between the still prevalent old paradigm and the new TEP. Many individuals and groups have strong vested interests in the old paradigm, and the existing regulatory and institutional framework restrains the exploitation of the new TEP’s full economic potential.

Extending and enhancing infrastructure and developing and harmonizing technical and legal standards becomes crucial for the dissemination of the new TEP and an economy’s ability to benefit from innovations that are rooted in the new paradigm. Economic agents – investors, firms, workers, consumers – need to adjust their behaviour to the challenges that come with the new TEP, and policy makers are required to adapt the institutional and economic framework. Innovation and reaping the benefits that derive from the new TEP can be impaired or at least decelerated if the institutional framework is not adequately adjusted or if its adjustment is delayed.

A prominent obstacle to innovation in this phase is the availability of finance because after the burst of the speculative bubble at the end of the Frenzy phase many investors have lost considerable amounts of capital. In this situation it is crucial for providing capital for investment and innovation to restore investors’ confidence and to give them incentives for investing in the “real” economy. In the turning point phase of the recent long wave (that covered most of the 2000s years) economic policy and monetary policy successfully avoided a recession after the burst of the speculative bubble in 2001, but at the same time this policy contributed to creating ample opportunities for financial investment and thus impaired investment activity in the real economy.

The impact of economic policy measures that are implemented in the turning point phase (and of measures that are not implemented although they would be supportive to the take-up of the new paradigm!) is not limited to this period but reaches into the “*synergy phase*” of the development surge. Infrastructure that is necessary for establishing the new TEP is available already in many areas and



many economic agents have the physical equipment that is required for access to the infrastructure. The new technologies have become more user-friendly than in the prior phases of the development surge and are socially accepted now. Specific knowledge and skills that are required to use the technologies are well developed as young generations have grown up with these technologies and parts of the older population have acquired the necessary skills at least at a basic level. Therefore, much is prepared for reaping the individual and social benefit from the new GPT.

The diversities of innovation in this phase are dominated by the roll-out of the new paradigm over the whole economy. Innovation is triggered because an increasing number of firms and industries adapt to the new technology and try to adjust to the TEP that has become dominant in the meantime. During the earlier phases of the recent development surge the consumer world was most markedly influenced by the internet while in the synergy and maturity phases the integration of manufacturing and ICT emphasizes the roll-out of the new paradigm to the manufacturing sector. In the synergy phase, the dominant GPT is combined with industry-specific technologies and applied to industry-specific problems and tasks which results in a broad range of innovations. Enabling innovations facilitate the dissemination of the new TEP, e.g. electronic money transfers of small amounts and other innovations in the financial sector that have facilitated internet commerce in the recent development surge. The possibilities for reaping the benefits from innovations that are based on the dominant TEP are influenced by strategic decisions about accommodating the economic framework to the requirements of the new TEP. This means both regulating the GPTs (e.g. setting technical standards), adjusting regulation in policy fields that are indirectly affected by new GPT (e.g. adjusting labor relations and developing new regulations of business transactions and competition) and exerting complementary macroeconomic policies.

Finally, a TEP reaches its last phase (“maturity”) when its potential to further increase productivity and to generate attractive goods and services becomes exhausted. While there are many firms and individuals still benefit from the dominant TEP, a growing part of the population perceives the dominant TEP less desirable compared to the attractive newly emerging GPT. Financial investors are increasingly faced with difficulties to find profitable investment opportunities within the old paradigm, and consequently “turn



away from the core countries and core sectors” (Perez 2002, 83). Innovation within the dominant paradigm shifts from being science-based to being technology-based, and market risks of innovation become relatively more important compared to technical risks (Scherrer 2019a). Consequently, both real-economy entrepreneurs and financial investors start searching for opportunities outside the prevailing paradigm thereby giving way to a new TEP.

4. WHERE DO WE STAND NOW?

Most researchers of technology-driven long waves would agree that five surges have been observed since the coming of the industrial society in the late 18th century.³ The first wave was triggered by innovations in steam power and the textile industry and started in the 1780s in Britain, the second wave by the steam railway (starting in the 1840s), the third wave by steel and heavy engineering industries (starting in the 1880s), the fourth wave by applying the principles of mass production (starting in the late 1930s), and the fifth wave by modern ICTs (starting in the second half of the 1980s). The fifth development surge has reached its synergy phase now and is going to enter the stage of its maturity (Scherrer 2019a). In this phase of the long wave, the focus of basic research tends to shift away from the core of the prevailing GPT towards developing possible new GPTs. Applied research and development in industries and disciplines in which ICTs are implemented has gained prominence. As the search for new applications within existing technologies has intensified, and technology-based innovation has become relatively more important compared to science-based innovation. The mix of input factors that are required for innovation and efficient production on the basis of the new TEP has changed, and together with regional variations of industry structure and policy responses this contributes to explain why innovation activity and the speed and intensity of adaptation to the new TEP differ across regions. The formation of dominant market players and monopolies has been fostered by the technological properties of ICT, in particular its extremely low marginal cost of production and the existence of strong network effects. Given the assumption that many firms of the ICT sector will provide the infrastructure and tools for technologies that will possibly form the core of the next wave’s GPT, some heavyweights of the fifth wave will very likely be important players also in the sixth wave.



Recently, a bundle of new technologies has been summarized under the label “Industry 4.0” (Kagermann et al. 2013) or similar labels that claim to initiate a “fourth industrial revolution”. While many academic writers, consultants, and policy makers have hyped Industry 4.0, a socio-economic theoretical foundation of its appearance and of its implications for the economy is still lacking. This gap is closed by the long-wave perspective of Industry 4.0 which provides such a theoretical foundation (Scherrer 2019b). Many examples of Industry 4.0 applications have been implemented in firms and industries within the (still) predominant ICT-based TEP as they focus on refining, further developing, adjusting and combining ICTs with other technologies. In the long wave model this roll-out of the predominant paradigm over more and more parts of the economy represents the synergy and maturity phases of the fifth long wave. While particularly the synergy phase provides the potential for strong economic expansion, many countries have found it difficult to fully realize the benefits from the ICT-based paradigm after having entered the synergy phase in the late 2000s. Economic expansion has been sluggish compared to the synergy phase of the preceding long wave as investors’ confidence might have suffered from an unstable global economic environment and the re-regulation of the economy for accommodating the ICT-based paradigm has progressed only slowly. Insofar, many applications of Industry 4.0 are representations of the later phases of the fifth long wave and thus fit nicely to the expected pattern of the long wave dynamics.

Two elements of those technologies that are captured by the *Industry 4.0* concept, in particular, have the potential to qualify as a GPT and therefore to reach beyond rolling out the ICT-based TEP (Scherrer 2019b): *first*, the conversion of analogue data and processes into a machine-readable format (“digitization”), and the use of digital technologies that result in new activities or in changes to all kinds of existing activities (“digitalization”; OECD; 2018), and *second*, artificial intelligence. Both elements can be applied in nearly any context and the possibility to combine them with other technologies generates a multitude of possible applications. While artificial intelligence allows the step from *automatization* to coming closer to *autonomization* of economic processes, digitalization in many cases means that marginal cost of production is close to zero and, by implication, the role of marginal cost as a fundamental concept of pricing will be undermined in more and more markets and circumstances. Although it is neither possible to predict all possible uses of these two elements of Industry 4.0 nor to predict the timing when these uses will eventually become effective, they have



the potential to become powerful GPTs that do not only generate productivity increases *within* existing business models but that also form the basis of new business models in the context of the sixth long wave. Empirical evidence of current innovation processes and re-structuring efforts suggest that many firms prepare for the next GPT by digitizing their processes, and that there exist already a growing amount of applications of AI and digitalization of economic activities. These are indications that a new GPT could be forming that the sixth long wave might have entered its very early phase.

5. DIVERSITIES OF INNOVATION: INSIGHTS FROM THE LONG-WAVE MODEL

The model of technology-driven long waves of economic development improves the understanding of innovation by offering insights from various perspectives. From a *theoretical perspective*, its major scientific benefit is the endogenization of technological progress in a non-deterministic socio-economic framework that is open to interdisciplinary research (Scherrer 2016). The long wave concept provides a structure for analyzing the emergence and diffusion of techno-economic paradigms and the variation of innovation and innovation policy during the diffusion process of a new TEP from its irruption to its deployment. Technological change is not exogenous to the economy but it is a consequence of economic decisions resulting from the interplay between agents in the financial markets and entrepreneurs in the “real economy”. The long wave-concept is non-deterministic as the long development surges are transformations rather than repetitions, and because important roles are attached to economic agents and policy makers for adapting to a new TEP. While technical feasibility is a precondition for change, institutional and regulatory decisions have a strong impact on the diffusion and on the scope of technology use, and, even more significantly, on the degree to which a society can benefit from the TEP during the phases of a long wave. The long wave-model is open to interdisciplinary research as the gestation and analysis of various forms of institutional change is a research topic in many academic disciplines. *Historical* time is becoming a distinct dimension of analysis because the model also allows analysing new development paths during a long wave and both business strategies and economic policies can perform effectively only if they target windows of opportunity that open only temporarily (Hilpert 2019).

From a *business perspective* the long wave model suggests that the interplay between financial investors and real economy-



entrepreneurs is of crucial importance for explaining innovation activity. When returns to investment within the dominant paradigm diminish financial investors tend to allocate resources towards more risky ventures thereby supporting innovation activity by real-economy entrepreneurs that is geared towards a new GPT. The build-up of new infrastructure is required and contributes to explain the long duration of the waves, as this process consumes much time. The roll-out of the new TEP induces innovation in an increasing number of economic sectors and thus also provides ample business opportunities. The history of long waves suggests that the operation of the infrastructure that is relevant for the dissemination of the TEP has not always been profitable in contrast to business with hardware, software, consulting and other services that are complementary to infrastructure. As the combination of inputs required for efficient production within the new paradigm and the properties and degrees of standardization of inputs change, locational advantages of production are likely to change during the wave.

The history of long waves shows also that the newly emerging GPTs could always build on the achievements of its predecessors, as it was the case e.g. with the steam railway in the 19th century (that could build on steam power) or with mass production in the second half of the 20th century (that could build on electricity). The GPT that will drive the sixth long wave very likely can also build on the preceding GPT (the internet as the major manifestation of modern information and communication technologies) but for the first time in the history of long waves it will be possible to use the preceding GPT explicitly as a powerful tool of research and innovation. Together with even more systematic research and development effort of firms this might accelerate the development and dissemination of new technologies and thus the duration of a long wave might be shortened. If future long development surges will actually become shorter depends on the characteristics and perceived risks of the new technologies, and on the scope and willingness of society to adapt to technology-driven change.

While it has been argued that there exist strong implicit rationalities of innovation there are also ample opportunities for economic policy makers to intervene, foster, change and to take advantage of new GPTs at different points of development (i.e. phases of the long wave). From an *economic policy perspective*, in addition to the importance of properly timing policies the long wave model suggests that for the full economic benefit from a new GPT becoming effective several types of policies are required (Scherrer 2019b). The *first* type of policies refers to policies that are directly





related to the regulation of the dominant GPT (e.g. technical standards). While in the current fifth long wave legal foundations of internet commerce (e.g. digital signature) had been established early, the development of IoT-standards – which are required for rolling out ICT particularly in the manufacturing sector – has come only recently. The regulation of privacy and data security is a most interesting example how new phenomena that come with a new GPT are conceived differently by different societies and how differently societies respond to it. On the one hand after long discussions the European Union adjusted its legal frame to the requirements of the “new” TEP by releasing the General Data Protection Regulation only in 2016. On the other hand, privacy and related issues – even taking differences in political systems into account – do not seem to raise major concerns in all societies. A *second* type of policies addresses areas beyond technology policy and refers to policy fields that are indirectly affected by the new TEP. Such policies refer to adaptations of existing regulations and implementing new regulations in various fields (e.g. labor relations, competition policy, social security systems) and to policies that address the changing skill requirements.

While the idea of implementing these two types of policies is rather straight-forward, the long wave-model highlights a *third* type of policies that comprise complementary macroeconomic policies and thus reach beyond the above mentioned micro-oriented policies (Scherrer 2019b). A new TEP starts with a focus on the supply side of the economy when the development of new technologies is fueled by financial markets and income inequality is set to increase. During the roll-out of the new TEP the purchasing power of the population – that has been affected by growing inequality – tends to restrict demand, and therefore the demand side of the economy needs to be addressed in this phase. Hence, innovation activity during the unfolding of a new TEP has implications for economic policy that reach far beyond mere innovation policy as it is understood in a narrow sense with its focus on technology, research and development.

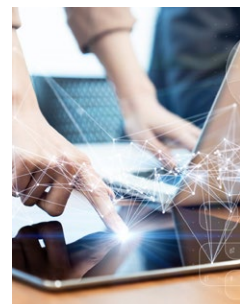
In conclusion, a long wave view of innovation suggests that economic decisions at the individual level and strategic choices at the macro level have systematically influenced the emergence of GPTs and the dissemination of related TEPs. Different phases of economic development are represented by the long waves and are characterized by different varieties of innovation. Both from the perspective of socio-economic theory and from a business perspective it is concluded that a broad variety of innovation exists, that is even further enlarged by the many possibilities of economic policy makers to influence innovation activity.

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NOTES

1. See Perez (2002) for the original source and Scherrer (2016) for a summary.
2. Please note that the concept of techno-economic paradigm used in this paper suggests a much broader understanding of what a general purpose technology is compared to other authors' (e.g. Bekar et al. 2019) narrower understanding of GPTs.
3. For an overview see Scherrer (2016) and Gallegati (2019), for detailed descriptions see Freeman and Louçã (2001).





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Diversities of Innovation in Advanced Manufacturing – the aerospace and automotive industries

Diversidades de Innovación en Manufactura Avanzada – Las Industrias Aeroespacial y de Automoción

I. INTRODUCTION

The aerospace and automotive industries have each played a major role in the development of modern societies and economies, providing highly skilled employment and allowing consumers unparalleled mobility. In both industries technological advance is vital to product differentiation, and hence to firm competitiveness. Both are in a state of rapid technological change. However, innovation is not simply a technological matter for them. In order to identify, evaluate and pursue technological opportunities individual firms require a range of managerial, organizational and commercial capabilities.

At first glance, the innovative opportunities for automotive and aerospace industries can appear almost limitless in their diversity. However, in practice, innovation involves choices and risks. The wrong choice can threaten the competitiveness, even the very existence, of a firm. In making these, often difficult, choices a firm needs to consider not only its own internal resources. It must also consider the resources and constraints of its external environment – customers, suppliers, labour markets, government regulators, etc.

The aerospace and automotive industries have much in common. Both are assembly industries taking tens of thousands – even millions – of parts to make vehicles. Their research and



EXECUTIVE SUMMARY

This article explores the diverse opportunities for innovation in two advanced manufacturing industries, which make widespread use of high technologies, and for which there seem to be almost limitless innovative opportunities. It analyses the forces that impact upon the industries – in particular, the variety of technologies they employ, globalization, market structures, supply chain capabilities and regional ecosystems. It is argued that these forces both make innovation essential for firm competitiveness and entail risks that require high levels of managerial skill, technological capability, financial resources and entrepreneurial acumen. Finally, the article explores the likely future impact of digitisation on innovative opportunities in these industries.

RESUMEN DEL ARTÍCULO

Este artículo explora las diversas oportunidades de innovación en dos industrias manufactureras, que hacen un uso generalizado de tecnologías complejas, y para las que parece haber oportunidades innovadoras casi ilimitadas. Analiza las fuerzas que afectan a las industrias, en particular, la variedad de tecnologías empleadas, la globalización, las estructuras de mercado, las capacidades de la cadena de suministro y de los Ecosistemas regionales. La investigación argumenta que mientras estas fuerzas hacen que la innovación sea esencial para competitividad de las empresas de estos sectores, entrañan riesgos que requieren altos niveles de habilidad directiva, capacidad tecnológica, recursos financieros y actitud emprendedora. Finalmente el artículo explora el probable impacto futuro de la digitalización en las oportunidades de innovación en estas industrias.

development are generally closely linked to particular product developments and are hugely costly. Production is immensely capital intensive and based upon globalized and tiered supply chains. Civil aerospace is an effective Boeing-Airbus duopoly. Currently, in automotive some industrial concentration is underway as technologies proliferate and development costs rise.

There are, however, some key points of difference between the two industries. The automotive industry sells to both consumers and producers, whereas aerospace is almost exclusively a producer goods industry, selling to airlines and aircraft leasing companies. Both industries have high levels of political saliency and their technological development is much influenced by government policy (e.g. safety regulation). Finally, while neither industry is based on short-termism, their time horizons are markedly different. New automobiles tend to be designed, built and sold on a seven-year cycle, whereas the design and development alone of a wholly new aircraft can take seven years or more, and it may be in production for decades.

The aerospace and automotive industries have each played a major role in the development of modern societies and economies, providing highly skilled employment and allowing consumers unparalleled mobility

2. THE NEED TO INNOVATE – SUPPLY CHAIN DIVERSITY

Because both industries make vehicles they have core technologies in common: designing and manufacturing vehicle bodies, engines, control systems and interiors. Hence, there are many overlaps in their innovation priorities. Both are deeply involved in the development of new types of engine that use less fuel, or may use new fuel sources (notably electric engines). Both are interested in making vehicles that are both lighter and more aerodynamic, so that they burn less fuel and are less polluting. Sensor technologies offer a key means of improving the reliability and maintenance of both cars and aircraft. Robots are already widely used to enhance the speed and reliability of production processes.

In order to develop innovatory new products, Original Equipment Manufacturers (OEMs) like Airbus or General Motors have to embody multiple technologies in their new vehicles. Each technology brings its own diverse opportunities and choices. For example, an innovatory new automobile like the BMWi8 hybrid

sports car does not simply incorporate an innovatory power train. It incorporates a range of other innovations (e.g. an aluminium chassis and a carbon fibre passenger compartment). Engaging with multiple technologies adds diversity and complexity to the supply chain. Firstly, OEMs do not own the intellectual property, or have sufficient expertise in all the technologies embodied in their vehicles. They rely heavily on suppliers to be at the leading edge of their specialist technologies (e.g. Boeing relies on global aero-engine makers, like Rolls Royce or General Electric). This implies a very strong dependence upon the technological, managerial and financial capabilities of the engine supplier, which impact directly on the competitiveness of a new aircraft. Secondly, many valuable new technologies are within the expertise of companies outside the traditional aerospace or automotive sectors, which are newer entrants into their supply chains. This challenges OEMs by adding technological and organisational diversity and cost pressures. For example, they need to develop the engineering expertise both to understand and use these new technologies in their products and processes (e.g. 3D printing). However, the technological, organizational and commercial pressures are not identical for both sectors. For example, automotive is a mass production industry and so is a leader in process innovations that cut manufacturing costs (e.g. Just-in-Time technology in the 1980s), whereas in aerospace, weight reduction is critical - hence its leadership in the use of composite structures. In aerospace, arguably the biggest long-term challenge is to develop technologies to produce very large composite aero-structures, which could revolutionise airframe design. Whereas, in automotive, reducing cycle times for manufacturing composite body structures is a more pressing challenge, because cars are produced in much greater numbers than aircraft.

Currently, key commercial pressures in the two industries are somewhat different. Some automobile manufacturers face quite severe challenges simply to pay for the R and D upon which their futures depend, because the market is crowded and global demand is sluggish. (Global demand was stable in 2018 at about 86 million vehicles). Thus there are global pressures towards industrial concentration (e.g. General Motors sold its European operations to PSA in 2017) and towards R and D collaborations in product development, which enable innovatory developments that

KEY WORDS

Industry 4.0;
Advanced
Manufacturing; Supply
Chain.

PALABRAS CLAVE

Industria 4.0;
Manufactura
Avanzada; Cadena de
Suministro.

individual automakers would struggle to finance. In contrast, civil aerospace is a duopoly and global demand forecasts for airliners are buoyant. (Boeing is forecasting that 44,000 civil airliners will be sold between 2019 and 2038.) So, whilst the costs of R and D are huge and challenging in aerospace, it is clear that over time a successful airliner will be able to repay its development costs. Commercial success, however, requires a firm to choose the right innovation and pursue it competently –no easy task.

3. DIVERSE, BUT COMPLEX, INNOVATIVE OPPORTUNITIES IN TECHNOLOGIES OLD AND NEW

The development of a new vehicle (a car or airliner) is a vast undertaking. It is likely to involve a diversity of innovations, some incremental and others more fundamental (e.g. electric motors, carbon fibre structures). Such innovations can bring product differentiation and market competitiveness, but also uncertainty, cost and risk. In the automotive sector, currently life is difficult for OEMs launching innovatory new vehicles. Automotive manufacturers are currently faced with the need to undertake major innovations (new types of engine, driverless vehicles) that may take many years to develop. Consumers expect more economical, safer and more environmentally friendly vehicles. Equally, government regulators are setting higher emissions and safety standards. Not to innovate is to lose competitiveness. However, stable demand and a crowded market are not conducive to making huge technological investments, and the precise trajectory of long-term demand is difficult predict (e.g. the adoption rate of electric vehicles).

To offset demand uncertainty and the inherent financial and technological risks, manufacturers are seeking to collaborate with one another (e.g. on common vehicle platforms). This is a sensible strategy, but carries with it increased complexity, as the automotive OEMs have to manage their collaborations and subsume their particular technological ambitions within a common project. These organizational innovations might appear in principle to reduce the diversity of potential innovations, but in practice are likely to create more successful innovations, as collaborating firms undertake projects jointly that they may be incompetent, and lack the resources, to fund individually.



For Boeing and Airbus the decision to develop a new airliner is, if anything, even more complex. The lifecycle of a new automobile is about seven years. A successful aircraft will take longer than this simply to enter service, and may be in production for decades. Hence, the decision to develop a new airliner is a response to airlines' projections of future demand for several decades ahead. In principle, this may seem relatively straight forward, given the projected buoyancy of global demand. But, in reality, it is far from easy. For example, Airbus's decision to build the A 380 superjumbo in the early 1990s was based on accurate long-term predictions of growing passenger traffic in the early 21st century, but misjudged passengers' precise requirements. Experience eventually showed that passengers preferred to fly in the 787 Dreamliner, as it allowed direct long distance flights without the need to change planes at hub airports. However, even Boeing's foresight was insufficient to ensure it the market leadership it might have expected. To offset the huge development costs of the highly innovatory 787, Boeing relied too heavily on its leading suppliers to fund and manage their own R and D. In practice this led both to manufacturing issues and the grounding of the aircraft soon after it entered service (due to fires in its Lithium batteries). Having correctly forecast consumer preferences, Boeing's managerial innovations failed to deliver the aircraft on time and to cost. In summary,



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“The jet makers spend years and millions developing jet engines for planes that don’t exist, while the plane makers like Boeing and Airbus spend years and millions developing planes that won’t fly without engines that do not exist.”
(Baldwin, 2019, p.93)

If launching technologically advanced vehicles is challenging for established OEMs, it is much more so for new entrants. In automotive, new entrants have followed diverse strategies to develop innovatory models. For example, Tata were able to draw on the vast engineering and industrial experience of the whole Tata Group, in creating the Nano - a cheap, technologically simple small car, designed explicitly to serve a new market sector in India. Yet, even with market familiarity, the Nano has not been the success, because of production and perceived quality problems. Tesla adopted a wholly different strategy, developing



a technologically very advanced, luxury all electric car, designed to compete initially in the US, and then globally. Its battery and recharging technologies were highly innovatory and remain market leaders. The company's growth has been encouraged by an ever more favourable regulatory environment yet, 15 years after Tesla entered the market, the company is still experiencing higher levels of manufacturing faults than would be acceptable to other luxury car makers, and in 2018 lost \$1 billion. Both Nano and Tesla illustrate that successful innovation involves not only successful product technologies, but also manufacturing technologies capable of delivering a perfect vehicle on time every time. In recent decades Chinese automotive companies (such as Dangfeng) have followed a more conservative and collaborative market entry strategy, either building partnerships with well-established manufacturers (e.g. with Renault and Nissan), or through acquisitions (such as Shanghai Automotive's takeover of MG/Rover). This strategy allows the novice manufacturer to draw on the design and process skills established partners. Their experience indicates that for newcomers, even with an enhanced knowledge base, the successful design of whole cars *ab initio* requires deep pockets, and patience, because it is unlikely that early vehicles will be globally competitive.

In aerospace the task of designing and building a whole aircraft from the beginning is even more challenging. The most successful example is Embraer of Brazil, which over a period of decades achieved huge success with smaller, regional jets. COMAC of China is a more recent entrant and is illustrative of the inherent difficulties involved. Its new airliner, the C919 (a competitor to Boeing 737 and the Airbus A320) has now flown successfully, but its development is years behind schedule – and no doubt over budget. Without patience and deep pockets entry or re-entry into the aerospace market as an OEM is not feasible, as the sale of Bombardier's airliner interests to Airbus in 2018 illustrates. Finally, it is important to note that new entrants must rely on the global supply chain of experienced aerospace companies for many of their key technologies, as COMAC does (e.g. with Honeywell, CFM and General Electric).

For supplier companies in the automotive and aerospace there are diverse innovatory opportunities, depending on their experience, their technological and managerial capabilities, and where they

wish to locate themselves within the supply chain. For established, often global, Design and Build suppliers in the upper tiers of the supply chain, the desire of OEMs to co-innovate (sharing costs and risks) and to rely on fewer suppliers potentially strengthens their position in the supply chain. They are enabled to build a technological knowledge and skills base that is discrete from that of the OEMs they supply, adding to the diversity of potential innovations. This in turn increases the interdependencies within the supply chain, and so strengthens their competitive position. However, this carries with it a danger for OEMs, because in the long run they can lose understanding and control of technologies upon which their competitiveness is critically dependent. Boeing's decision to make the 777X wing in-house rather than in Japan illustrates an awareness of this issue.

Lower down the supply chains at Tiers 3 and 4, firms are often smaller, can be locked in to older technologies and have less sophisticated management, both in their awareness of impending technological changes and their ability to manage within a global supply chain. For example, some small suppliers of, say, conventional metal fastenings may find it difficult to adjust to a market where their customers move substantially to composites. Similarly, Just-in-Time automotive manufacture can require suppliers to deliver components to the production line with lead times of 45 minutes. This entails a degree of sophisticated logistics management that may be beyond them. K&Z Consulting found, worryingly, that many smaller, but well established, players in aerospace were ill equipped to meet the managerial challenges of the 21st century supply chain – about one third of German suppliers in 2013. Such suppliers are likely to be displaced by more innovative competitors offering new technologies, more efficient manufacturing and/or better logistics.

For new suppliers who might enter these industries there are opportunities to innovate and even displace less efficient suppliers. Build-to-Print suppliers manufacture components to a design provided by a customer further up the supply chain. This is simplest, least risky way to enter the supply chain. Even so, to set up as a new Build-to-Print supplier company in a well-established supply chain is not easy. The aspiring company must have a competent labour force (e.g. blue collar manufacturing employees working to industry standards, experienced supply chain



managers capable of working internationally, and engineers able to understand the technical specifications and to devise process innovations) (Baker, 2019). OEMs will expect even small suppliers to understand the culture and practices of the industry and to make some of their own process innovations. These barriers can be overcome with patience and investment (e.g. Strata the Abu Dhabi-based manufacturer of composite aerospace parts). Such suppliers can enhance the geographical diversity of the supply chain, but are unlikely to be major innovators.

Entry into these sophisticated manufacturing supply chains at more advanced levels – designing as well as building major components, or manufacturing whole vehicles – is a much more challenging proposition. Designing components requires not only the mastery of the firm’s own particular technology, but a capacity to understand the technology of the vehicle as a whole. Hence, a firm with Design and Build ambitions faces more demanding financial, technological and managerial challenges (e.g. employing a design team over a period of perhaps 10 years whilst it develops its technological and team working capabilities). Such barriers can be overcome (e.g. by Aernnova, the Basque aerospace manufacturer of composite structures). Rapid technological advance in both sectors creates diverse innovative opportunities, but these involve risks and uncertainties even for firms with decades of experience. For new entrants, the risks and uncertainties are almost inevitably greater.

For firms participating in these industries, there are also two geographical considerations that can impact upon their success – one is globalization and the other is their regional ecosystem. The geography of the automotive and aerospace industries has shifted over the past decades as OEMs and their Tier 1 and 2 suppliers globalized their supply chains. They relocated activities abroad, in particular to developing economies where costs are lower and where there is a ready supply of skilled and well-educated labour – especially where such a relocation brings enhanced market access with it (e.g. Volkswagen has plants in the Czech Republic, Hungary, India, Brazil China and Mexico – among many others; and Rolls Royce has its own major engine plant in Singapore). This globalization certainly enhances the diversity of manufacturing activity, but it does not necessarily greatly enhance the diversity of innovation. A small Build-to-Print supplier of automotive parts



in Eastern Europe may make process innovations, but these are likely to be minor and specific to its local context, so adding little to the innovatory profile of the global industry. However, as K&Z found in aerospace, there are many innovatory suppliers in developing economies capable of competing effectively in the global supply chain (e.g. Indian software companies supplying the aerospace - and the automotive - industries). Not only do they add to the geographical diversity of the supply chains, but they bring with them new products, processes and ways of working.

Growing globalization and diversity does not mean that successful automotive and aerospace suppliers can be set up anywhere (Hickie and Hilpert, 2019). The most successful regions in the aerospace and automotive industries are characterised by a rich and diverse ecosystem of public and private institutions that support their competitiveness (e.g. Munich, Stuttgart, Toulouse, Seattle). Such institutional networks facilitate the development of new suppliers. For example, the existence of a local labour force with the necessary skills and values to work efficiently in supplier companies implies the existence of an education system capable of educating potential employees to high school, technical college and probably university levels –especially in STEM subjects. Indeed, aerospace and automotive companies often work closely with the educational institutions where their plants are located to ensure the supply of skilled labour (e.g. Washington State runs technical training institutions to train and accredit skilled aerospace workers). National and regional governments also help fund research activities in universities and research institutes, which help to drive industrial innovation. In so doing, they develop research institutions which are magnets for firms' development activities. Hence, M-Byte the Chinese electric car-maker builds cars in Nanjing, but its development activities are conducted at Munich and Santa Clara (California). A favourable regulatory environment can also be critical in allowing the development of new technologies. For example, several companies have been attracted to Arizona by a liberal regulatory environment to test their driverless cars.

Similarly, some components and services provided by the private sector are better supplied from nearby than from a distant supplier in another country. For example, for a new Build-to-Print Supplier it is beneficial to have a local engineering company that



has the expertise to conduct non-routine maintenance for its manufacturing equipment and holds a ready supply of spare parts. New entrants in regions still establishing an automotive or aerospace industry are unlikely to benefit from a sophisticated regional ecosystem. To create one a sector and its infant companies need a formal organisation to brand and market their region, and attract new suppliers. There is then the potential for a snowball effect, building a stronger, deeper regional supply chain. For example, the relatively new aerospace industry in the Basque Country set up HEGAN, to represent the industry regionally and provide specialist facilities that can be shared by member companies. Hence, although aerospace and automotive firms participate in global supply chains, they rely on regional ecosystems, which reciprocally can enhance the innovatory diversity of the supply chain as a whole.

4. DIGITALIZATION/INDUSTRY 4.0 AND A NEW INDUSTRIAL REVOLUTION

To understand the future of innovation in automotive and aerospace, one must explore the impact of rapid developments in a suite of generic, ICT-based technologies.

“Digital technologies had been laughably bad at a lot of these things for a long time – then they suddenly got very good.”
(Brynjofsson and McAfee, 2014, p.5)

These changes go under a variety of names – digitalization, Industry 4.0, Advanced Manufacturing, etc. and they include a group of computer-based technologies, such as Artificial Intelligence, Virtual Reality (VR), Augmented Reality, and Robotics. These in turn often require integration with other advancing technologies, such as Sensors, Additive Manufacturing and New Materials. Furthermore, these advances must also be integrated with specialist technologies developed within the automotive and aerospace industries (e.g. Just-in- Time logistics; fly-by-wire controls). The automotive and aerospace industries make widespread use of these technologies (e.g. VR in design, robots in manufacturing, and in radically new products, like driverless vehicles).



The integrative character of these industries creates diverse innovative opportunities engaging both established OEMs and suppliers, and new entrants with niche expertise in these new technologies. Industry 4.0 technologies are already having an impact across these industries' value chains, from design concepts to the end user experience. The new technologies are bringing forward innovations, that integrate the design process and cut costs (e.g. VR allows engine and component designers to 'see' inside a new engine to optimize its functioning). Once vehicles are in production the capacity to transfer huge volumes of data between OEMs and suppliers creates the potential more closely to integrate manufacturing processes between OEMs and suppliers. For automobile manufacturers, supply chain integration already allows the building of cars to order. In future, as the Internet of Things becomes a reality, integration will become even closer as machines in different locations share data in real time without human intervention.

Automobile customers and airlines already expect to receive vehicles built to their exact specifications. VR has the potential to enhance their experience further. It will enable car buyers to 'drive' the exact vehicle they intend to buy. Airlines can already 'walk' through mock-ups of different airliner interiors to precisely specify their interior layouts. Similarly, sensor technologies allied with instantaneous data transmission have the capacity radically to change the relationship between manufacturers and customers. Currently in aerospace servitisation is cutting the costs of owning an airliner (e.g. Rolls Royce can monitor the detailed performance of its engines in service in real time). This profoundly changes the manufacturer's value chain. For example, in the Maintenance, Repair and Overhaul subsector of aerospace, innovations in Additive Manufacturing has the potential to allow MRO organisations to manufacture spare parts on site only when they are needed.

Given that there are wide ranging innovative opportunities in these two industries, what uncertainties and constraints should firms consider in choosing when and where to invest? Broadly, these fall into four categories -

Firstly, the speed and scale of the technological changes associated with Industry 4.0 are remarkable. For example, thirty years ago Artificial Intelligence was fundamentally an academic



discipline, now high performance computing and the capacity to manage Big Data have transformed its usefulness (e.g. creating a 'digital twin' of a vehicle, which can then feed back into the digital design process, optimizing the design before constructing a prototype). Suppliers unable to manage the necessary large volumes of data in real time are likely to be displaced, except perhaps at the bottom of the supply chain.

Secondly, Industry 4.0-related innovations frequently involve several different technologies so adding complexity, because there are inevitable leads and lags in technological development (Scherrer, 2019). A well-known robotics case is General Motors' Hamtramck plant, built to be the most automated automotive plant in the world in 1985, but a source of endless teething problems, essentially because the robots could not be adequately controlled. More recently, battery technology has been a brake on development for both planes and cars. Using composite materials long cycle times are a particular constraint for volume car-makers, while the limited size of composite aero-structure components is a constraint on radical airliner design improvements.

Thirdly, public attitudes towards new technologies can create uncertainty. Public resistance can come both from consumers (e.g. who are unwilling to pay a market price for a product), or from citizens (who object to its social consequences). These issues are especially troubling in automotive, given sluggish demand and public reluctance concerning some new technologies. For example, Renault and Nissan are developing electric engine technology jointly to cut their individual R and D costs. However, although demand for electric vehicles is growing, it remains low (1.26 million sold globally in 2018). Many consumers are unconvinced by the higher price and shorter range of electric vehicles, and the lack of a widely accessible charging infrastructure. Similarly, whilst the public seems to accept the increasing use of driver aids (e.g. to prevent accidents), they may not be prepared to purchase or use driverless cars (e.g. as taxis).

Public concerns about these new technologies is mediated through public policies that may help or hinder their development. For example, governments have encouraged the development of electric propulsion systems for cars with support for R and D, subsidies for consumers (e.g. in Norway and China), subsidising the development of an infrastructure of charging points (e.g.



Norway), and allowing preferential access for electric vehicles into cities. However, in the case of autonomous vehicles (e.g. drones, autonomous air taxis, autonomous cars) there are significant public concerns about their impacts and usefulness, and high regulatory standards act as a brake on its development. For example, Uber tested its experimental autonomous car in the relatively relaxed regulatory environment of Arizona. However, the death of a pedestrian killed during the trial is likely result in stricter regulation internationally.

Fourthly, even with apparently promising digital technologies, individual firms must make critical investment decisions and evaluate their own capabilities and resources and those of their ecosystems and supply chains. To innovate firms need not only technological knowledge and skills to master 4.0 technologies, but also a blend of managerial and technological skills to assess its potential economic costs and benefits. A strong and supportive ecosystem, especially located close at hand, can provide materials, components and services the firm does not have in-house. Even when a firm has access to the necessary resources, it must make a strategic judgement about how the innovation will enhance its competitiveness and capture greater value in the supply chain (e.g. Rolls Royce's move into servitisation). This can be a difficult decision for some suppliers lower down the supply chain, whose products may be commoditized, easily obtainable globally, and whose prices are often 'soft'.

Adding to this uncertainty, digital technologies have added potentially disruptive geographical unpredictability to investment decisions. Globalization has often meant the offshoring of activities to plants or suppliers in lower wage economies (e.g. automotive plants in Eastern Europe). Usually, this has been predominantly in less technologically complex manufacturing activities (e.g. Build-to-Print). Advances in digital technologies: which allow data to be transmitted, analysed and used in real time (e.g. Big Data, improved connectivity); and, which allow direct human interactions in real time (e.g. VR, Augmented Reality), create the potential for offshoring to grow even further. For example, the Internet of Things would allow robots at European or US car plants to communicate directly with robots at a supplier's plants in South Africa and Indonesia to coordinate production directly without human intervention. Similarly, an aerospace MRO facility in Singapore



could use 3D printed components using data transmitted direct from a manufacturer in Europe.

Such innovations could mean more offshoring, geographically diversifying supply chains to developing economies. However, on closer inspection this seems too simplistic an analysis. Advances in robotics require less of the semi- and low-skilled labour, which gave developing economies much of their competitive advantage. This has the potential to alter the economics of the supply chain. If labour costs become relatively less significant, then re-shoring to newly automated plants in Western Europe or North America becomes a more attractive proposition (Bramanti, 2019). If components can be manufactured nearby by robots, it makes little sense to manufacture them thousands of miles away using other robots. Furthermore, in a knowledge-based economy, competitive advantage lies primarily in people's heads, in teams and organisations. These are found more frequently in well-established industrial regions with sophisticated innovative ecosystems (e.g. Toulouse, Stuttgart).

"Increasingly, value is created by labor working with knowledge – either knowledge clusters controlled by firms..., or knowledge stuck into people's heads in the form of education and experience."
(Baldwin, 2019, p.70)

Regions relying on cheap, less knowledgeable labour, then become vulnerable to advances in digitalization in more developed ecosystems.

5. CONCLUSIONS

Technological innovation is critical to competitiveness in aerospace and automotive, and so is pervasive throughout their supply chains. The potential opportunities for such innovations seem almost endless in their scope, scale and diversity – from the transformative (e.g. driverless vehicles) to the incremental (e.g. minor process improvements). These innovations may take place within well-established firms and technologies, or they can incorporate new firms and technologies into an established supply chain, and so diversify both. They may affect products (e.g. the BMWi8), design and manufacturing processes (e.g. VR, robotics), or both (e.g. 3D printing).



The very existence of this great diversity of innovatory opportunities creates pressure to innovate, as do government regulations and subsidies. So, the need for firms to innovate or die may appear self-evident! What is less clear is what, how and where to innovate. Diverse technologies develop at different rates and with different degrees of practical applicability, creating risk and uncertainty. A poor technological investment can lead up an expensive 'blind alley'. Even experienced entrepreneurs can misread innovatory opportunities in such circumstances (e.g. James Dyson's withdrawal from electric vehicle market in October 2019). Hence, commercially successful technological innovation is much more than a straightforwardly technological matter. It challenges: the managerial skills of companies; their financial resources and their entrepreneurial acumen.

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Labor-based Innovation: The Advantage of Skills and Education

**Innovación basada en el Trabajo: La ventaja de
las habilidades y la educación**



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I. INTRODUCTION: DIVERSITIES OF THE WORKFORCE

Western economies rely in great part on a constant stream of innovation in order for their economies to grow and prosper. It has become a necessity for most nations around the globe in order to be competitive. Historically, all of these innovations have relied on the development of new skills and have, albeit sometimes drastic changes to the labor force, resulted in a steady supply of employment parallel to changes in the nature of work. Labor and the changing demands and requirements to the labor force have been the common denominator of all if these developments dating back as far as the steam engine – and yet when we look at most of the economic literature and policy recommendations in recent years related to digitalization and innovation policy they are mostly focused on improving business environments, strengthening investment incentives and expanding university-industry partnerships (Campbell 2017, Ivascu et al. 2016, Huang & Chen 2017). Innovation policy is developed in the nexus between industry, government and university, but where does this leave labor, the active part that made all of these innovations in the past a reality?

Product innovation is a socio-economically crucial aspect of economic activity and society. Our very economic models are dependent on an ever-evolving drive forward and stagnation is essentially retraction. Innovations require process changes and therefore skills, training and education need to match these new requirements (Kohnke 2017). While innovation has always had extensive effects on the workforce



EXECUTIVE SUMMARY

Innovation has become a necessity for our economic models and new developments in science and technology are the requirement for progress and economic growth. Historically, the labor force has been able to adjust amidst transition difficulties to these new requirements, but the speed of innovation and of the adjustments needed is expedited in light of Industry 4.0 and the New Digital Era. Labor, however, continues to be the puzzle piece that makes innovations possible and products marketable. The innovation impact of a skilled labor force is obvious and evidenced by how regional developments have varied (especially after the 2007/8 crisis) along the cleavages of industrial sectors (manufacturing vs. services) and skills portfolios of the workforce. Regional diversities of innovation and skills are a key aspect that matter in workforce changes and requirements. Social partners play an important role in this context and a shared responsibility for education and training between employers and unions may serve as a solution to the possible blow of threats and changes to the workforce by new technologies. Long-term, foresightful industrial policy can assure workers skills match the needs of industry, a smoother and improved process in the value chain, and a better transition into manufacturing with advanced technologies.

RESUMEN DEL ARTÍCULO

La innovación se ha convertido en una necesidad para nuestros modelos económicos y los avances en ciencia y tecnología son requisito indispensable para el progreso y el crecimiento económico. Históricamente, la fuerza de trabajo ha sido capaz de ajustarse a estos nuevos requisitos a pesar de las dificultades en la transición, pero hoy en día la velocidad de innovación y de los ajustes necesarios se han acelerado con la Industria 4.0 y la Nueva Era Digital. El trabajo, sin embargo, sigue siendo la pieza del rompecabezas que hace que las innovaciones sean posibles y los productos comercializables. El impacto en la innovación de una mano de obra cualificada es evidente y se refleja en la forma en que los desarrollos regionales han variado (especialmente después de la crisis de 2007/8) en función de las divisiones de los sectores industriales (fabricación frente a servicios) y las distintas competencias de la fuerza de trabajo. Las diversidades regionales en términos de innovación y habilidades son un aspecto clave que influye en los cambios y requisitos de la fuerza de trabajo. Los interlocutores sociales desempeñan un papel importante en este contexto y una responsabilidad compartida de la educación y la formación entre empleadores y sindicatos puede servir como solución al posible impacto de amenazas y cambios en la fuerza de trabajo por parte de las nuevas tecnologías. Una política industrial a largo plazo y previsoramente puede garantizar que las habilidades de los trabajadores coincidan con las necesidades de la industria, un proceso más ajustado y mejorado en la cadena de valor, y una mejor transición a la fabricación con tecnologías avanzadas.

since the First Industrial Revolution, policy making, welfare systems and education have – at least in the developed world – been able to cushion most of the effects, and with generational transitions actually positively impacted employment and working conditions.

The question remains whether this new wave of innovation, the rise of the Digital Era, will follow along the same pattern or whether it reflects a paradigm change in the nature of innovation. Industrialization and globalization came along with a diversity of different levels of development across the globe and innovation therefore varies between countries, societies, the strength of their industrial sectors and the products and product groups being manufactured (Hirsch-Kreinsen 2017, Rajnai & Kocsis 2017).

***Appropriate labor
for the regional
and industrial
realities becomes
a key for socio-
economic growth
and marketable
innovations.***

Regardless of the types of industries, the products and the technology level of nations, the balance of skills that are available in society and those required for the available jobs needs to be maintained in order to achieve sustainability in economic development, innovation capacity and growth. Appropriate labor for the regional and industrial realities becomes a key for socio-economic growth and marketable innovations (Peluffo & Silva 2018, Vivarelli 2018). Labor can only develop industry and the innovation economy, and strengthen its innovative capacity when jobs are available in the region or country with the corresponding skill demands.

Without these jobs, skilled labor cannot contribute to socio-economic development and transitional costs are accrued (e.g. unemployment of skilled labor, see the example of Spain in the late 2000s and early 2010s, outward migration of skilled labor and abandonment of less innovative national environments). Innovation and labor policy are two faces of the same coin, each needed in sustainable industrial policy making. *Diversities of labor* and available jobs are therefore crucial for nations, regions and metropolitan innovation performance. Those very diversities allow for innovation in several industries, throughout the value chain and synergy of industries with new technologies.

2. ECONOMIC DEVELOPMENT BASED ON INNOVATION DEMANDS FOR SKILLED LABOR

New technological advancements offer a variety of opportunities for businesses and new product developments. New production methods offer cost cuts in the manufacturing process due to more

advanced industrial technology and allows companies to focus more on developing high-quality products and exploit the technologies to the maximum for their improvement. This process has accompanied most of technological advances since the Third Industrial Revolution, when electronic machinery was introduced in the manufacturing process. Throughout these changes, manufacturing jobs have already become more sophisticated and advanced – and turned the industrially employed craftsman into a blue-collar factory worker (Burmeister 2018).

In light of digital technology such as the Internet of Things (IoT), digital assistance systems and Artificial Intelligence (AI), this process is accelerated and boosted – especially in developed Western economies. Blue-collar jobs continue to be upgraded and the lines between blue-collar workers and shop floor white-collar workers relating to their skills are increasingly blurry (Christensen 2019). An increased number of university-trained labor in manufacturing such as engineers and technicians only added to this process and companies made a noticeable effort in attracting this labor that is required for their growth and innovation (Matková & Szarková 2019; Kaur et al. 2018).

Innovation and new products are based on the appropriate labor for these sectors. And while this is a known fact when it comes to incremental innovation in product optimizations in the manufacturing process, it also shows that companies' growth as a whole are reliant to no small extent on the skilled labor they demand and attract. A highly skilled manufacturing labor force not only increases the nation's and industry's economic position in global markets – it is a competitive advantage.

It is worth noting the relationship between positive regional development and skill-based innovation: a strong manufacturing base (a *modern* manufacturing base, that is!) has shown to be a resilient strategy to maneuver economic crises and has proven to be less impacted by job losses and unemployment. A comparison on a smaller aggregate level (e.g. metropolitan areas), but within nations is worthwhile here and ensures that differences in development cannot be explained through different national policies (i.e. unemployment and reemployment measures, social welfare etc.). Data in the US – a national economy much more characterized by their high share in services (80%, versus 19% manufacturing³) than, say, Germany (69%, versus 31% manufacturing⁴) – shows that metropolitan

KEY WORDS

Skills; Trade
Unions; Continuous
Education; Skill-biased
Technological Change.

PALABRAS CLAVE

Habilidades;
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continua; Cambio
tecnológico sesgado
por las habilidades.

areas characterized by a large share of employment in the services sector have shown significantly lower employment and GDP/capita throughout the 2007/8 financial crisis and have come out of the crisis far weaker and at lower growth rates than metropolitan areas characterized by manufacturing (see figures 1 and 2 below). This is, in a way, nothing surprising: In financial crises people avoid or limit their use of services – they save first on restaurants, hotels, etc. –, but when their car or fridge or stove breaks it becomes unavoidable to purchase a new product, nor is it avoidable even in times of scarcity, to cure a disease with the adequate medicine. Similarly to the continued demand for high-quality machinery and equipment even throughout crises, skilled labor continues to be in high-demand, and such a labor force continues to be more resilient than lower skill (and usually lower paid) labor.

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Figure 1. Time Series Analysis for US Employment Rate

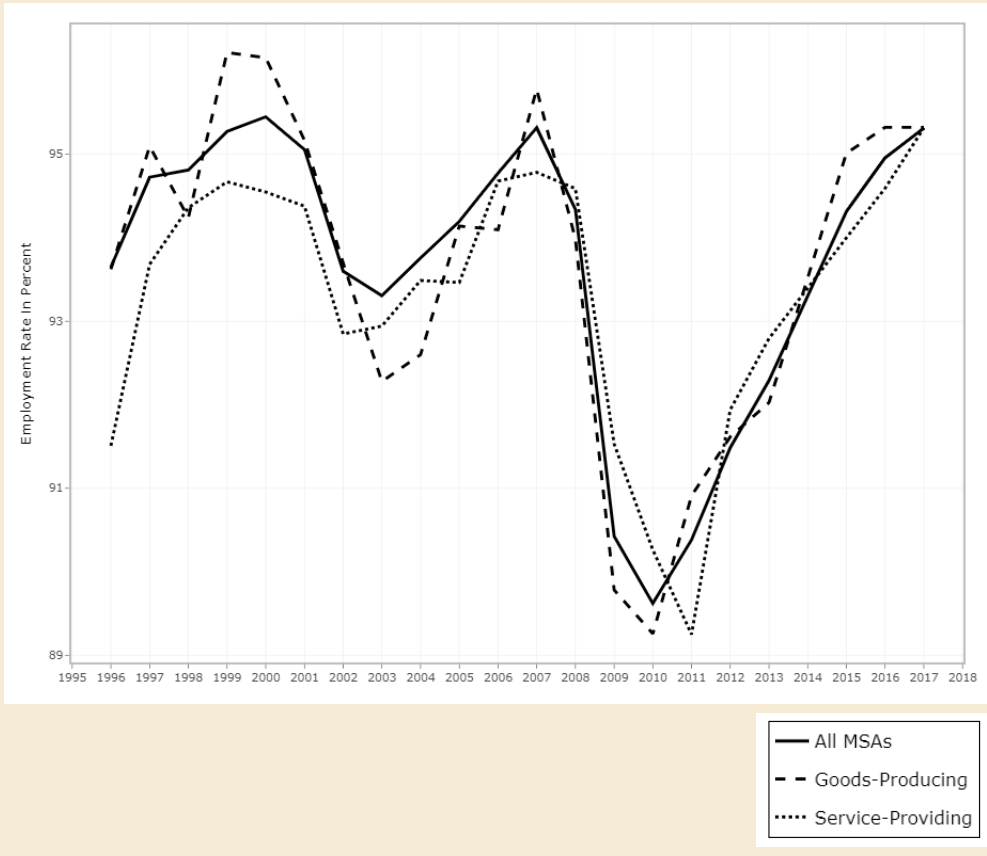
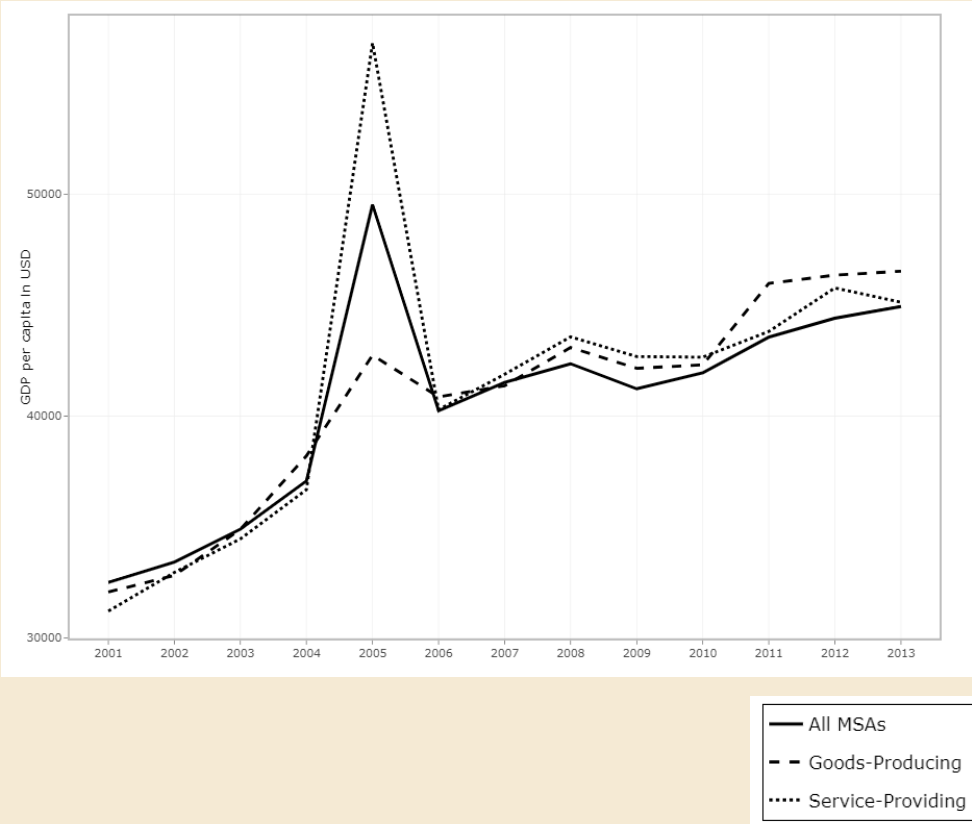


Figure 2. Time Series Analysis for US GDP per capita in USD



High value-added manufacturing based on skilled and educated labor – as evidenced by this empirical example – is not only a means for national growth and economic prosperity, it can almost be seen as a strategy to safely sail the waters of economic crises, recession and economic downturn. Increasing the share of industrial manufacturing and maintaining it sustainably (socially, economically and environmentally) can therefore be seen as a successful industrial and economic policy, especially since these industries are most likely to employ high-skilled workers in safe, well-paying jobs.

3. INDUSTRIAL HISTORY AND EXISTING INDUSTRIAL RELATIONS

Economic development follows specific historic path dependencies: Economies with already highly developed industrial and service



sectors provide a basis for further development and in light of new technological advancements through Industry 4.0, the cost of transformation varies for countries, regions and industries depending on their current level of development.

Existing industrial and research structures provide specific ecosystems that need to match with the newly emerging opportunities from new technologies and sectors. While companies and their strategic decision-making on the use of new technologies at the plant level can attract skilled labor from outside as well (Qiu & Wang 2018, Czaika & Parsons 2017, Cerqua & Pellegrini 2020), their immediate success is accelerated if these new technologies are met with an already existing skilled labor that merely needs to be upskilled to a small extent for the use of new technologies. Labor plays an important role in this context. Where high-skilled labor is scarce, it may be more beneficial for companies to invest in highly automated manufacturing. This shows that companies and labor alike have an interest in a highly skilled labor market. For companies it provides an added determinant in their own success and can significantly accelerate the effect of new technologies; for the labor side it provides safer jobs since high-skilled workers are less likely to be made obsolete by new technologies. Employers are a strong beneficiary of a well trained and educated workforce with direct impact on their own profit and success of their products. Employers should therefore share the interest in training and education measures and have an interest in expanding upon existing employer-sponsored training.

This also shows a need for proactive and foresighted policy-making to support this clear advantage of skilled labor to the resilience and success of sustainable manufacturing economies: There is a clear relationship between existing training agreements between the social partners and the need for public policy. Where employer-sponsored trainings are still rare (such as in the US), they need to be implemented and supported with the adequate legal frameworks.

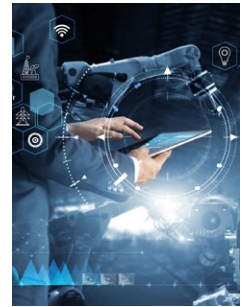
Skilled workers are an asset to any company and a skilled labor force presents a competitive advantage for nations, regions and clusters (Täube et al. 2018, Vassiliadis 2019). Strengthening the labor force means strengthening the performance of the nations in global comparison, resulting in an increased ability to attract new investments and increasing productivity. However, employer-sponsored trainings in the US have decreased from 19.4 percent in 1996 to 11.2 percent in 2008 and government spending on labor

policies has consistently decreased over the last 30 years, with the exception of the final years of Obama's presidency (Maxim & Muro 2019) – a trend that should be turned around quickly and incentivized more than ever before in order to ensure that workers are not left behind.

A look at the German case offers a good insight, since the education and training infrastructures are well developed, agreed by the social partners and embedded in national law. Depending on the states, the *Bundesland*, German workers are entitled to up to 10 days of continued education for which employers are legally obliged to continue paying a full salary and educational courses attended in this context are paid by the employer⁵.

Where such education and training channels and infrastructures already exist, it will be significantly less friction in the process of adapting to new technologies – a perspective that is reflected in the much more positive prognosis for the German labor market in global comparison. A study from the ifo Institut from 2018 suggests a decrease in employment in all of Germany until 2030 of only 4.8 to 5.5 percent (ifo Institut 2018: 59). And while this prognosis may be a little too positive, it is in no way comparable to the prognosis made for the US labor market by a study by McKinsey from 2017 that estimates 60% of jobs will experience a reduction of 30 percent of working hours by 2030 (McKinsey Global Institute 2017: 27). These variations are explained by a number of factors:

First, the US labor force is significantly lower-skilled than the German labor force. The dual vocational training system with in-depth and lengthy apprenticeships in Germany ensures that workers enter the work force with an already high degree of industry-specific knowledge and are consistently updated in their training through the afore-mentioned employer-sponsored education embedded in German labor law. In the US system, apprenticeships and industry experience prior to entering the workforce are rare and most are less than 6 months in duration. The McKinsey report shows that occupations requiring only a high school degree (like most traditional manufacturing jobs in the United States) are more than 200 percent higher at risk of being automated than occupations requiring a college degree (McKinsey Global Institute 2017: 30). Being dismissed, this labor cannot contribute to innovation and will continue this way because of the lack of training.



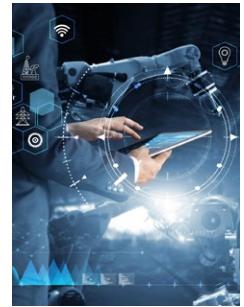


Second, social partnership is a crucial aspect of industrial relations in Germany. While the position of labor is in its very nature one that is more reactive than active, social partnership provides a platform for exchange and discourse, rather than conflict, one for compromise in times of crises, rather than clash. A clear example is the temporary reduction of working hours in the manufacturing sector during the recession after the 2007/8 financial crisis (Obermeier & Kühl 2016). It allowed for workers to keep their job, with a reduction of working time and a reduction in monthly income reflecting the hours worked, rather than a wave of skilled workers being let go into unemployment, burdening the social welfare system, losing momentum in their own education and training that is applied to industry and making a re-entry into the workforce for older workers more difficult. Had these workers been dismissed, their unemployment would have not only stressed the welfare system, it would have also meant a significant loss of innovation capacity in industry that instead could be reactivated the moment the economy changed into an upturn. The exchange and discourse in social partnership committees and parity boards played a large role in the decision to go this route and successfully played out in the eventual upturn post-recession and the continued success (and foresightful company planning) of the German manufacturing sectors (Tortorella et al. 2018, Nangoya et al. 2020, Bradley et al. 2016).

Third, industrial policy in Germany is focused on a strong foresight and policy makers are well aware of the competitive advantage that the skilled worker provides for Germany in global comparison – ensuring that this remains the case is a sustainable industrial policy strategy. Industrial policy is not merely an economic policy that focusses on manufacturing, it is rather the overlap in the venn diagram between economic, education, labor, social welfare and healthcare policy (Audretsch & Lehmann 2016). It is not simply a policy made for industry, but rather based on the knowledge that the model of our society is based on industrial development. A policy addressing these challenges must therefore have an equally holistic approach.

It is important to note that the reduction of working hours in the prognosis from McKinsey does not necessarily imply a reduction of workforce through automation. Where increased and improved technology applications provide new business and profit opportunities to companies, working hours could be reduced for workers while providing them with a salary that is commensurate with the increased

profit and skills profile required from them. Labor can only develop its innovative capacity in employment. And while this might be a more short-term solution with limited applicability as technologies become even more advanced in the decades to come (say, for example, 2050 and onwards), for now companies and labor alike have the shared interest of keeping the innovation potential within the company and ensuring a high employment all the while applying new technologies. New technologies and developments in innovative processes open windows of opportunities depending on the existing infrastructures on the ground. These windows appear and change over time and they are regionally and sectorally path-dependent. But the example of Germany (similar to other Central and Northern European countries), with its strong social partnership system, shows that these transitions can be significantly simplified and eased when employers and unions are working together to ensure a sustainable future of manufacturing. Windows of opportunities for innovation and regional development appear and change over time. They need to be used promptly when they arise in order to develop the highest innovation capacity. A highly skilled labor force can also adopt to diverse processes of innovation and turn these into positive socio-economic development and prosperity.



4. THE LOCALITIES OF TALENT: THE PROBLEM OF MISMATCHING AND POLARIZATION

When new technologies find application in companies, qualifications change and skilling and training is needed – so much is agreed between academia, policy and social partners. Qualifications are one of the most prominent challenges when it comes to digitization. The changes in the required skills are not just a challenge for workers, who need to go through courses and receive industry-applicable knowledge both before entering the workforce and then as continued education, but they also have strong impacts on societies, especially in developed countries: A strong skills shortage and an increasing skills misfit are common problems of the labor market (McGowan et al. 2017). Where medium skills used to be a safe ticket to the middle class, skills misfit and the changes due to increased global division of labor threaten the middle class and could cause a potential precarization of mid-skilled workers. Ensuring that fitting and attractive jobs are available locally to match the existing skills in the



work force is therefore crucial for a sustainable industrial policy.

In most developed economies, one can witness an increased polarization of skills demand: while the design and manufacturing of high-quality products increasingly requires engineers and highly qualified workers, at the same time, there is also a continued and growing need for private and personal services that often require less skill to perform (such as cleaning, laundry, maintenance, etc.). Since the increased global division of labor and a relocation of mass production plants to the developing world and emerging markets, medium-skilled workers are less in demand in most of the developed word.

Modeling the existing qualifications in Western European societies show that they differ greatly in distribution from those needed (Sandulli & Fernandez, 2019). Well established educational systems (and in some cases apprenticeship programs) means that a large share of the society has at least medium skills, and a relatively small share of the population has low skills. While this might be a good sign for educational systems, it also points to a problem of supply and demand: The overproduction of a medium skilled workforce means that there is a large share of this group struggling to find a job to match their qualifications—they are overqualified for the lower-paying low-skill jobs and they are not skilled enough to fill the skills shortage in the higher qualification jobs. With industrial work and design losing its appeal to younger generations in Western economies, the problem of skills shortages has arisen in higher-skilled jobs. In response, both companies and governments in Europe have taken measures to make industrial jobs more appealing, i.e. by giving out specific scholarships for STEM subjects and guaranteed job offers after successful apprenticeship programs (Hirsch-Kreinsen 2017).

This tier of mid-skilled workers who could potentially fall into precarious situations due to the skills polarization is an issue that must find its policy match now and it must be addressed through training and education. Given the shared interest of employers and unions in a high-skilled labor force, social partnership becomes even more important and allows for strategy that is building the skills transition from the existing mid-skilled to the much needed high skilled workforce. Unions and employers need to be strongly involved in the parallel policy process to ensure that this transition does not leave certain groups behind (such as women, people of color, people with disabilities, etc.). Developing the skills amongst the labor force is

therefore not just a social policy initiative but can rather be seen as an economic policy that boosts productivity and regional (and national) competitiveness.

Previously, we argued that skilled labor is important for this development in the realm of human capital – as a competitive advantage. But it becomes even more important in this context as a catalyst for regional economic development and prosperity. The regional distribution of fitting skilled labor to fill the positions in industry is a challenge: High-tech and skill-intensive manufacturing is predominantly clustered around large metropolitan areas and thereby attracting a great amount of skilled labor into the cities (Hilpert 2019a; Sandulli & Fernandez 2019) – as evidenced by the ever-rising urbanization rates (see for example the prognosis for the US to rise from 82 percent in 2018 to 87 percent in 2050⁶). When urban areas attract skilled workers, those same workers are drained from the more rural areas. Regionally mismatching skills and regions that are characterized by strong income polarization can long-term not provide the needed environments for such economic development: where the skilled labor is missing, and workers are paid poorly, building an infrastructure for innovation and economic development becomes increasingly difficult (Täube et al. 2018). Especially in a country as wide spread as the United States, this becomes a challenge and a worsening of the divide between well-developed cities with skilled workers in well-paying jobs and less developed rural areas with few opportunities due to the lack of high value-added industries and a dominant low-skill, low pay and high precarity service sector (Giannakis & Bruggemann 2019, Braesemann et al. 2018).

When this urban-rural divide worsens, policy is called for action that goes beyond just training and education: existing welfare systems need to be reexamined, infrastructure must be boosted to improve connectivity from urban to rural areas, and incentives need to be created for companies to consider settling and skilled labor to find jobs in rural areas.



**5. SOCIETIES AND POLICIES PROVIDING A CULTURE OF
EDUCATION AND MODERNIZATION: ISLANDS OF INNOVATION
INDICATING DIFFERENT SOCIETAL STRUCTURES**

The increasing urbanization and agglomeration of high-value added industries in metropolitan areas creates centers of change, centers of skilled labor, Islands of Innovation (Hilpert & Lawton Smith 2013). By attracting and reproducing such highly-skilled labor, these unique metropolitan and regional centers provide for constant modernization of skills and competences and thereby attract companies to settle. These urban areas enter an upwards spiral of innovation: Companies settle in urban areas because there is more skilled labor, jobs created attract more skilled labor from the surrounding areas, making the metropolitan region thereby even more attractive for companies to invest, expand and settle.

What is created is a unique innovation ecosystem where skilling initiatives, public-private partnerships, investment, business opportunity, economic development and prosperity interact with each other like clockwork, fueled in large part by the skilled labor and its innovation potential (Hilpert 2012, Hilpert 2019b). The diverse innovation developments (based on regionally existing structures, sectors, industrial specializations etc.) correspond with the opportunities for the development process and potential new applications.

And while these innovation hubs grow and prosper and develop into dynamic cities with a growing population of high skilled, well paid labor, they are also a symptom of the simultaneously declining rural areas that are deprived of innovation capacity through labor, detached in regards to infrastructure and “brain drained” (Peluffo & Silva 2018). So what is a sustainable policy in this context? It is hard to argue against these excelling centers that Islands of Innovation present – they are modern, diverse, well connected and highly educated. But their development and prosperity are relying also on the attraction of skilled labor and knowledge resources of rural areas – smart young people from rural areas come to the cities to pursue their education and often stay because of the availability of fitting jobs. And while one could argue that an increasing number of people lives in cities so those are the areas that should prosper most, those people in rural areas need to have solid opportunities locally and must not fall behind. Inactive and underpaid labor burdens welfare systems and other societal problems; there are plenty of examples from the



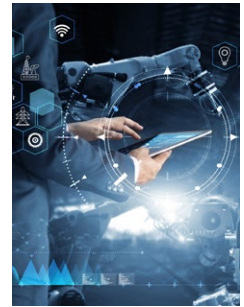
United States such as the opioid crisis in Kentucky and West Virginia showing the issues related to precarious work, high unemployment and industries that moved away from rural areas (Ghertner & Groves 2018).

From a policy and regional development perspective it is advisable to invest into strategies that create a “brain circulation” rather than “brain drain” from rural areas to cities. Skilled labor must be put into positions where their innovation potential can flourish and bring prosperity to rural areas, down the value and supply chain and into more medium to high-tech industries.

Where skilled labor is developed, process innovations are common and develop their full capacity when applied not only in one plant, one branch of a company’s production, but rather throughout the production process and into the supply chain. Companies that produce within a regionalized cluster with suppliers relatively nearby in less metropolitan areas therefore are often the most innovative – and in doing so they also provide jobs to medium-skilled workers down the supply chain, services, and retail.

A widespread collaboration between companies, regions, countries and continents is based on a diversity of factors: a) companies develop industry-specific competences (in no small part regionally effected by their workforce) and engage themselves in related and fitting projects with collaborators, b) the exchange of personnel to take advantage of knowledge and skills acquired elsewhere contributes to opportunities for innovation and provides for a richer innovation ecosystem and c) these ecosystems of innovation provide diverse opportunities for collaboration based on synergies between suppliers and regional collaborators.

A more circular innovation ecosystem with knowledge flows throughout the regions is much more inclusive of rural areas – but it does require a functioning and maintained infrastructure. This creates a common interest of companies, labor and policy makers alike: Boosting infrastructure provides investment and new business opportunities for companies, sustainable, decent work for labor and provides tax payers and relieves welfare systems for governments.



6. CONCLUSIONS

The stress of digitization needs to be met with smart policy making that takes into consideration the necessity of reform in economic,



social, education and welfare policy –an action plan for future work in the innovation economy. What we have shown is that there is no one scenario for how digitization will impact our economies and societies. The effects are diverse and the solutions are multifaceted. What remains clear through the empirical data is:

First, manufacturing based economies face crises better and more resilient than those based in services. Nations, regions and metropolitan areas are therefore advised to invest resources and effort into developing their manufacturing bases and attracting business and investments in this sector.

Second, a high-skilled workforce is more resilient towards the risk of automation through digitization and, somewhat ironically, so are low-skill workers because their labor is cheap and not economical to be automated. Medium skills are over-supplied and under-demanded in most modern industrial societies. Education and training solutions need to leverage the existing decent level of training and build upon this to supply the high-skilled workforce that is demanded in industry. Therefore, skills and education as well as continued employment of skilled labor is a contribution to continued, sustainable innovation. The skills that are needed now will vary from those needed in the decade to come—flexibility in education, both academic and non-academic (i.e. through apprenticeships) is therefore crucial. Where social partnership and industrial relations are weak, employer-sponsored trainings need to be incentivized and enforced by the adequate legislative framework in order to maintain the competitiveness and the capacities of existing industries.

Third, cooperative models with a strong focus on social partnership are more resilient in global comparison because they ensure more long-term perspectives and allow for collaborative efforts such as continued education that address newly arising skilling needs of innovative industries. Social partnership and parity models are more important than ever. The success of this transition greatly depends on the willingness to compromise, to develop solutions that boost our economies and distribute wealth, one that develops our cities into centers of innovative human capital without the precarization and weakening of the skills basis of more rural communities. Where there is more revenue and profit made, it is only natural to re-invest part of this capital into the sustainable future of work and ensuring a strong manufacturing-based middle class. Well-paid workers have a stronger purchasing power and in today's consumerism centered

systems, create a circular boost from worker, to society to companies. The comparison of the US and Germany shows that socioeconomic development relies to no small degree on the corresponding workforce that creates a climate for innovation and allows companies to be more competitive in global comparison. Diversities of skills in the labor force when compared across nations, regions, and metropolitan areas, help to understand and take advantage of divergent opportunities that emerge with new technologies and their varying degrees of application in industrial manufacturing.



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NOTES

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