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Innovation, Productivity,
and the Labour Market**

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ABSTRACT

The Economics of Diversity: Innovation, Productivity, and the Labour Market¹

The empirical evidence on the economic impacts of diversity is mixed. Many studies in the literature present context dependent and data driven results which are challenging to reconcile with each other. This paper offers a systematic synthesis of the empirical findings on the economic impacts of diversity on innovation, productivity, and the labour market. It presents a structured framework which takes the spatial scale of the analysis in the papers as a reference to understand the inconsistency of some previous predictions and the varying magnitudes of the diversity impact. The empirical findings reconcile more meaningfully when diversity effects are documented discretely at the regional, firm and individual levels. The paper further sets out an agenda for future research and links the findings for policy relevance.

JEL Classification: J24, J15, F22, O15

Keywords: innovation, cultural diversity, migration, knowledge production function

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1. Introduction

Why can large crowds of people sometimes make better decisions than individuals or even experts? The central idea is that a large crowd is likely to represent a range of complementing perspectives (Surowiecki, 2004) and pooling such perspectives can lead to enhanced decision-making (Page, 2007). This is the core theme within research by economists on the impacts of immigration and diversity. The somewhat ambiguous term 'diversity', and recently 'superdiversity' (Vertovec 2007, Phillimore 2015) harbours distinct attributes of people, and in particular immigrants, in terms of age, skill, occupation, gender, language, religion, marital status, residency status and distinct attributes of country of origin and destination. In addition to various personal characteristics of people, the motivation for their migration (such as (seasonal) work, study, safety, retirement, etc.) adds to and increases their diversity.

In recent decades many countries have experienced a considerable growth of immigration and diversity in their labour markets, whether due to efforts to achieve gender balance, LGBTI representation, efforts against discrimination in labour markets or simply the consequences of globalisation. As a result, private companies, public organisations, policy makers and citizens are trying to find ways to capture the benefits and mitigate the challenges of diversity.² At the same time, a vast literature from a range of disciplines provides conflicting (or better put 'context dependent') results about the wide array of potential impacts of diversity, which vary from country level analyses to studies examining what diversity means for individuals.

Growing demographic disparities, technological improvements, new global and political changes, and social networks have shaped the global economic landscape and therefore its demographic and ethnic diversity. The changing demand for certain occupations (Acemoglu and Autor, 2011; Autor et al. 2013), technological change and the growing demand for basic non-traded services in the developed world seem to play a role in people's movements.³ While the globally mobile population is characterised by being much more diverse than before, reflection of this diversity in the economic sphere has been limited in many countries. In many economies we observe a dominance of native-male groups, particularly within certain occupations and/or positions within firms, governance and education fields. Economic research has recently documented a wide and somewhat confusing range of evidence of the conditions under which receiving economies may utilise the diversity of the workforce and the conditions which could act as barriers to a well-functioning diverse society.

² See Forbes 2011; and The Economist (2016) at <http://www.economist.com/node/21692865>, Article 'Diversity fatigue', Accessed on Sept 21th, 2020.

³ The altered nature of these flows by gender, age groups, occupations, country of origin as well as destinations is documented by the OECD. On average, 18 per cent of the total population in the OECD was foreign-born or a decent of foreign-born parents in 2013 (OECD/EU, 2015). Moreover, as in Widmaier and Dumont (2011, p.7): "these recent immigrants, in 2000-2006, tend to be more diversified by country of origin, more highly educated, more concentrated in the most active working ages (25-49), and in some cases more feminized. The 15 most important countries of origin account for more than half of overall recent migration, but smaller countries of origin also make an important contribution, illustrating the diversity of migration sources to the OECD". This trend also continued in the next decades after the millennium.

In light of this growing body of literature, the purpose of this paper is to provide a detailed review of the economic impacts of diversity. While studies such as Dustmann et al. (2016) and Edo (2019a) have reviewed the economic impacts associated with an increasing share of immigrants, less attention has been paid to reviewing the economics of diversity itself. This is despite the fact that in recent years the literature examining the economics of migration has clearly progressed from solely concentrating on the supply shock effect of immigrants, and hence the effect of immigrants on the displacement and crowding out of natives, to scrutinising the economic externalities that specifically stem from hosting diverse populations. The rapid increase in the number of studies using a variety of methods and data make it a challenging task to isolate the economic effects of diversity. An earlier paper from Kemeny (2014) tries to review the pre-2014 empirical evidence associated with diversity. His broader approach in combining the economic and social dimensions of diversity and focusing on 7 different outcome measures however can only provide a general sense of direction of the overall impacts. Given the complexity of the diversity concept due to its multidimensional nature, the variety of methods used and the range of economic outcomes scrutinised in the literature, it is ideally necessary to focus on studies that utilise the same diversity metric on the same economic performance measures using similar econometric frameworks in order to reveal the economic impacts of diversity estimated in the literature to date.

This study therefore provides an up-to-date review of the literature examining the economic impacts of diversity. It focuses *only* on quantitative studies and predominantly uses the fractionalisation index in order to maximise our ability to compare the magnitudes of the estimated effects. It also focuses on the three most commonly examined economic outcomes associated with diversity, namely innovation, wages and productivity, and reviews the studies examining each. In so doing the review distinguishes between the differing spatial scales of the analyses and the respective mechanisms of influence. While the emphasis within the literature is on the commonly used fractionalisation index this review also examines the evolution of other commonly used diversity metrics and provides a discussion of their underlying theoretical backgrounds.

It would be a considerable task to try to summarise the multi-disciplinary literature on diversity impacts in one review article. This article therefore documents only a selection of ways through which the diverse composition of a population may impact economic performance. There are many separate channels through which diversity influences socio-economic outcomes (e.g. Ozgen et al. 2014). Most research to date simply estimates an observable net effect of these channels in terms of economic measures like output growth, productivity, profitability, income, wellbeing, innovation, trust, participation, discrimination, and spatial interaction (trade, tourism, FDI, etc.). The *economic* externalities that can be obtained from diverse populations/employees/individuals can be broadly classified into two economic areas: the economics of production and the economics of consumption. For this review, firstly, I *exclusively* focus on the former to examine the impact of diversity on firm and regional innovations, productivity and labour markets.

Secondly, the findings presented here aim to give a shape to the body of economic literature on what is, in Scott Page's words, the vague and imprecise concept of 'diversity' (Page 2007, p7). In order to do so, this review focuses on econometric studies, where possible using the same *metric* to measure diversity, and tries to analyse particular mechanism(s) through which diversity may impact productivity outcomes at macro (country), meso (region) and micro (firm or employee)

levels, respectively (See Figure 1). This approach helps refine the empirical findings with the aim to explore whether one size fits all or whether this research question should be examined at multiple spatial levels in order to correctly contemplate the relevance, mechanisms and policy implications. The particular relevance of this is such that although immigration policy is typically implemented at a national level, the impacts of immigration and diversity are likely felt the most at regional and local levels. However, to show how alternative metrics of diversity, typically used in earlier studies, led to different conclusions, where possible I discuss these measures comparatively.

The rationale behind this research design is that the main research question is economically relevant for different geographical scales and production units, however, the *mechanisms* operating at these different scales can be rather different. For example, the spatial selectivity of migration, and subsequently immigration induced diversity at the regional level may increase productivity and wages due to the creation of new jobs, knowledge spillovers and entrepreneurship. Whereas at the firm level, the net effect of foreign employees and diversity composition on firm innovation would require an examination of the precise mechanisms such as within-firm knowledge exchange channels and how firms utilise the pool of ideas. Similarly, at the country level, the degree to which society is welcoming or hostile towards immigrants may influence redistribution policies while at the same time the variety of immigrants from different countries of origin may, for example, lead to new trade links and higher productivity. Therefore, the quantitative empirical evidence is reviewed on the basis of *channels of influence* and the *spatial unit* of analysis.

Third, since the diversity debate primarily revolves around cultural or ethnic diversity, the findings presented here focus on that aspect of diversity. However, where relevant and comparable, other forms of diversity (age, education) are also highlighted in the discussion. It should be noted that the economics research has been overwhelmingly concerned with outcomes with respect to population diversity in European countries and in North America. There are relatively few studies of other parts of the world in the economics literature.

Finally, the relevant literature discussed in this review takes people and their characteristics as supply side inputs of a knowledge production function. These studies consider mechanisms through which diversity may affect, in particular, productivity and innovation but also labour markets by addressing the following questions: Do regions with greater diversity in the population innovate more? Are firms, which have a more diverse composition of employees more productive? Does working in diverse cities or at diverse workplaces pay off in terms of employees' earnings? Does workplace diversity reveal higher performance records for individual workers? Hence, the review provides a comparable econometric evidence base for social and economic policies of managing and improving diversity.

Literature Search and Compilation of the studies

With the above background in mind, I now summarise the details of the literature search and the compilation of the studies selected for this review.⁴ A key point to note is that a number of different metrics are used to measure diversity within this literature. The papers included within this review all contain a formal measure of diversity, most commonly a fractionalisation index, and all provide an econometric estimate of the effect of diversity on innovation, productivity or labour markets.

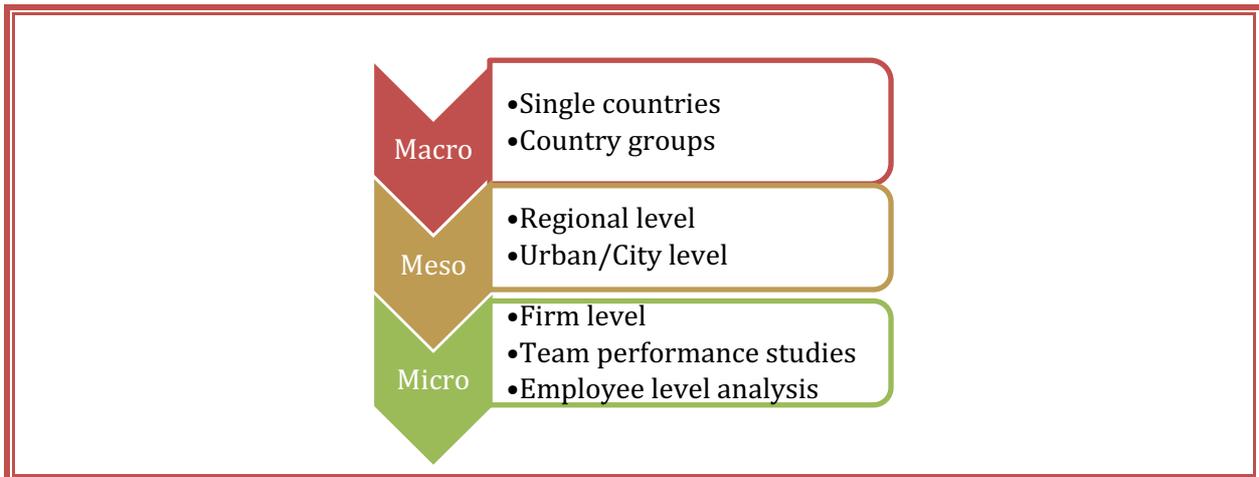
The review focuses exclusively on English language studies for practical reasons. The search terms in academic journals and related websites (e.g. IZA, ResearchGate, EconLit, Repec) and search engines used include, but are not limited to: cultural diversity, ethnic diversity, economic impacts of diversity, innovation and diversity, (un)employment and migration. I also benefitted from examining the references of each paper and tracing their references, too. This review comprises of papers in high-quality peer-reviewed journals with a significant number of citations, while working papers that offer an innovative angle and make a substantial contribution are also included. In deciding which articles to focus on in detail I tried to emphasise articles that make a significant contribution over those that are merely incremental, articles that offer a new research direction or use innovative methods or data over those using more conventional analyses and finally to emphasise more recent studies (mostly from 2010 onwards). The overall collection of 42 studies reviewed shows a skewed geographical distribution towards a focus on the US and Europe reflecting the nature of this literature as mentioned above.

The three Appendix tables (Tables A1, A2, and A3) follow the same format displayed in Figure 1 and provide a brief summary of the studies discussed in this review. Finally, the aim of this review is not to mechanically map a DNA of what kind of studies (by study characteristics) is available in the literature, but more, given the available set of studies, whether we can increase our understanding of the ‘diversity impacts’ in a systematic way, especially when the spatial levels of analysis are taken into account.

The rest of the article is divided into 4 sections. Section 2 provides definitions and discusses measurement issues, modelling and identification challenges in diversity studies. Section 3 focuses on individual studies sharing a common econometric framework and explains the impacts of diversity on innovation, productivity, and labour markets. Section 4 positions the results from this review and its relevance within the international migration literature and discusses policy issues and an agenda for future research.

⁴ A simple example outlines the challenge of identifying relevant articles for this review and illustrates the considerable attention that this topic has received from academics. A Google Scholar search of the terms ‘economic impact of diversity and innovation’ returns 2.5 million hits. Search engine applications designed for academic research such as *Publish and Perish* also return a similar volume of studies.

Figure 1: Mapping of the empirical findings by spatial level of analysis



2. Definition, measurement, modelling and identification

2.1. Definition

Many researchers have tried to model under what circumstances receiving countries or firms might benefit from immigration and diversity. Due to the limitations of available data and measurement issues, almost none of the economic theories and empirical models of diversity is able to incorporate its multidimensional formation over time. Obviously, what makes an individual different from others can be a unique combination of culture, language, religion, race and birthplace. In a recent study, Desmet et al. (2017) suggest that the overlap between ethnic identity and cultural attitudes is indeed a small share of overall cultural variation, and the extent of this overlap varies by location.

The main challenge is that some of these layers are time-invariant such as country of birth while some others can change over time like nationality, religion and language. This fluidity of identity introduces an inevitable subjectivity into the measurements of diversity. This subjectivity is particularly prevalent when it comes to quantifying diversity through a common metric. Akerlof and Kranton (2010) established a useful framework to conceptualise identity and its role in one's economic behaviour and choice. Especially, in the case of immigrants, how migration experience changes the immigrants' definition of self-identity is crucial. The alteration in the forms of identity (which would include a wide range from personal characteristics to workplace norms for behaviour and professions) is likely to influence newcomers' utility and profit derived in the host countries which could then directly affect their work-related incentives in labour markets. In general, the economic interactions and market outcomes of people can alter depending on the extent to which people's identity relates to their place of residence. A number of studies introduced the behavioural consequences of identity and group belonging mostly in the form of linguistic diversity into modelling. For example, there is some evidence for differentiated economic interactions depending on the size of the (minority/majority) groups and their level of exposure to linguistic diversity (Ginsburgh and Weber, 2014; Berliant and Fujita, 2012; Lazear,

1999) as well as other forms of diversity (Dale-Olsen and Finseraas, 2020). However, the economics of diversity literature has largely focused on how the presence of diversity of groups affects economic outcomes and distribution in the host countries rather than how identity can affect the choices and trade-offs of people.

Consequently, quantifying different markers of identity and culture simultaneously remains a challenge. Therefore, economic models of cultural diversity mostly use one operational definition and then try to analyse the performance, productivity and growth impacts. The operational definition of diversity mostly depends on the availability of the data and relevance of the definition within a country context. For instance, in the European context racial diversity is considered less significant than it is in the US. There is an ongoing effort to define and measure diversity and due to the nature of diversity itself, the definition could depend on the phenomenon under consideration, namely heterogeneity, compositional aspects, size dominance of groups (Jost, 2007). Examples include Fearon, 2003; Montalvo and Reynal-Querol, 2005; Desmet et al., 2009; Ozgen et al., 2013, Alesina et al., 2016; Grinza et al. 2018; Dale-Olsen and Finseraas, 2020; Brixy et al. 2020.

Commonly used metrics in the literature so far include fractionalisation indices (Alesina et al., 2003), exposure measures (Massey and Denton, 1988) and (spatial) segregation indices (Massey and Denton, 1988; Nijkamp and Poot, 2013). Evidently, these metrics offer a trade-off between defining diversity through its single or multiple attributes (See Section 2.2). The fractionalisation index, that is identical to 1 minus the Herfindahl-Hirschman index (explained in Section 2.2 in detail) aims to measure the richness and the evenness of a population though and is by far the most commonly used measure. The interpretation is as follows: when two different people are randomly selected from a sample the index measures the probability of those two people belonging to different groups. Some more recent studies point out the necessity of distinguishing between polarisation and fractionalisation aspects of diversity, where the former signifies, for example, the degree of potential conflict that may arise due to the dominance of majority against minority group within a population, while the latter captures the increase in available knowledge, occupational richness and abilities due to the diversity of a population. Empirical analysis by Ager and Brückner (2013) indeed illustrates the importance of including polarisation and fractionalisation indices jointly in econometric specifications in order to prevent incorrect conclusions on the predicted impact of diversity on economic outcomes. The relative level of fractionalisation with respect to that of polarisation influences whether diversity may positively impact the economic outcomes.

2.2. Measurement of diversity

Very early studies of migration-induced diversity and economic performance tend to focus on the notion of segregation. 'Segregation' is a general concept that is composed of 5 distinct conceptual dimensions; *evenness*, *isolation*, *concentration*, *centralization* and *clustering*. The first two concepts focus on the distribution of groups, while the last three assess the physical location of these groups. Although these dimensions may empirically overlap or their bilateral combinations may create new dimensions at different spatial scales, conceptually each dimension is distinct. For instance, minority groups can be centralized, but not necessarily concentrated. In other words, they can be predominantly located in the city centre, yet in a more scattered type of

settlement. Moreover, segregation may take place differently at different geographical levels from macro (states, counties) to micro levels (municipalities, neighbourhoods) (Massey et al., 2009), so aggregation of spatial scale may hide the real variation of segregation.

The notion of segregation refers to groups that are not spatially located in a mixed manner. Because segregation emerged as a concept to explain the distribution of black and white communities across space, particularly in US cities, the measurements of the concept are focused on two major groups rather than the existence of multiple groups. Therefore, the indices used to measure spatial and ethnic segregation do not aim to measure the diversity of multiple groups in a certain location; instead they particularly look at the spatial distribution of minority and majority, while considering their exposure to each other.⁵

Against this background, in economics a common metric to control for the heterogeneity of the population has been to use the share of foreign-born in the total (employee) population. However, the share of foreign-born is unlikely to be a true measure of the diversity of the population (or employee composition) because it implicitly assumes within-group homogeneity among the immigrants by grouping all the immigrants and their attributes in the numerator.

More recent models of the economics of international migration and diversity enhance our understanding through emphasizing the size, scale, diversity, technology and consumption impacts (see Nijkamp and Poot, 2012, for an extensive review). With the increasing availability of micro-data and geo-spatial data, more recent empirical modelling of diversity has gone beyond the area approaches (e.g. country, state level or city studies) to focus more on individual or refined geographical levels at which diversity effects are modelled in production functions.

Thus, immigrants are no longer viewed as a group of homogenous and mobile labour, but they can change/influence the composition of economic sectors and establish their own enterprises

⁵ Below is the definition of these 5 concepts together with their preferred method of measurement according to Massey and Denton (1988):

- 1) **Evenness:** Compares the relative size of the groups across geographical units. It is not measured in an absolute sense but is scaled relative to some other group. **Measurement:** Dissimilarity index (not suggested for multi-group cases; the entropy index should be chosen for this purpose).
- 2) **Exposure:** Degree of potential contact, possibility of interaction between minority and majority groups within a geographic area. **Measurement:** Isolation and Interaction indices (both should be reported).
- 3) **Concentration:** Relative amount of physical space occupied by a minority group. **Measurement:** Relative concentration index or spatial measures.
- 4) **Centralization:** A group located spatially near the centre of an urban area. **Measurement:** Absolute centralization index.
- 5) **Clustering:** Distribution of minority groups in a 'contiguous and closely packed' way, creating a single ethnic or racial enclave. **Measurement:** Spatial proximity (In addition, there are other measures assessing the exposure to minority or majority groups that decays with distance).

The obvious conclusion of the explanations above is that some concepts are *space-dependent* (locational) while others are *group-dependent* (distributional). For instance, evenness, isolation, dissimilarity, heterogeneity, and diversity of two or more groups are *not* particularly defining their location across space, while concentration, centralization and clustering are determining how groups are 'located' in a geographical unit. Especially in the case of clustering, the measurements are informative about pattern recognition; patterns in variation such as outliers, clusters, hotspots, trends and boundaries.

and/or offer product and service varieties. Moreover, the diverse composition of immigrants brings additional economic externalities into the host countries. This change in the theoretical underpinnings is reflected in the metrics used to measure the diversity of immigrants starting from the turn of the millennium.

The so-called fractionalisation index (Alesina et al. 2003), became the standard means to account for population diversity in modelling its impact on economic performance. The index has desirable features since it is informative both in terms of the *evenness* (equiprobability of occurrence or uniformness) and *richness* (number of different diversity types) of the underlying population. D_{it} , the fractionalisation index, is then measured as:

$$Diversity_{it} = 1 - \sum_{g=1}^n s_{git}^2 \tag{7}$$

where s is the share of the g^{th} cultural-ethnolinguistic group in region i at time t . The total number of g^{th} groups is n and the diversity index D_{it} is equal to one minus the sum of the squared share of each group. The lower the sum, the higher the diversity index. The share s can refer either to the different shares of workers in firms or to the share of foreign residents by country of origin in one particular region or geographical area. The index values span between 0 (when all cases belong to the same group; maximum homogeneity) and $1-1/N$ (when there are an equal number of cases from each of all N groups; maximum diversity). However as in many indices, the index has its limitations, in this case being sensitive to the size of the dominant groups in the population (Dawson 2012). Table 1 provides two examples of such distributions.

Table 1: An example of the fractionalization index when underlying composition changes

	Even distribution				Isolated distribution			
	a	b	c	d	a	b	c	d
Number of groups								
N: 42	10	12	9	11	2	3	1	36
Fractionalization index value (D_i)	0.747				0.257			

Source: Author's own calculations.

This simple example shows two different distributions of a population across 4 groups together with the resultant fractionalization index values. It shows that a high level of evenness produces a relatively high value of the diversity index while the presence of one dominant group results in a substantially lower index value. In the case of, say, two dominant groups instead of one, the index would take on a value in between the two values presented above.

Given that in many host countries native populations are the dominant groups, Alesina et al. (2016) proposed a modified fractionalisation index that is decomposed into 2 components, namely diversity between natives and all immigrants, and diversity within immigrant groups. Alesina et al.'s (2016) reformulation allows one to remove the influence of natives, i.e. the dominant group, and to construct the diversity measure purely on the basis of the immigrant population. However, one limitation of this 'birthplace diversity' measure is that it considers only between-group heterogeneity (in this case immigrants) rather than within-group heterogeneity, as in the case of Ashraf and Galor (2013). In other words, when calculating skill diversity for example, people with the same educational degree are assumed to have the same characteristics hence the distance between the different groups is treated as equal. To deal with the dominant group issue when utilising the fractionalisation index Kahane et al. (2013) also include a relative

foreignness share variable that is constructed by the share of the non-dominant group, in their case in a hockey team, relative to the league's average of the same measure. In this way, the two parameters estimated together indicate the teams with relatively high concentrations of non-dominant group players and, having controlled for those relative concentrations, which teams have a large share of immigrant players coming from a single foreign country.

Other measures of diversity that are less commonly used in the economics literature include the Shannon–Weaver entropy index (e.g. Parrotta et al. 2014a; Østergaard et al. 2011; Dohse and Gold 2014; Niebuhr 2010), a measure typically defined as follows:

$$Shannon_{it} = - \sum_{g=1}^n s_{git} \cdot \ln(s_{git}) \quad (8)$$

Entropy measures allow the calculation of the frequency of each group and also weight each group according to its frequency. The weights may have significant impact on the influence of the underrepresented groups on the index value. The Shannon-Weaver index is known to be more robust for the extreme values of a distribution, while less sensitive to intermediate values. An example from Jost (2007) shows the difference in the sensitivity of these two indices to a change in diversity. Jost asks 'if a continent with 30 million equally common species is hit by a plague that kills 50% of the species, what happens to diversity?' i) the Shannon-Weaver entropy index reports a 4% decrease in diversity: from 17.2 to 16.5; ii) the Gini-Simpson index decreases from 0.99999997 to 0.99999993 indicating a far smaller percentage decrease in diversity. It should be noted that though that these indices are highly correlated once number equivalents are calculated. This example suggests the care that needs to be taken when interpreting the results of different diversity indices each of which is capturing a subtly different aspect of diversity.

Finally, a number of studies have used ethnic polarisation indices in combination with diversity measures. These studies focus on the effects of polarisation and diversity, jointly, on economic outcomes as well as on the distribution of public services and social conflict (e.g. Ager and Bruckner 2013; Gören 2014; Reynal-Querol 2002). Ethnic polarisation is maximised when there are equally sized groups in a population, while polarisation decreases with the number of equally sized groups. This literature suggests that ethnic polarisation can hinder economic development through a number of mechanisms, one of which being civil war. The evidence also suggests that the diffusion of ideas and knowledge transfer are impeded in countries that experience higher ethnic polarisation. However, the direct influence of ethnic *diversity* is found to be positively correlated with economic outcomes, even within ethnically polarised countries. Niebuhr and Peters (2020) indirectly take this point into account by including a cultural isolation measure in their wage-diversity analysis to explore how the entry wages of a worker are influenced when he/she does not belong to the predominantly prevalent cultural group within a firm.

2.3. Theoretical and methodological underpinning of diversity in the knowledge production function (KPF)

Monopolistic competition models introduce the 'variety' concept in terms of 'productivity' or 'consumption' that immigrants may bring and the way in which they are 'sorted' accordingly in an economy. As a result, the extent of the benefits that the host economy obtains depends on how different the immigrants themselves are as labour inputs and how differentiated the goods and services are that they produce.

The group of models that break away from the conventional Harrod-Domar and Solow growth models are recent models of technological progress. They tend to see immigrants as a resource, which creates and develops new technologies, innovates and applies new methods and procedures (Bodvarsson and van den Berg, 2009). This means that the newcomers are not just an undistinguished part of other productive resources, but they themselves are a potential source of innovative and creative ideas. This strand of the literature explains the various mechanisms through which people's mobility should affect technological advancement in sending and host countries. The most obvious ones can be listed as follows: firstly, through migration people carry ideas and knowledge that are exclusive to them or that they acquired during the stages of educational attainment; therefore, they facilitate technology transfer. Secondly, the selective nature of migration is likely to mobilize more entrepreneurial and innovative workers. Third, by purely increasing the size of the economy, they mobilize technological progress in the host countries. Finally, they add to innovative competition, thus challenging the vested interests that tend to slow down innovative processes.

Although comments on the creative and innovative contributions associated with the arrival of people are not new (William Petty, a social scientist, wrote in 1682 "... it is more likely that one ingenious curious man may rather be found among 4 million than among 400 persons", as quoted in Bodvarsson and van den Berg (2009), p. 232), economic models integrating this aspect of immigration are relatively recent. Schumpeterian models clearly incorporated the abovementioned roles of immigrants into models of economic growth. This group of models saw monopoly profits as a necessary incentive to innovate. From this perspective the economy's pace of technological growth is assumed to be dependent on entrepreneurs and inventors' incentives and how far they are able to execute their creative and *destructive* power.

The endogenous growth models of Romer (1990), Grossman and Helpman (1994) and Aghion and Howitt (1992) have been built around the Schumpeterian perspective on technological progress but with some subtle differences. One common feature of these models and their successors is that they shifted the focus from unskilled migration to migration more broadly, especially in urban areas (e.g. Glaeser and Maré 2001), and also to high-skilled mobility. The literature has already documented that high-skilled immigrants have important analytical and innovative skills; are predominantly in science and engineering fields; and have a tendency to cluster in innovative sectors (Saxenian 1999; Hunt and Gauthier-Loiselle 2010). Developed countries like Australia, Canada, and the US adopted skill-biased migration policies and enjoyed a significant increase in human capital.⁶ For example, during the 1995-2006 period foreign-born

⁶ "The United Kingdom (800 000), Canada (530 000) and Spain (495 000) also received significant numbers of high-educated people. (...) In 2005/06, the share of highly educated among all immigrants ranged from 11% in Italy to 47% in Canada and in the United Kingdom. In almost all destination countries, the share of migrants

people accounted for 67 per cent of the net increase in the number of scientists and engineers in the US (Kerr and Lincoln, 2010).

Until now, many economists took a receiving country perspective and focused predominantly on the labour market effects of immigrants on natives. It is, however, crucial to recognize that the impact of migration cannot be only confined to labour supply and wage effects. Migration is a key factor in increasingly interdependent relationships between trade, economic development, investments and knowledge flows between the developed and developing world.

Additionally, new economic geography models emphasise the importance of the unique 'buzz' provided by economic diversity and knowledge spillovers in urban agglomerations, and thus quantify the so-called Jacobs externalities in cities (Jacobs 1961; Jacobs 1969). Given the increasing urban population of the world as well as the sorting of immigrants with diverse backgrounds into urban areas, models of the productivity of diverse teams and workplaces appear as a very interesting and inspiring research area for labour and urban economists (e.g. Berliant and Fujita 2008; Hong and Page 2001).

These models show the benefits from scale economies as well as the emerging combination of skills and diversity at urban areas within an agglomeration externalities framework. The theoretical evidence combined with the insights of the endogenous growth theory led to an emergence of a literature on the long-term technology-enhancing economic impacts of *diversity*. Polanyi stated that '*we can know more than we can tell*' (Polanyi 1967: 4). This tacit and embodied knowledge of immigrants becomes available in destination countries, as immigrants are mobile across the world.

Therefore, the focus of the economics of diversity literature is whether host countries/ regions/ firms may gain some productive externalities through knowledge spillovers by attracting and employing immigrants with diverse backgrounds. The scientific evidence that supports this hypothesis at varying spatial levels has already been provided by case studies of developed countries such as Germany, Netherlands, New Zealand, the United Kingdom, Canada, United States, and Denmark (Niebuhr 2010; Ozgen et al. 2012; Ozgen et al. 2013; Maré et al. 2014; Nathan and Lee 2013; Partridge and Furtan 2008; Kerr and Lincoln 2010; Parrotta et al. 2014a).

Diversity may have many potential channels of influence, providing both opportunities and challenges for host countries and therefore warranting an evidence-based understanding of these varied diversity impacts. Figure 2 specifically outlines these mechanisms. The economics literature has been more silent or *less conclusive* on some of these channels such as community cohesion, diversity as amenity or gender aspects, while it is more suggestive and established on others such as economic growth, innovation, and labour markets. The reason for the former is clearly influenced by the availability of data and/or suitable methodologies.

holding tertiary degrees is higher than that of the native-born. This pattern was already observed in 2000, but has been reinforced recently in many countries, because of the selective nature of recent migration flows. In 2005/06, the United States was the leading net beneficiary of high-skilled migration with 11 million (7.8 million in 2000). Canada was the second net receiver with 2.4 million in 2005/06 and the country, which has experienced the highest growth rate since 2000 (+47%, +765 000)" (Widmaier, and Dumont 2011).

A recent yet fast trending topic in economics includes more micro-level analysis of diversity. The diversity of teams and groups (Kahane et al. 2013; Lee and Cunningham 2018) that has long been empirically studied in management sciences emphasises that diversity can lead to more scrutiny, superior problem-solving and creativity (Hoogendoorn and van Praag 2012). Similarly, individual level studies by Kerr (2008) and Saxenian (2006) examine the generation and transmission of ideas through co-ethnic networks and ethnic entrepreneurs.

Figure 2: Channels of influence of diversity and immigration in host countries

Positive Channels	Negative Channels
<i>Within Firm</i>	
<ul style="list-style-type: none"> • <i>Positive self-selection of immigrants:</i> e.g., intelligence, creativity, willingness to take risks, entrepreneurship, “star” knowledge workers (e.g. trained in host country universities) • <i>Youthfulness of immigrants:</i> increased mobility, creativity, progressivity • <i>Cultural diversity among immigrants:</i> knowledge spillovers, new ideas and practices, trade facilitation (networks, trust, institutional knowledge) • <i>Resilience of immigrants:</i> enhances decision making • <i>Immigrant supply enables firm expansion:</i> reduces shortages/vacancies of key personnel 	<ul style="list-style-type: none"> • <i>Fractionalisation of employees:</i> cultural and language differences and barriers, leading to communication problems, less trust, greater potential for conflict among staff, discrimination • <i>Greater labour intensity of production:</i> lower reservation wages of immigrant workers lead to lower wage costs and, hence, lower capital investment in the short run (substitution effect), possibly offset by firm expansion in the long-run (output effect)
<i>Externalities</i>	
<ul style="list-style-type: none"> • <i>Diversity as an amenity:</i> increased availability of ethnic goods and services in the community • <i>Population growth:</i> agglomeration advantages, greater demand and gross fixed capital formation, with new technology embodied in new capital • <i>Community cohesion:</i> bridging-type social capital leads to cross-cultural cooperation 	<ul style="list-style-type: none"> • <i>Sorting:</i> Residential and labour mobility leads to greater spatial segregation: less cross-cultural relations and trade, lower spatial mobility and knowledge transfers • <i>Polarization:</i> Bonding-type social capital leads to between-group conflicts • <i>Representation:</i> Political fragmentation and instability

Source: Ozgen et al. (2013).

Obviously, natural experiments to analyse the effects of diversity are very rare. Thus, most studies have to rely on area analysis, where diversity is induced by an increasing number of immigrants in a region, in order to analyse the (un)employment, wages through substitution/complementarity mechanisms (Peri and Sparber 2009) or diversity and consumption links (Bakens et al. 2013). Most past research has focused on whether a rising number of immigrants creates a competition effect, and subsequently a displacement occurs, in the local labour market for the natives (Borjas 2003; Card 1990). Moreover, the impact of local ethnic diversity on

boosting the variety of consumption goods and housing prices has been a recently emerging field (Bakens and de Graaff 2020).

However, a significant improvement in this research area have been incorporating diversity of the workforce into production functions. The main motivation behind the way in which diversity enters the production function relates to the fact that people differ in their productive skills and cognitive abilities in their interpretation of information and problem solving (Alesina and La Ferrara, 2005). The most common way to address the generation of productivity outcomes from a theoretical perspective, in particular linking innovation to the change in the labour force due to immigration, is the knowledge production function. This is usually specified as a firm or industry specific labour-augmented technology Cobb-Douglas function, such as:

$$Y_j = K_j^{\alpha_j} (L_{Y_j} A_j)^{1-\alpha_j}, \quad (1)$$

where Y is the level of production, K is the level of capital with firm specific productivity α_j , L_{Y_i} is the labour used to obtain the level of output Y which is multiplied by the level of technology A (in this case firm specific stock of knowledge). The subscript j indexes j -th firm for all variables. The output growth of a firm stems from the generation of firm specific new ideas, \dot{A}_j , that is embedded in the *growth* of A and it is defined follows:

$$\dot{A}_j = \bar{\theta}_j L_{A_j}, \quad (2)$$

where the term $\bar{\theta}_j$ denotes the average productivity for the worker carrying out research and L_{A_j} the number of workers doing research in the firm j . Following Bosetti (2015), the structure for $\bar{\theta}_j$ is further specified as:

$$\bar{\theta}_j = \theta_j (A_j)^{\gamma_j} (L_{A_j}^{\varepsilon_j - 1}) (D_{L_{A_j}})^{\sigma_j}, \quad (3)$$

where $D_{L_{A_j}}$ refers to the level of diversity among the workers undertaking research activities. Thus, the average productivity of R&D workers depends on firstly, the amount of knowledge within the firm, secondly, the number of R&D related workers, and third, the composition effect of R&D workers. The latter is the channel through which the diversity/immigration background of workers enters the knowledge production function as ‘idea workers’. The values of $\gamma > 0$ would lead to the so-called *standing on the shoulders of the giants* effect; while $\gamma < 0$ exhibit a *fishing out* effect, meaning that due to a firm’s existing stock of ideas being limited, new generation of ideas is decreasing in the stock of ideas. The third component of Equation 3 is of particular interest as it is related to worker diversity, hence the transmission and pooling of distinct knowledge of workers with in a firm boosting productivity.

Once equations 2 and 3 are put together then the following equation can be obtained:

$$\dot{A}_j = \theta_j (A_j)^{\gamma_j} (L_{A_j}^{\varepsilon_j}) (D_{L_{A_j}})^{\sigma_j}, \quad (4)$$

meaning that the creation of firm specific knowledge depends on the stock of ideas, the number of workers in R&D and the level of cultural/ethnolinguistic diversity.

In many empirical specifications that estimate the relationship between diversity and economic outcomes, in particular innovation, Equation 4 is transformed into a linear model through logarithms in order to obtain a regression model. In this new specification, as shown by Ozgen and De Graaff (2013), the following model is obtained:

$$\ln(\dot{A}_j) = \ln(\theta_j) + \gamma_j \ln(A_j) + \varepsilon_j \ln(L_{A_j}) + \sigma_j \ln(D_{L_{A_j}}) + \ln(\mathbf{C}_j) \beta_j + \ln(\mathbf{R}_i) \delta_j + \varepsilon_j, \quad (5)$$

where \mathbf{C}_j is a vector of control variables specific to firm j and \mathbf{R}_i is the same for region specific variables. In practice though this equation is typically estimated through a logit or probit model as the variable (\dot{A}_j) is a dummy taking the value 0 or 1 if firm has announced innovations in a given period or number of patent application over time. The model can be estimated either using cross-sectional or panel data depending on whether data are available for different periods of time t . In the case meso-level panel data is used, such as at city or regional level for many years, and the following specification is estimated:

$$\ln(\dot{A}_{it}) = \sigma_{it} \ln(D_{it}) + \ln(\mathbf{C}_{it}) \beta_{it} + \ln(\mathbf{R}_{it}) \delta_{it} + \vartheta_t + \varepsilon_{it}, \quad (6)$$

The dependent variable will then be a continuous variable indicating for instance the number of patents or other measures of innovation. One would include time fixed effects given by ϑ_t indicating the time period, which typically are years or months in the most common databases on innovation outcomes, and in this case the subscript i refers to the geographic area instead of the firm. The variable of interest D_{it} is, commonly, an index constructed to account for the various dimensions of the underlying composition of the population. The metrics used to measure diversity are discussed more broadly in the following section.

Other economic models of diversity also incorporate the possible negative effects of diversity, which may cause ethnic segregation, the reduced availability of social capital and, efficiency loss due to communication barriers. However, these models estimate only the 'direct' negative impact of diversity and do not focus on indirect effects that may lead to conflicts, crime or wars. The models of Ottaviano and Peri (2005), Prat (2002), Hunt and Gauthier-Loiselle (2010) do not account for the costs of diversity and assume that more heterogeneity is always better than less, although Ottaviano and Peri (2005) model implicitly the potential cost of diversity through simultaneously estimating wages with rental prices to show that partial capitalisation of productivity gains may push the rents up. On the other hand, Alesina and La Ferrara (2005), for example, model welfare maximization in the presence of a proliferating number of diverse groups as a trade-off between increased productivity and variety versus fewer public goods available for all of the groups in the economy. Lazear (1999) also shows how costs may be incurred in diverse teams due to communication difficulties. There is clearly a trade-off between the productive benefits of diversity and the costs of increased heterogeneity and therefore some studies pointed

out an optimal level of diversity. Examples contrasting African countries with countries like the US, Canada, New Zealand, suggest that institutional mechanisms may mitigate the negative effects of cultural diversity and help to reap the benefits from it. In this respect Guiso et al. (2006), Fearon and Laitin (2001) provide useful insights on the relationship between cultural diversity and institutions.

2.4. Research design, identification and data

The literature examining the impacts of diversity provides evidence of these impacts at a variety of scales, ranging from micro to macro. For instance, evidence is provided by area level studies (e.g. where patenting performance of foreign-born graduate students with diverse backgrounds are analysed at country level) as well as individual level studies (e.g. patenting performance of immigrant inventors or entrepreneurs is followed over time and space). The research design is often determined by the availability of, and access conditions to, data. Often micro-level linked firm and employee data sets are subject to confidentiality agreements with the institutions providing the data, and can be accessed only through secure environments, such as so-called data laboratories in situ or through remote access. Moreover, research on cross-country compatibility of data appears to be non-existent. This is not only due to the access conditions limiting use to restricted locations, but also due to the lack of an internationally agreed legal framework that allows researchers/statistical institutes to exchange administrative data.

The identification of the causal effect of diversity on economic outcomes provides several econometric challenges. Firstly, the factors that influence the diverse composition of cities or firms may correlate with unobserved factors that affect the economic performance of these cities and firms. For example, investment in state-of-the-art machinery by a firm's management may improve the productivity of both firm and workers and could potentially correlate with the firm's diversity. In this situation a failure to take into account a firm's *investment practices* would attribute an effect to diversity that may not be warranted. The potential impact of this *unobserved heterogeneity* may simultaneously influence the outcome variables and the diversity itself and hence is likely to bias the estimated coefficients.

Panel data fixed effects models are used to help account for unobserved omitted variables. However, these models provide little information on the impacts of time-invariant variables and slowly trending measures of diversity. Firm-level studies tend to suffer from this problem as within-firm variation of diversity measures is often significantly limited, so where possible studies try to use longer time series to overcome this limitation. Therefore, the most appropriate time frame for analysing the effects of diversity has been a key issue within this literature. This is particularly the case since an assessment of the impact of policies that promote diversity for firms or regions sometimes requires post-evaluation decades after the introduction of those policies.

A second and related challenge to establishing a causal link between diversity and economic outcomes is provided by the possibility of reverse causality. This can arise if, for example, unobservable productivity shocks lead to better economic outcomes which in turn attract a wider group of foreigners from diverse backgrounds. For instance, greater job opportunities in metropolitan areas may attract a diverse group of workers, while the presence of a diverse

workforce can affect the level of productivity in cities through diversity of knowledge and creativity. This mechanism would bias the OLS predictions upwards. Instrumental variables estimation is clearly the most used econometric technique to overcome this potential simultaneity bias.

As many studies within the literature on the economics of diversity focus on immigration-induced diversity, one of the most commonly used instruments to-date is the historical share of immigrants. In particular, since Card (2001) pioneered the supply-shift approach, researchers have adopted the shift-share methodology almost as standard. This methodology is based on the idea that the existing groups of immigrants attracts newcomers from the same group of origin. To the extent that the existing country fellows attracting the newcomers correlate with the increase in diversity, rather than with location specific productivity shocks, the effect of diversity is interpreted as causal.⁷

Typically, the initial share of immigrants by country of origin in a *region i* by a lagged period is used to calculate the growth rate of each group within the whole *country* for the entire study period. The predicted share of each group of immigrants then indicates the average growth rate of these groups within the country. By using these predicted shares of immigrants by country of origin, a shift-share or 'predicted' diversity instrument in a location is constructed. More recently, this instrument is also widely used in firm-level analysis.

Although a detailed discussion of the shift-share approach is beyond the scope of this review, a short discussion of its validity is warranted given how frequently this approach has been used. The existing literature has raised two main concerns relating to the shift-share instrument. Firstly, the instrument is likely to be invalid if current economic circumstances continue to adjust to past immigration flows or shocks. In this situation, past immigration would continue to correlate with the current outcomes, e.g. wages (Jaeger et al. 2018). This issue is less of a concern though when home country related push factors (e.g. wars or forced migration) are the driving force behind the inflow of immigrants rather than the economic cycles of the host country (e.g. Edo 2019b). Secondly, the shift-share instrument would be invalid if the past economic conditions that determined the location choice of immigrants are serially correlated over time (Lewis and Peri 2015). The use of deeper lags can help to reduce the correlation with current economic outcomes.

Similarly, meso-level analysis (cities or regions) frequently makes use of instrumental variables estimations in which push or pull factors are used as instruments for the level of diversity; where push factors refer to characteristics of the sending countries (e.g. geographical and/or cultural distance between the sending and the receiving countries) and pull factors to those of the receiving countries (e.g. number of immigrants already residing in the receiving countries, multicultural level in the cities or regions).

⁷ Ottaviano and Peri (2005: p.328) explain: "For instance, due to the large increases in Spanish speaking communities, a city with a large initial Spanish speaking population would be assigned a larger share of this group in 1990 and, through this channel, a larger diversity, independently of how this city attracted the foreign born."

Other types of instruments may include policy programmes as used within Longhi's (2013) panel data analysis using the British Household Panel Surveys. Longhi addresses the self-selection of migrants to neighbourhoods by using "The New Deal Programme" of the British government as an instrument. This programme aimed to bring selected groups of unemployed and inactive people back to the labour market and was implemented nationally with the variation across local authority districts. The precise instrument used is the proportion of immigrants on the programme in each area which is highly correlated with the immigrants residing in the local authority districts (0.949) but has only a low correlation with economic outcomes such as hourly wages (0.088).

To offer some sense on the extent of the bias due to endogeneity issues, Table 2 summarises a number of studies covered in this article selected on the basis of being largely comparable in terms of methods, data and measure of diversity. In Table 2, these studies are classified by economic outcome measure; namely innovation, productivity and wages; and by the spatial scale of the analysis; namely regions, firms, and worker level. The table provides a comparison of the OLS predictions of each study and the estimations that correct for the endogeneity. The magnitude of the predictions almost always become larger once the researchers take sorting and reverse causality into consideration. This observation is particularly true for innovation studies where the change in magnitude is substantial, irrespective of the spatial scale of the analysis. Similarly, for the productivity studies the IV estimates tend to be larger than those estimated using OLS. However, the difference in magnitudes between the two is smaller for the productivity estimates compared to those in the innovation studies.

It is worth noting that it can prove very challenging to find a truly exogenous variable that is highly correlated with the endogenous explanatory variable but not with unobserved factors that influence the outcome variables. An alternative approach to the use of instrumental variables is to use matching methods and difference-in-difference models to try to emulate controlled experiments in observational studies. This group of estimation techniques is referred to as quasi-experimental design (Lozano and Steinberger, 2010) and requires a fairly large number of observations. A number of studies have used natural experiments that occurred as a result of population exchanges or wars between countries. Several examples of such studies include Tumen (2016) who focuses on the labour market, consumer price and housing rent impacts of Syrian refugees in Turkey, Borjas (2017) who revisits the Mariel Boatlift incident between Cuba and the US, Edo (2019b) who examines the wage adjustment due to the mass repatriation to France from Algeria, and Clemens and Hunt (2019) who study the labour market impacts of refugee flows.

3. The Economic Impacts of Diversity: Innovation, Productivity, and the Labour markets

3.1. Innovation

Empirical studies focusing on the innovation impacts of immigrants follow two major strands. The first strand uses a diversity metric, in many cases the so-called fractionalisation index. The second strand generally focuses on foreign graduate students/inventors/high-skilled workers as a percentage of total graduate students/inventors/all workers or they simply follow ethnic

inventors and their collaborations.

Although some of these studies do not focus explicitly on diversity, and hence would seemingly be outside the remit of this review, they do focus on immigrant inventors and the extent to which they cooperate with other inventors from different countries of origin (See Kerr 2008; Akcigit et al. 2017; Nathan 2015; Saxenian 2006). As such, since their underlying motivation is to examine diversity externalities, they are included. However, the studies that aim to quantify, for example only the high-skill or the overall supply shock effect of immigrants on individual level or natives' outcomes (e.g. Borjas and Doran 2012; Waldinger 2012), deviate from the focus of this review. These studies do not explore the productivity effects of knowledge spillovers stemming from ethnicity externalities or from co-ethnic collaboration (e.g. as in Borjas et al. 2018⁸ or Kerr 2008).

Not surprisingly, most analyses offer evidence from the United States. Given the large foreign population, and the large share of graduate students and immigrant inventors, the US based studies include a wide array of evidence from aggregate level country studies to micro-level inventor impact studies. In addition to the US, there are a handful of countries such as the UK, Netherlands, Germany, in some cases the European Union as a whole, Denmark, Ireland, Canada and New Zealand where scholarship provides knowledge on channels of diffusion of formal and informal information; the importance of scientific/technological knowledge transfer within/across countries and how the ethnic composition of scientists/inventors/entrepreneurs facilitate innovativeness. These studies describe the mechanisms of influence in 4 broad categories (as summarized in Ozgen (2015)); i) Assimilation of the second generation (do second generation workers contribute economic outcomes to a similar extent as their native peers?); ii) Diversity as a high-skilled sector phenomenon (Are diversity externalities more complementary to knowledge-intensive high-tech sectors?); iii) Segregation of immigrants at the workplace (Is co-ethnicity at the workplace detrimental or beneficial to productivity?); iv) New forms of knowledge that immigrants embody (what are the impacts of (co-)ethnicity-based collaborations on host and home countries).

3.1.1. Knowledge Spillovers via Graduate Students/ Scientists/ Inventors Mobility and Collaboration

One of the very early attempts to study the country level impacts of graduate students on productivity is provided by Chellaraj et al. (2008). Their analysis uses time-series data from 1963-2001 and examines the impact of the share of foreign graduate students on patent applications (with a 5-year lag); patent grants (with a 7-year lag) and non-university patent grants (with a 7-year lag), all 3 indicators as a percentage of the US labour force. For all three indicators they find a positive impact in the order of 4.5 percent, 6.8 percent and 5.0 percent for a 10 percent increase in foreign graduate students as a percentage of total graduate students.

⁸ Although Borjas et al. (2018) focus on the productivity gains from co-ethnic collaboration due to an increased number of Chinese graduate students, part of this paper discusses the effect of supply shock that had additional ramifications on the pre-existing workers who do not share the same ethnic origin.

Table 2: A comparison of *selected* studies by spatial level of analysis and economic outcome variable

Authors	Level of Analysis	Outcome variable	Period	Data	Dependent Variable	OLS Magnitude	IV (or endogeneity corrected) Magnitude
Ozgen et al (2017)	Firm	Innovation	1999-2006	2,800 Dutch firms & 16,000 German firms with LEED	Binary variable, 1 if a firm did product innovation over last 2 years, 0 otherwise	A 0.1 increase in fractionalization in the Netherlands increases the probability of product innovation by 0.9 percentage points	A 0.1 increase in fractionalization in Germany increases the probability of product innovation by 4 percentage points
Parrotta et al (2014a)	Firm	Innovation	1995-2003	12,000 Danish firms pooled over 9 years	Binary variable 1 if a firm applies for a patent application, 0 otherwise	A 0.1 increase in fractionalisation increases the probability to apply for a patent by 0.036 percentage points	A 0.1 increase in fractionalisation increases the probability to apply for a patent by 0.05 percentage points
Ozgen et al (2013)	Firm	Innovation	2000-02 & 2004-06	2,789 Dutch firms with LEED, panel	Binary variable, 1 if a firm improved, or produced a new, product/process, 0 otherwise	A 0.1 increase in the Simpson index decreases the probability of innovation by 0.9 percentage points	Not significant
Ostergaard et al (2011)	Firm	Innovation	2006	1,648 Danish firms with LEED, cross-section	Binary variable, 1 if a firm introduced new product or service, 0 otherwise	Not significant	Not significant
Nathan (2015)	Regions/ Individuals	Innovation	1993-2004	TTWAs in the UK regions, panel data	Patent counts	A 10 point increase in fractionalisation leads to 0.025 more patents	Not reported
Bratti & Conti (2014)	Regions	Innovation	2003-08	103 Italian NUTS3 regions, panel	Ln(patents per 1000 inhabitants)	Not significant	A 0.1 increase in fractionalisation reduces patent applications by 0.34%
Ozgen et al (2012)	Regions	Innovation	1991-95 & 2001-05	170 EU NUTS2 regions, panel	Ln(patents per million inhabitants)	A 0.1 increase in fractionalisation increases patent applications by 0.16%	A 0.1 increase in fractionalisation increases patent applications by 0.18%
Niebhur (2010)	Regions	Innovation	1940-2000	95 German regions, panel	Ln(patents per capita)	A 0.1 increase in the Shannon index increases patents per capita by 6.7%	A 0.1 increase in the Shannon index increases patents per capita by 18.9%
Dale-Olsen & Finseraas (2020)	Firm	Productivity	2003-12	3,995 Norwegian workplaces, panel	Ln(Firm value added)	A 10% increase in linguistic diversity decreases productivity by 1.1%	A 10% increase in linguistic diversity decreases productivity by 3.0%
Trax et al (2015)	Firm	Productivity	1999-2008	11,343 German establishments, panel	Ln(Firm value added)	Not reported	A 0.1 increase in fractionalization increases manufacturing productivity by 3.2%
Parotta et al. (2014b)	Firm	Productivity	1995-2005	28,000 Danish firms	Ln(Firm TFP)	A 0.1 unit increase in linguistic diversity reduces TFP by 0.39%	A 0.1 unit increase in linguistic diversity reduces TFP by 0.64%

Niebhur & Peters (2020)	Individuals	Entry wages	2000-09	280,000 new employment relationships, panel	Ln(Daily wages)	Not significant	Not reported
Kemeny & Cooke (2017)	Firm	Innovation	1991-2008	US LEED of 33.5m workers & 1.2m firms, panel	Ln(Annual wages)	A 0.1 increase in fractionalisation increases wages by 1.7% (low social capital) and by 9.2% (high social capital)	A 0.1 increase in fractionalisation increases wages by 19% (high social capital)
Longhi (2013)	Individuals	Native wages	2002-07	2785 individuals across England, panel	Ln(Hourly wage of white British workers)	Not Significant (once fixed effects are included)	Not Significant (once fixed effects are included)
Ottaviano & Peri (2006)	Regions	Native wages	1970 and 1990	160 US MSAs, panel	Ln(Average annual wage of US natives)	A 0.1 increase in fractionalisation increases wages by 12.7%	A 0.1 increase in fractionalisation increases wages by 9.5%

Note: The magnitudes are only reported if estimated coefficients are statistically significant at 10% or above. Where necessary, the reported magnitudes are the result of the author's own calculations in order to aid comparability.

Another country level study, again from the US, focuses on the extent to which foreign graduate students increase innovation. Hunt and Gautier-Loiselle (2010) use 2003 National Survey of College Graduates for their individual level analysis and a 1940-2000 state level panel data from the US Patent Office and Trademark (USPTO) for the aggregate level estimations. In their individual level study, they run regressions for three separate samples, which include college graduates, post-college degree holders, and scientists and engineers. The results suggest that US resident immigrants who are scientists and engineers are overachievers and boost innovation more than college students from immigrant backgrounds. For the US-state level analysis concerned with spillovers effects, they predict a percentage point increase in the share of college graduates of immigrant-background in the population boosts patents per capita by 9-18 per cent. Their results are robust to various specifications and controls for reverse causality.

Blit et al. (2020) try to replicate Hunt and Gautier-Loiselle (2010) in Canada, where they regress per capita patents in 98 Canadian cities on the change in the share of Canadian university-educated immigrants and use shift-share instruments to correct for the self-selection of the immigrants. They construct a 1981-2006 balanced panel of Canadian Census Metropolitan and Agglomeration Areas in 98 cities every 5 years. In order to compare their results with the US, they employ a baseline empirical model as close as possible to the first-difference weighted least squares specification of Hunt and Gautier-Loiselle's (2010). Blit et al.'s findings suggest that increasing the Canadian university-educated immigrant share by 1 percentage point leads to an increase in patents per capita of about 1.1 log points, while the comparable estimate for the US is 14.7 log points. Given that the econometric specifications in the studies are almost identical, Blit et al. (2020) interpret the differences in findings as being due to the greater presence of labour market barriers in Canada preventing immigrants from being employed in occupations that they are suitably educated for.

A very recent regional level study from Crown et al. (2020) presents an evaluation of how the Australian temporary graduate visa program spurs regional innovation outcomes. The authors use register and regional data, and control for the sorting of the brightest students to the most productive regions via a shift-share instrument. They report a positive impact of the visa program, measured by the share of Temporary Graduate visa holders as a fraction of the total population, on the number of patent applications, but find no impact on the number of design rights or trademarks. The authors report "a 0.1 percentage point increase in the share of visa holders corresponds with an additional 1.49 patents due to an additional 4.74 Temporary Graduate visa holders in the Sydney SA-3 Region" (p.8).

A complementary study focusing on the individual level diversity impacts on publication outcomes, is presented by Stuen et al. (2012). They provide evidence from an interesting sample from the National Science Foundation Survey of Earned Doctorates micro-database, which includes native and foreign doctoral students in science and engineering fields in the US between 1973-1998. Taking the university-field as an academic department, the unit of observation, they estimate publication/citation counts with respect to the number of doctoral students. They show that an additional student adds about 0.13–0.16 publications per year to his/her department. A further analysis offers an estimate on the diversity composition of doctoral students (through a fractionalisation index) with respect to both publications and citations and the point estimate is comparable to those of the literature with an elasticity in the order of 0.04 publications per year.

Another study that provides a robust and significant improvement in our understanding of knowledge diffusion by immigration is Moser et al. (2018). Focusing on the effects of Jewish émigrés from Nazi Germany on total changes in research outputs (patents in chemistry field) of the US, they also suggest strong knowledge spillovers from inventors from different countries of origin. For their analysis they adopt a difference-in-differences approach and compare changes in US patenting by US inventors, in research fields of German Jewish émigrés vs in research fields of other German chemists. For the most conservative estimate, the arrival of at least one German chemist in the patent classes meant a 31 percent increase in domestic patenting (75.1 more patents). Moreover, the intensity of exposure to émigrés of the US invention by USPTO classes leads to an estimate of four patents for each additional émigré patent. Therefore, the authors point out a very strong complementarity between German Jewish émigrés and natives that boosted the productivity of the new inventors in the US, rather than the incumbents, such that the US inventors who collaborated with the émigré professors experienced an exceptional increase in their productivity over the two decades from 1940.

Following Moser et al. (2018), Borjas et al. (2018) examine how the inflow of Chinese-origin doctoral students affects the productivity of their supervising professors in mathematics departments in the US. The authors use the “Open Up” policy of China in 1978 as an identification for causal interpretation. They use administrative data of the American Mathematical Society and the data collated for the Mathematics Genealogy Project. Using a difference-in-difference methodology their empirical analysis concludes that the advisors from Chinese origin mentored disproportionately large number of Chinese doctoral students. As a result of these collaborations, these pre-existing Chinese-American academics in American universities experienced a significant increase in their scientific output in terms of the number of papers published. Therefore, the authors confirm a strong existence of knowledge spillovers due to ethnic complementarities.⁹

Kerr (2008) provides a very interesting inventor level study from the US. In this study he analyses the innovative and scientific spillovers impact of US based foreign inventors on their origin countries and uses an ethnic name-classification system to identify the inventors’ origin. He studies how knowledge diffuses and technology is transferred through international patent citations across countries. Kerr shows that stronger scientific integration with the US research/innovation frontier through ethnic networks increases the manufacturing output in foreign countries with an elasticity of 0.1–0.3. Further analyses include employment and labour productivity gains in origin countries. Additionally, international knowledge transfers are found to be of most benefit to high-tech industries and to the Chinese economy. In a follow up study, Kerr and Kerr (2018) use patent data from 1975 to 2009 to scrutinise knowledge diffusion across borders, proxied by global collaborative patents, through the cooperation of ethnic and US inventors for new knowledge creation within US public companies. Global collaborative patents are defined as patents owned by at least one inventor who is located outside of the US and at least one inventor located within the US. They show that the ethnic composition of US-based inventors

⁹ Although an earlier study by Freeman and Huang (2015) focuses on the impact of same ethnicity co-authorship on citations and the impact factor of journals, this research does not consider the diversity effect on a specific outcome such as the number of publications or patents. Nevertheless, their conclusion suggest that the research conducted by co-authors from diverse backgrounds and locations leads to greater scientific contributions, proxied by citations and journals’ impact factors.

is an important determinant of a firm's engagement in international collaboration. The effect is especially significant when firm is active in a country with weak intellectual property protections.

The strength of these studies lies partly in their research designs either due to exploiting a policy change or benefitting from a pseudo-natural experimental setting. In all levels, macro-meso-micro, the empirical evidence is indicating a clear direct positive effect of knowledge spillovers from foreign graduate students for country, regional or individual level innovation. Moreover, as Blit et al. (2020) show, to the extent that the conditions that complement the skills of the foreigners are ensured, positive spillovers also translate into higher productivity. This is further reinforced for the natives who collaborate with foreigners, particularly in knowledge-intensive high-technology sectors. Finally, the magnitude of these positive externalities is most pronounced at the individual level when people are working in the same or similar scientific fields.

3.1.2. Innovation and Diversity

This section documents innovation and diversity studies that use a fractionalisation index to measure the diverse composition of the workforce or population. While a small number of studies do not explicitly use the fractionalisation index to scrutinise the diversity-innovation link, their main focus is still how immigrant composition affects innovative outcomes. One example of such studies is Akcigit et al.'s (2017) state-level analysis of US patenting; other examples include several studies which estimate *employee productivity* (wages) at the firm level due to an increase in the diversity of workforce or an increase in the share of immigrant workers by skill type.¹⁰

Akcigit et al. (2017) estimate how historical patenting by immigrant inventors in certain technology areas between 1880 and 1940 impacted state level changes in patenting between 1940 to 2000. They use patent records and federal census data that allows them to link the inventors to their patents. They also construct a *foreign-born expertise* variable that shows the technology areas in which immigrants' country of origin have been most prevalent in the past. This variable captures the transmission of tacit knowledge inflow into the US through immigrant inventor mobility from all countries in the world. The construction of this variable also takes into account the innovation frontier advantage of an immigrant's country of origin in a technology area (patent class). Their results suggest a standard deviation increase in foreign-born expertise boosts patents (citations) by 43.1 (by 39.6) percent of its standard deviation and thus indicate a substantial contribution to US inventions.¹¹

¹⁰ A recent study by Fassio et al. (2019a), though does not fall into any of these categories of studies mentioned above, they point out to a potential complementarity between skilled immigrants and *sector-level* diversity. By using European Patent Office (EPO) data at the sectoral level and benefitting from Labour Force Surveys, Fassio et al. (2019a) offer new evidence for three countries - Germany, France and the UK. After addressing endogeneity concerns, they show that high-skilled migrants have a positive yet smaller effect on innovations, in terms of magnitude (with elasticities 0.3 vs 0.09), compared to natives. However, their positive contribution is limited to high-tech sectors and to sectors which have above the country average level of diversity in employment, measured by the Shannon index. Therefore, high-skilled immigrants' contribution to innovation seems to be more pronounced in high *diversity* sectors, signalling a complementarity effect.

¹¹ By using OECD Stat database Bahar et al. (2020) reconfirms the findings of Akcigit et al. (2017), however their study is not directly comparable as they do not focus on the interaction between foreign inventors, hence foreign

Bratti and Conti (2014) regress the natural logarithm of patents per 1000 inhabitants in 103 Italian regions on the diversity of immigrants and find a significant and negative impact. The share of immigrants is instrumented using lagged immigrant enclaves. They explain the potentially detrimental impact of diversity by further distinguishing their analysis on the basis of low and high skilled immigrants. They find that a 1 percentage point increase in low skilled immigrants leads to 0.2 percent decrease in innovation. While they predict a positive coefficient for high-skilled immigrants their findings are inconclusive.

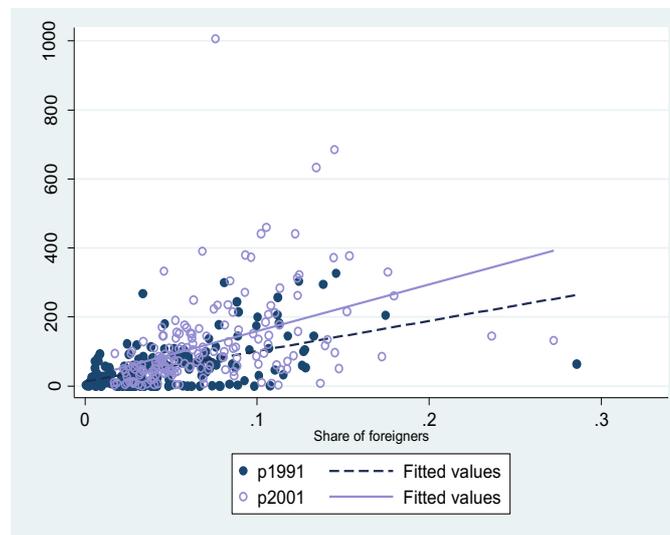
Ozgen et al (2012) focus on 170 NUTS 2 level regions of the 12 western European countries (with country choice limited by the availability of data), and explore the impact of culturally diverse groups of immigrants on regional innovation levels, as measured by patent applications. The study utilizes Eurostat's general and regional statistics database; while for migration, regional accessibility and economic growth indicators the databases of IAB, Oxford econometrics and ESPON are used. This regional-level study discusses the long-run technology enhancing economic growth effects of international migration within an agglomeration economies framework. The study depicts a positive correlation between regional innovation rates and the share of foreigners in the NUTS 2 regions in these countries (See Figure 3). It further tests the robustness of this relationship through longitudinal data analysis, instrumental variables and spatial econometrics to address various methodological issues. Moreover, discussing the inherent heterogeneity in terms of skills and culture that the immigrants hold, and the spatial inter-dependencies the innovating regions retain, the study was one of the first to go beyond the mainstream innovation literature that considered all skilled workers as a homogenous group. The research shows that, accounting for cross-country differences, a distinct composition of immigrants from a different country of origin is a more important driving force for innovation than the sheer size of the immigrant population in a certain locality. Moreover, the average skill level of immigrants (proxied by global regions of origin) also affects patent applications, once the diversity of immigrant populations is properly accounted for in the regressions. In contrast, an increasing share of foreigners in the population does not conclusively impact on patent applications. Given that the period of analysis is 1990-2001, the study also brings light to the policy debates on the so-called East-West migration in Europe.

Dohse and Gold (2014) is another European level study that analyses the link between cultural diversity and innovation in European regions and does so for the period 2005-2010. Using six waves of regional level panel data and first-differenced estimates, they determine an inverse U-shaped relationship between the Theil¹² or Fractionalisation diversity indices and patents per capita. This is in line with Ozgen et al (2012) suggesting an optimal level of cultural diversity with respect to innovation. Accordingly, they suggest a one standard deviation increase in diversity in regions increases patents per hundred thousand by 0.12 to 0.21 percent. However, as Dohse and Gold do not explicitly tackle the sorting of immigrants into the most productive regions, their results may not be robust to an endogeneity correction.

knowledge accumulation, but they rather look at the effect of the size of immigrant inventors on patenting of the receiving countries in certain technology areas.

¹² Although authors argue that they are using a Theil index, the specification in their paper is a Shannon-Weaver index.

Figure 3: Patent applications per 1000 inhabitants vs Share of foreigners in 12 Western European NUTS 2 regions



Source: Ozgen et al. (2012)

Following Kerr (2008) and by using a 12-year panel of patent microdata, Nathan (2015) explores whether UK based foreign inventors originating from various countries in the UK's travel to work areas (TTWAs) boost counts of patent activity over the period 1993-2004. He also explores whether it is solely the immigrant background or the diversity of immigrants that increases patenting activity. Nathan's results indicate a positive association with patenting and foreignness of the inventors, particularly those of East-Asian origin. He predicts a 10-point increase in the fractionalization index, for example increasing the diversity index value from Bristol's to that of Oxford's, would lead to slightly less than 0.025 patents for a 4-year period. He offers a back of the envelope calculation showing this aggregate effect would then mean 40.4 unweighted (or 17.7 weighted) patents by 1628 inventors for this area. The magnitude of the impact is rather small, which might be due to noise in the aggregation of the data across local authority areas and then to TTWAs and due to problems in patent counts. This though should not overshadow the fact that the results suggest a positive correlation.

A number of firm levels analyses further explore employee composition effects and therefore contribute to the discussion on within firm knowledge spillovers and the pooling of diverse knowledge for higher productivity. Lee (2015) examines 2000 UK firms in 2004-2005 from the Annual Small Business Survey. He focuses on both firms, regional and TTWA level effects of employee diversity on firms' probability of various types of innovation. He finds that a greater share of ethnic ownership of firms increases the innovativeness of those firms. However, he finds no effect of city level fractionalisation on firm level innovation.

Ozgen et al. (2013) take a micro-level approach and focus on the smallest unit of production: the firm. An important contribution of this analysis is the introduction of employee heterogeneity to the knowledge production framework for the first time using linked employer-employee data. The heterogeneity of employees comes not only from their varying skill levels but also from their

cultural background in terms of country of origin, demographic characteristics, and their assimilation to the host country. A unique linked employer-employee micro dataset of 4582 firms that includes qualitative information on firms and innovation was constructed and analysed. The empirical analysis provides robust evidence that firms employing a relatively higher share of migrants are less innovative. However, there is evidence of integration in that this effect is generally less strong or even absent for second generation immigrants. The authors emphasize that in the Netherlands the sectors that employ immigrants tend to be those in low-skilled service sectors like hotels, restaurants and catering businesses. Moreover, firms employing a more diverse foreign workforce are more innovative, particularly in terms of product innovations. The benefits of diversity for innovation are more apparent in sectors employing relatively more skilled immigrants.

In another micro-level analysis, Ozgen et al. (2014) offers further methodological insights into the measurement of cultural diversity. The paper also takes a longitudinal perspective by using a panel of linked employer-employee data. The paper explores whether altering diversity measures would inform us better on the channels of how a diverse workforce affects firms' productivity. It shows that diversity is a multi-dimensional concept and that firms may benefit differently from its unique components. In addition to the standard diversity measure, the authors jointly include two more measures of diversity in their specifications. Firstly, a co-location index that measures the exposure to fellow compatriots among foreigner workers (see Akerlof and Kranton (2010) discussion in Section 2.1); and the total unique number of countries present due to foreign workers in each firm to measure the potential distinct features brought into the firm. The firms benefit from the diversity of employment, when measured by the natural logarithm of the unique number of countries present in a firm, only for process innovations. In a panel data setting, no statistically significant benefits are found for product innovations.

Parrotta et al. (2014a) find that ethnic diversity facilitates patenting activity at firm-level. The authors use data from the European Patent Office (EPO) and from a matching employer and employee database in the Integrated Database for Labour Market Research (IDA) created by Statistics Denmark, for the period 1980-2006. They measure diversity through a fractionalisation index separately in terms of education, demographics and ethnicity. Their results show that, in general, education diversity has no significant impact on the probability of applying for patents, while ethnic diversity significantly increases it. In particular, ethnic diversity positively affects patent applications in three ways; it increases the probability of patenting and the number of patent applications and it broadens the technological fields in which firms applied for patents (Parrotta et al. 2014a). On the other hand, demographic diversity does not appear to affect innovation significantly.

In line with Parrotta et al. (2014a), the work of Ozgen et al. (2014) found a small positive impact of cultural diversity on innovation. The authors synthesized the empirical evidence from Europe, North America and New Zealand and analysed the determinants of innovation success for firms in Germany and the Netherlands comparatively over the period 1999-2006. Their main findings are that the size and industry of firms are the dominant factors for innovation. Furthermore, organizational changes and adverse factors also affect innovation. As for the composition of the workforce, high-skilled workers are fundamental for innovation, while cultural diversity positively affects product innovation. However, the magnitude and significance of the latter depends on the country being analysed and the methodology employed. Overall, putting together

the results of the paper and the previous literature, cultural diversity results in a positive, but modest and country-specific, effect on firm-level innovation.

Positive effects from diversity on firm-level innovation are also found by Brunow and Stockinger (2013). They construct a Herfindahl type fractionalization and ethnic diversity index, distinguishing between low and high-skilled foreigners and they use annual survey data for German establishments in 2001, 2004, 2007 and 2009. Their findings show that the diversity of high-skilled foreigners has a positive and highly significant impact on all types of innovation, while the same effect is not significant for low skilled foreigners. The authors discover similar results also in the analyses carried out on the samples of West German establishments and of those that only employed foreigners. Diversity for high-skilled foreigners matters also for establishments in knowledge-intensive industries.

A recent paper by Ferrucci and Lissoni (2019) explores the effect of inventor diversity on US and European patent quality over the period 1990-2010. More specifically, they estimate the effect of the ethnic diversity of the inventor team, of the wider firm and of the local area, on forward patent citations (the number of citations received from subsequent patents). In each case diversity is measured via a fractionalisation index and, for robustness, inventor team diversity is additionally measured by a fractionalisation index weighted by cultural distance and adjusted to address the problem of the number of categories being higher than the number of group members which would mean the theoretical maximum value of the index could not be reached. Ferrucci and Lissoni find that team diversity is positively associated with patent quality, irrespective of whether it is measured using the raw fractionalisation index or the weighted or adjusted variants. For instance, they find that an increase in the latter of 0.1 is associated with a 2.0% increase in forward citations in the EU and a 1.4% increase in the US. These findings persist even when firm and local diversity are controlled for, both of which are themselves positively associated with forward citations. The positive relationship between forward citations and diversity also persists after controlling for the share of migrants in the team which the authors suggest is evidence of the effect of cultural, and not only functional, diversity. Finally, Ferrucci and Lissoni test the effect of several measures of a separation index, based on the distances between different nationalities' beliefs and norms, on forward citations. Separation indices are not significant for the EU but are positively associated with patent quality in the US which the authors explain in terms of the greater cultural heterogeneity that exists among US inventors compared to those in the EU.

In addition to ethnicity, Østergaard et al. (2011) exploit other dimensions of diversity, such as age, gender and education in their study of 1648 Danish firms. While education and gender diversity appear to boost innovation, age diversity is associated with a negative effect on innovation. They found an inconclusive impact of ethnic diversity on firms' innovative performance. Similarly, McGuirk and Jordan (2012) use survey data and Irish census data to explore the link between diversity of human capital at county level and business innovation. They apply an innovation production function to data taken from both the Irish Innovation Panel (IIP) and the Irish Central Statistics Office; the former covered the period from 1991 to 2005, while the latter referred to the time span 1996-2002. Their main findings are that both education and nationality diversity have positive impacts on the probability of innovating products. However, in relation to process innovation, nationality diversity is significant and negative. It is important to note that both Østergaard et al. (2011) and McGuirk and Jordan (2012) do not address endogeneity concerns associated with a diverse population being attracted to innovative firms

raising the question of how robust their findings are. Nevertheless, they conclude that greater external labour market diversity and greater levels of internal tertiary education could be substitutes, meaning that a business in a diverse location might not require higher levels of educational attainment among its workforce.¹³

3.1.3. Co-worker and Individual-Level Wage Effects of Diversity

Another stream of the diversity literature explores the impact of immigration and diversity on firm-level outcomes or team-level production and performance. A common finding is that diverse teams may provide some challenges, such as communication costs (e.g. Lyons 2017), yet team diversity may have significant advantages based on tasks performed if firms provide co-worker settings that are conducive to mitigate these costs. A handful of original papers within this group of studies provide evidence on how immigrant workers affect the productivity of *their co-workers within firms*.

This is a fairly new area of research fed by the availability of LEED data. Recently, the wider availability of such LEED data has allowed researchers to further explore whether there are worker-level benefits gained from immigration and/or diversity, in addition to aggregate labour supply effects at the firm level. A number of studies of this type do not directly take diversity externalities into account but provide useful information on the complementarity and substitution between skill groups, on occupational mobility with respect to inflow by skill types, and subsequently on the effects on worker productivity in terms of wages. Although beyond the primary focus of this review a few early examples of these studies are highlighted below to provide a benchmark of immigration effects when looking through the lens of firm level studies.

Malchow-Møller et al. (2012) provide one of the earliest findings to address whether immigrants can affect firm-specific wages. They argue that under both monopsony and rent-sharing explanations for firm-level wages, an increase in the number of immigrant workers may influence native wages through two channels; i) negative effects through substitution within skill groups (from low-skilled immigrants to low-skilled natives); and ii) positive effects through complementarity between skill-groups (from low-skilled immigrants to high-skilled natives). They examine LEED data from Denmark in 1993-2004. By including worker-workplace fixed effects and applying an IV strategy based on firm level shift-share instruments they confirm that the log hourly wages of native workers are reduced by 0.4 percent if the share of low-skilled immigrants increases by 10 percent.¹⁴ This finding is inconclusive for middle and high-skilled workers.

Another firm level Danish study by Foged and Peri (2016) explores a similar research question with a more innovative identification strategy that uses a dispersal policy for refugees. They do so using longitudinal register data for the period 1991-2008. Using the universe of workers, they

¹³ A number of other studies such as Nathan and Lee (2013) or Maré *et al.* (2014) also scrutinise the link between innovation and foreigners. They report positive externalities from increased ethnic ownership or share of foreigners in the firm composition respectively on innovations. Nevertheless, the diversity metrics utilised are not directly comparable to those utilised by the other studies in this section.

¹⁴ The magnitude of this estimate is based on the OLS result. The authors estimate a much larger coefficient in the IV estimation, with larger standard errors, though still statistically significant.

try to overcome the common critique of ‘area’ studies which is that such studies do not capture the true effect of immigrant supply on native outcomes as immigrants are mobile across the official demarcations. The authors try rigorously to overcome endogeneity issues: firstly they employ a standard two-stage panel data model; secondly they adopt a novel difference-in-differences approach where they use the dispersal policy for the surge in refugee-country immigration beginning in 1995, to identify the effect of the differential exposure (exposed vs non-exposed) of the less educated native workers¹⁵ to refugee-country immigrants based on their 1994 municipality of residence. Their findings suggest that the influx of refugees mobilised low-educated natives to more nonmanual occupations (thus mobility towards occupations that includes greater complexity of tasks) when they changed firms. At the same time, natives encountered positive or null (hourly) wage and (full-time) employment effects. For instance, wages for low-skilled native workers increased by 1 to 1.8 percent for 1 percentage point increase in the share of low-skilled immigrants from refugee-sending countries. These effects are comparable to those found in US studies.

Malchow-Møller et al. (2012), Foged and Peri (2016), Hummels et al. (2014), and a number of other studies open an important window to discuss the impact of immigrant workers on the firm-level outcomes of natives. They identify three theoretical channels of influence, namely productivity, ethnic segregation, and bargaining effects. Their findings are in line with meso level (area) studies. However, these studies do not explicitly scrutinise how firm-level *diversity* effects worker-level outcomes.

A micro-level analysis of the *diversity* impact on employees provided at the firm level is provided by Ozgen and van Ommeren (2020). Although the papers by Stuen et al. (2012) and Kerr (2008) study the contribution of foreign students and inventors, the outcome measures are aggregate level indicators and they do not consider how the students or inventors themselves gain from higher productivity. The employee level analysis by Ozgen and van Ommeren (2020) therefore addresses a novel research question. This study analyses workers' earnings growth with respect to their past employment experience in diverse workplaces. This study particularly stands out among the wage impact studies because it focuses on the effect of firm diversity (and firm size) in employees' previous workplaces on their future earnings growth. The identification strategy relies on comparing the wage growth of workers belonging to the same firm, yet with different past employment experiences. Using administrative data from the Netherlands, the wage growth of approximately 50,000 young employees with four years of work experience in the period 2004-2008 is analysed. The study demonstrates that past experience in diverse firms is rewarded only when an employee moves into a significantly large firm while for most specifications the diversity effect is inconclusive. This suggests that the externality of ethnic diversity only operates through the teams a person belongs to and not through the individuals. So, if one has a timely opportunity to belong to a diverse team, the employee and firm benefit from that increased productivity, but when the employee leaves the team, the benefit cannot be taken with them.

A similar worker-firm level analysis is presented by Grinza et al. (2018) for Belgium firms utilising firm register data. Instead of using the country of origin to construct the diversity index, they

¹⁵ The choice of low-educated workers is determined by the Peri (2012) study which premises that the wage and employment prospects of low-skilled natives worsen with respect to an increase in immigrant supply, as they compete for the similar types of jobs.

utilise the Human Development Index (HDI) values of the country of origin of each worker and they compute the absolute difference between the HDI values of each country pair. Then, they take the firm level average of this pair-wise distance values to calculate their diversity metric.¹⁶ They argue that once the productivity and segregation effects of a diverse workforce are controlled for, any remaining (negative) diversity effects can be interpreted as evidence of discrimination. They estimate the effect of HDI diversity on average hourly wages per firm and correct for endogeneity using GMM-IV specification in first differences with instrumental variables. They find diversity to have a small negative impact on wages although they also find that collective bargaining agreements can attenuate this link between diversity and wage discrimination.

Kahane et al. (2013) provide evidence from the unique setting of the US National Hockey League on the effects of co-worker diversity on firm (team) level output and the performance of individual workers (players). They use data from the NHL seasons 2000-2001 to 2007-2008 and jointly use a fractionalisation index and relative European share as measures of diversity. Their findings suggest an increase in firm productivity with respect to having more diverse teams by country of origin. Additionally, co-worker homogeneity within teams proves to be more beneficial for individual-level performance, proxied by 3 indicators, win percentage, percentage of total points earned and difference between number of goals scored and goals allowed. The authors point out the specialisation of different country players on different tasks in the game increases player-level productivity, while potential cultural integration and communication costs arise when team players are from a wide range of European countries.

The empirical evidence on the link between diversity and innovation generally confirms the theoretical expectations. An important distinction however to be made is the spatial context of the analysis. In other words, micro-level studies are not only strongly conclusive on the positive innovation effects of diversity, but they also report sizeable magnitudes. This suggests that the diversity of immigrants both facilitates the diffusion of tacit knowledge as well as complementing native workers in knowledge intensive technological output in receiving countries. For instance, a strongly positive impacts of diversity and immigration on patent applications, publications or citations are reported by Crown et al. (2020), Akcigit et al. (2017), Blit et al. (2020), Borjas et al. (2018), Nathan (2015), Moser et al. (2018), Chellaraj et al. (2008), Hunt and Gauthier-Loiselle (2010) and Kerr (2008).

A similar pattern is found for firm creativity and workforce composition. Using LEED data Ozgen et al. (2017; 2014; 2013), Parrotta et al. (2014a), and Brunow and Stockinger (2013) all show higher worker diversity to be associated with greater firm innovation. Though not accurately comparable, as indicated in Table 2, the magnitudes of the coefficients found in firm level analyses are rather small. Very roughly, most studies report for 0.1 increase in fractionalisation to lead about less than 1 percentage point increase in the innovation outcomes of firms.

¹⁶ Unfortunately, we do not know how this measure compares to the standard fractionalization index. Whether the HDI based diversity measure is more informative than the existing diversity measures is not known and their correlation is somehow difficult to interpret, as the underlying indicators used to compute the HDI through the Euclidian distance to Belgium may not be a good enough proxy for potential productivity of workers coming from different country of origins. In other words, this measure assigns different weights to each worker depending on the development level of her/his country of origin.

At the regional level, the findings are more nuanced and context-dependent such that the underlying conditions of receiving countries seem to matter as much as the underlying composition/quality of the migrants. Therefore, at a more aggregate levels it seems that the complementarities between immigrants and receiving countries are somehow more difficult to be identified. One reason for this may be the greater variation in human capital accumulation and skills of migrants at region level compared to the more homogenous samples used in firm or individual level analyses. At the European or country level a positive association between diversity and innovation is reported by Ozgen et al. (2012), Nathan (2015), Lee (2015), Dohse and Gold (2014). On the contrary, Bratti and Conti (2014) find a negative effect of diversity on innovation in Italian regions; while Østergaard et al. (2011), and Maré et al. (2014) find no significant impact of diversity on innovation. Again, for a 0.1 increase in fractionalisation regional innovation outcomes increase between around 1-18 percent, depending on country.

Finally, at the micro level, the within firm effects of diversity on *co-worker productivity* signal a positive spillovers conditional on task division among the foreign vs immigrant workers and on the level of exposure of team members to each other (in particular to foreign members of the teams). Nevertheless, this is a newly growing literature which requires a larger body of empirical evidence to draw firm conclusions.

Overall, the empirical findings concerning the innovation effects of workforce composition seem to indicate the *mobility of foreign inventors/students/scientists* as a clear mechanism that advances high-skilled sectors and productive firms. Another mechanism –*co-ethnicity*– commonly observed both in business networks and in firms seems to lead to substantial benefits to individual and firm outcomes. However, these benefits can be reduced by greater linguistic diversity and ethnic segregation.

The innovation and diversity research show a significant variation in terms of research approach and measures of diversity. This introduces a large degree of heterogeneity when documenting how diversity impacts economic outputs, yet when a more focused and concise approach is adopted through comparing studies with similar research frameworks and measures of diversity, the findings appear to align well with theoretical underpinnings.

As explained in the theoretical background section, empirical findings show that the externalities reaped from the presence of diverse populations do vary at the group-regional-country level. This review suggests that it is important to isolate the mechanisms behind the economic impacts of immigration that are distinct from those behind the impacts of immigration-induced diversity. While focusing solely on immigrant supply indicates how the supply of labour changes by skill groups, studying immigration-induced diversity informs us how these skills are turned into idea creation and patenting and hence how positive externalities are generated as a result of complementarity effects.

3.2. Productivity and labour markets

This section presents a detailed discussion of the effects of diversity on productivity and wages. Earlier studies in this area had a strong focus on the impacts of immigrants on native wages. Recently, Edo (2019a) and Dustmann et al. (2016) summarise the methods used and compare the

empirical evidence provided by these studies that examined the labour supply effect of immigration on native wages. The studies discussed in this section therefore focus solely on the effects of the diverse composition of the population on wages as well as productivity. Early studies in this stream of research mainly analysed the diversity effects of birthplace, while more recent work takes into account other dimensions of diversity such as occupation, age and demographic characteristics.

A seminal study in this literature by Ottaviano and Peri (2006) explores the link between diversity at city-level in the U.S. and wage and rent distributions. They employ data from the Census Public Use Microdata Sample (PUMS) for the years 1970 to 1990 and examine 160 metropolitan areas. The authors measure diversity through a fractionalization index inspired by Mauro *et al.* (1995). Their main findings show that an increase in the diversity index by 0.1 caused a rise in natives' average wages by 13 percent and in rents by 9.5 percent. These findings are robust to a number of sensitivity tests. In another study of the US, comprising the period of 1980-2000, Sparber (2009) examines the industry level effects of racial diversity on wages through panel data models which includes state-industry fixed effects. His results suggest a sizeable positive correlation of diversity on wages. His instrumental variables estimation using the shift-share methodology indicates that a standard deviation increase in the diversity index increases wages by 42% in legal services, 16% in computer manufacturing, 13% in computer software, and 11% in advertising. He also detects a sizeable negative effect of diversity in seven industries known as traditional sectors such as mining, raw durables, fabricated metals, and transportation. These results therefore suggest that when a high level of group effort and communication is required diversity may decrease productivity, while when creativity and problem-solving tasks are required diversity seems to be beneficial.

Niebuhr and Peters (2020) analyse the impact of workforce composition in terms of age, gender and nationality, on entry wages in German firms between 2000-2009. Examining the impact of firms' diversity on entry wages is a new approach. To account for unobserved heterogeneity and the self-selection of workers to the most productive firms they include worker and firm fixed effects, while they also take into account each employee's relative position within the new firm (e.g. belonging to minority-majority, male-female, old-young age) through creating measures of 'self-isolation' for the 3 dimensions of diversity that they analyse. However, they do not explicitly control for endogeneity. Their findings suggest that firm level diversity measured by the fractionalisation index of immigrants, based on (GLOBE) clusters as defined in Gupta *et al.* (2002), do not exert a detrimental effect on entry wages. When diversity is measured by the share of foreign workers in a firm, the authors detect a negative effect on the entry wages of the *high-skilled workers*. Their interpretation is that high-skilled workers may treat the diversity of firms as an amenity and accept lower wages. Similarly, a one standard deviation increase in age and gender diversity reduce entry wages by 1.25 percent and 1 percent, respectively.

A recent study of Brazil by Ehrl and Monasterio (2017) adds an additional dimension to analyse the link between diversity and wages by considering ancestry diversity using machine learning algorithms. The study uses historical data that comprises the local and national government subsidised non-Iberian European immigration into Rio Grande do Sul in the period 1824-1918. Historical data allows the authors to construct long-lagged instruments based on the location of the immigrant settlers (colonies) to account for the potential endogeneity of the regional diversity variables. To isolate the productivity effect of the diversity the identification benefits from the

random allocation of immigrants into these colonies whose locations were chosen for strategic and military reasons rather than economic reasons. To do so, they decompose the fractionalisation index into the share of natives and the diversity of immigrants to take into account the dominant group influence on the index values. They use 3 instruments; i) cultural diversity in 1920 and the share of Brazilian citizens in 1920; ii) the diversity of street names in each municipality; iii) and the mean distance to historic official colony settlements. Across a number of specifications, their analyses test the spatial self-selection of workers, different agglomeration economies, first-nature advantages and issues relating to how the diversity index measures influence the outcomes. They indicate that “an increase in the share of workers with a non-Iberian cultural background by 10 percentage points is associated with a 9.7% wage increase in the local labor market” (p.3), suggesting a persistent positive diversity effect over generations.

Longhi (2013) utilises the British Household Panel Surveys to explore the link between regional diversity, using the fractionalisation index, and hourly wages in the UK. She shows that a statistically positive effect of diversity is found in a cross-section estimate, yet in a panel setting the diversity index does not have a conclusive effect on wages, and this result is robust to accounting for endogeneity. She stresses that the strong self-selection of immigrants to high wage areas should be a concern in estimating the diversity-wages link.

Cooke and Kemeny (2017) also find that wages are affected positively when employees are from a diverse array of countries of origin in urban areas. This finding is especially true for workers involved in complex problem-solving activities that require high levels of knowledge and engagement in creativity, innovation and within STEM fields. For an average worker in an industry featuring higher levels of problem-solving activities, they estimate a 7 percent increase in wages in response to one standard deviation increase in urban diversity. The same differential value at the firm level is 2 percent. However, the evidence is quite mixed when it comes to workers who engage in problem solving tasks that also require high levels of personal interactions, as the statistical significance disappears. For this analysis, the authors use LEED data for 29 states (restricted by the data availability) and 163 US metropolitan core-based areas over the period 1991-2008. They construct a fractionalization index similar to the one employed by Ottaviano and Peri (2006). For the lowest quantile of the wage distribution, city-level diversity generally does not appear to be significant in increasing wages; in some cases, it is even partially significant and negatively associated with lower earnings. Instead, workplace diversity has a small, but significant positive effect on annual earnings of workers under different categories of knowledge-intensive activities (e.g. creativity, innovation, problem solving, science, etc.). On the other hand, for the highest quantile, both city and workforce diversity indexes have a positive and highly significant impact on earnings. Moreover, the coefficient on city-level diversity is found to be much higher than that for workforce diversity. When examining the effect of diversity on earnings for activities with high complexity and low interaction, the authors find that both workplace and city-level diversity seems to be generally not significant in explaining variations in wages, except for Science, Engineering and Technology. On the other hand, for high complexity and high interaction tasks, both the diversity indices have a positive, significant and substantial impact on earnings.

In another study, Kemeny and Cooke (2017) exploit a longitudinal linked employer-employee database to understand whether the positive effects from diversity are more likely to take place in metropolitan areas with high levels of inclusion in terms of economic and social institutions.

Using quarterly data from 1991 to 2008, they construct a diversity index similar to the one in their previous study (Cooke and Kemeny, 2017). They measure social capital as a variable for social inclusiveness in the analysed areas, with the presence of associations and third sector institutions. Moreover, they also classify metropolitan areas based on their orientation towards immigrant laws and policies, referred to as ordinances by Kemeny and Cooke (2017); thus, they create two groups of metropolitan areas, one for pro-immigrant ordinances and one for anti-immigrant ordinances. Their main findings show that workers in the social capital institutions in the lowest tercile of the social capital distribution enjoy a wage increase of 2.4 percent following a 1 percent increase in city-level diversity. For the highest tercile of social capital, a 1 percent increase in the diversity index increased wages of the average worker by 21 percent. As for the immigrant ordinances, the authors show that diversity was not significant in explaining variations in earnings in areas that implemented anti-immigrant ordinances. In contrast, in areas with pro-immigrant sentiments, a 1 percent increase in diversity resulted in a 36 percent wage increase. However, due to the lack of availability of exogenous instruments mainly at the workplace level they only apply GMM FE to try to correct for endogeneity. Their results may therefore require a degree of caution but they suggest a positive link between diversity and wages in areas with high social capital and inclusive views towards newcomers.

More recent contributions on the impacts of diversity using the fractionalization index include Delgado Gómez-Flors and Alguacil (2018) focusing on wages in Spain; Elias and Paradies (2016) who examine Australian gross weekly wages; and Roupakias and Dimou's (2020) study of Greece which focuses on the employment of natives and log output per worker and finds an inverse-U shaped relationship between diversity and employment. These studies offer evidence from a number of countries that have not been studied before, yet the contribution of them, though important, is incremental. Elias and Paradies' (2016) findings on the link between wages and diversity is consistent with Longhi's (2013) such that the positive correlations found in the OLS (and IV) estimates do not persist when using panel data fixed effects models.

The literature on the productivity and labour market effects of immigrants provides a large body of evidence on how uneven these effects are across space and on other groups of workers. However, this stream of work predominantly concentrates on labour supply effects and scrutinises how the variation in the *qualities* of immigrant workers influence labour market outcomes. These studies typically examine the effect of human capital diffusion by foreigners on firm or sector level productivity and the subsequent impacts on the type and quantity of native jobs (e.g. Foged and Peri 2016; D'Amuri and Peri 2014; Peri 2012). This approach is a step forward from the line of research on the wage effects of immigration by showing how heterogeneity among immigrants may also lead to a change in the occupational complexity of labour markets although they have not placed any emphasis on diversity. However, a handful of recent studies do examine the productivity impacts of workforce or sector level diversity, which are now discussed.

Fassio et al. (2019b), in their sector level panel-data analyses of France, Germany and the United Kingdom examine the link between diversity and total factor productivity over the period 1994–2007. They use the EU KLEMS Growth and Productivity Accounts database for TFP measures and aggregate individual level micro-data from Labour Force Surveys for France and the UK; and from the Micro-Census for Germany to sector level. The authors disentangle the confounding effect of diversity of a region, proxied by the diversity of the regional economy, on productivity. Their

measure of diversity excludes natives and reflects only the diversity of immigrants. To correct for unobserved shocks that can influence both diversity and TFP in sectors they adapt Card's geographical shift-share instrument to sector level, arguing that the sectors immigrants are most employed in is remarkably stable over time, hence imitating the geographical patterns. Their results suggest a positive and statistically significant effect of sector diversity on TFP but only for the services sector.

At the more micro-level an earlier study by Parrotta et al. (2014b) presents the diversity and TFP link in the case of Danish firms. They use longitudinal linked employer-employee data for 1980-2005 from the Integrated Database for Labor Market Research in combination with firms' business records. In their work, 3 dimensions of diversity are considered by calculating the fractionalisation indices for demographic, cultural and skills diversity. The idea behind skills and demographic diversity is that when workers are fairly similar (different) to each other, there are fewer (more) communication barriers and more (less) complementarity. A particular contribution of this research is the explicit consideration of worker type and quality in the production function.¹⁷ In order to do so, they use 2 main methodological routes: First, through a 2-stage reduced form approach, in a Cobb-Douglas framework, implied TFP is estimated and included in the 2nd stage estimation of the effect of the diversity indices. They estimate the production function for 5 sectors -manufacturing, construction, wholesale and retail trade, transport, and financial business services using 3 different measures of TFP. Second, the authors use a structural estimation approach which takes different types of labour as production inputs and hence allows a more flexible substitution pattern. The reduced-form approach that also accounts for endogeneity suggests a positive association between diversity of education and firm productivity, and a negative association for the diversity of workers' ethnicity. In the structural approach the findings suggest that an increase in ethnic diversity decreases firm output, particularly for firms with a large overall dispersion of labour types (by education), implying labour skills (low vs high) are imperfect substitutes. Based on further sensitivity checks, the authors conclude that only in certain sectors does firm productivity increase with the diversity of highly educated workers. They report a 2.9 percent increase in TFP (based on the calculation by Akerberg et al. 2006) associated with a one standard deviation increase in educational diversity in the manufacturing sector.¹⁸

Trax et al. (2015) provide a similar analysis for Germany using LEED data between 1999-2008 to explore the link between cultural diversity of the workforce and TFP at the establishment level. The measure of diversity includes both the share of foreign workers and a fractionalisation index of foreign workers by nationality in each establishment. To take into account the fact that the diversity measure treats all nationalities as equivalent by construction, they create an extended measure of diversity which weights the impact of each foreign nationality by the physical distance of the respective country to Germany. To address the obvious causality concerns the authors

¹⁷ Diverse problem-solving abilities and creativity is mostly expected to increase the productivity of workers in distinct occupations, particularly white-collar occupations rather than those in blue-collar occupations.

¹⁸ Although not directly focusing on birthplace diversity, Garnerio et al. (2014) presents estimates of how workforce diversity, in terms of education, age and gender, impacts firms' productivity, employee wages, and productivity-wage gaps for Belgian firms. Their results report findings in line with Parrotta et al.'s (2014b). The authors report that a one standard deviation increase in educational diversity (by 1.15 years) raises productivity by 2.7 percent.

include industry, region, and time-specific dummy variables in their estimations so that their coefficients are identified only by within industry and within region variation in a specific year. This reduces concerns of reverse causality by filtering out common business cycle shocks and time-invariant industry or region-specific characteristics that may lead to systematic sorting. They report that the average change in diversity within a plant (0.001) results in an increase of manufacturing plant output by 0.03 percent. However, there is a sizeable variation in this productivity effect. For the minimum (-0.831) and maximum (0.743) values of annual change in plant diversity, the authors estimate productivity effects ranging between -22.7 percent to 25.9 percent. Similar results with a wider range of effects are obtained for the regional level diversity of nationalities and productivity. The study further distinguishes the effect of diversity by type of industry (high-tech and knowledge intensive) and type of goods (differentiated vs homogenous) produced. The positive diversity spillovers remain statistically significant only for firms in knowledge and technology intensive industries and for firms producing differentiated goods. Brunow and Nijkamp (2018) support these findings with another establishment level study from Germany. Their findings show that when the establishments are more culturally diverse in terms of high-skilled employment, they achieve positive gains for productivity and revenues. In other words, the diversity of high-skilled workers leads to productivity advantages and higher revenues for German establishments. Finally, the authors suggest that when formulating a migration policy, one should take into account the level of diversity among foreigners rather than merely the number of foreigners.

An innovative recent study by Dale-Olsen and Finseraas (2020) using manufacturing LEED data from Norway for the period 2003-2013 provides an opportunity to compare the effect of linguistic diversity as opposed to cultural diversity on firm productivity. To account for linguistic diversity, they first construct a linguistic distance measure which measures the rate of common words among the languages spoken in Norwegian firms. They then calculate the linguistic diversity index that corresponds to the average linguistic distance between two randomly chosen employees at the workplace. The authors argue that this metric improves upon the measurement of diversity index by overcoming the need to group countries by language groups as is commonly done when calculating a fractionalisation index based on country of origin. As is common in this stream of the literature, they utilise a flexible production function as this permits the authors to allow heterogeneous production technology and different types of labour (skill groups by natives and immigrants). Their findings are interesting. In all models they find that increased linguistic diversity leads to reduced TFP and value added (a 1.0 to 1.6 percent reduction results from a 10 percent increase in language diversity). This is mainly driven by the linguistic proximity of languages since, when this index is replaced by the fractionalisation index, the negative correlation disappears. The detrimental productivity effect is more pronounced for high-skilled (1.5-2.0 percent) than low-skilled (0.6-0.8 percent) diverse firms. Controlling genetic, cultural and religious diversity simultaneously in these specifications does not overturn their findings.¹⁹

¹⁹ Other recent studies of the economic impacts of immigration and diversity, focus on macro indicators such as FDI, savings, GDP per capita (Docquier et al. 2020), the growth rate of GDP (Bove and Elia, 2017) or firm-level indicators such as firm survival (e.g. Backman and Kohlhase 2020) and firm export behaviour (Parrotta et al. 2016). Many of these studies are not directly comparable to those covered in this review, but provide some intuition on the direction of the relationship between diversity of the populations or employees of firms and outcomes. These studies however are beyond the scope of this survey.

The wage and productivity studies of diversity broadly support the notion of there being positive gains from having a diverse composition of populations and workers. However, one recurring finding particularly when analysing firm productivity is that diversity effects are neither evenly distributed across types of firms nor do they lead to higher gains for every sector. There is a clear trend such that for firms, sectors or urban areas which are characterised by requiring complex problem-solving activities, communication intensive tasks or have STEM field intensive employment, the beneficial impacts of diversity are more pronounced. The magnitudes of the coefficients predicted for firms' TFP within and across sectors and countries are higher depending on whether or not firms fall into the aforementioned categories. Another important finding is that once a diversity index is measured by languages rather than country of birth or nationality, the empirical evidence seems to suggest a negative association with the diversity of the workforce and productivity again depending on the type of the firms, sectors or urban areas.

Concerning the wage effects of diversity, the literature provides more mixed evidence. The relationship is reinforced positively in urban areas. It is shown that especially when the local setting is more inclusive, and studies are conducted at city/regional level the hosting populations reap higher benefits from having diverse populations. Nevertheless, a number of studies also report no conclusive, or a slight negative, effect on the average wages of basic sector workers especially when panel data models are utilised. This suggests that strong unobserved factors correlate with wages. These findings are more in line with the earlier literature examining the supply-shift effect of immigration on wages.

4. Summary of the Findings

For comparability, this review has examined the empirical evidence relating to the main economic impacts of migration, specifically on innovation, productivity, and labour markets. The appendix tables provide an overview of the empirical studies discussed in this paper. One rather striking observation is that the economic impact of diversity has been studied in only a handful of OECD countries, mainly in high-income countries of Europe and Northern America and several examples from Australia/New Zealand. Another important observation is that the economic literature on diversity is mainly concentrated on immigration-induced diversity, and only a few studies look at other forms of diversity induced by gender, skills, occupations, age etc.

The diversity scholarship significantly benefitted from the use of improved methodologies and the extensive microdata which led to deeper scrutiny of the diversity outcomes and measures. The economics literature has provided a number of explanations to describe the varying impacts of diversity. Firstly, sorting and displaying the empirical evidence by the spatial level of analysis offers some thorough insights into the channels through which newcomers can potentially help or hinder the economies of destination countries. The literature documents that in receiving countries the aggregate impacts of diversity can be different from the impact on, for instance, firms. For example, an increase in ethnic fragmentation is associated with poor public policies in a country as a whole (although the productive, beneficial effects of diversity are likely to overcome the costs of such poor policies), while an increase in the ethnic diversity of the regional population or employees is found to boost regional level creativity and firm innovation. Furthermore, at a more refined level of analysis, the foreign graduate students and inventors are

shown to have two-fold benefits both for the receiving country and for the sending country in the long term. They not only increase the patent applications, patent grants and citations in the host countries such as the US and the UK, but they also significantly facilitate knowledge diffusion and international technology transfer from the countries at the frontier of technological advances back to their home countries. This leads to higher output in the manufacturing sector and, in particular, East Asian economies and China are the beneficiaries of these links, one study from the US shows (Kerr, 2010).

However, the magnitude of the estimated effects are generally small. One of the reasons seems to be that the knowledge production function used in the estimations so far measures an aggregate effect of diversity within firms and it remains a challenging task to measure the exact mechanisms of influence. Increasingly studies from post-2015 point to that fact that positive spill-overs which a firm may get from the diverse composition of its workforce are confined to capital-intensive sectors (for which the coefficients are predicted to be higher) because the value of employing workers from diverse backgrounds rests on the potential complexity of solutions required for firms' production. Indeed, team level studies infer that the sort of tasks to which foreign workers are assigned and the team's diversity composition – *co-ethnicity vs heterogeneity* – when executing these tasks seem to matter for enhanced outcomes. Several new research, e.g. Dale-Olsen and Finseraas (2020), Ferrucci and Lissoni (2019) and Grinza et al. (2018), Kahane et al. (2013) take into account, in their measurement of the diversity index, the potential importance of the linguistic, cultural and developmental proximity between the incomers and the receiving country in order to examine the level of complementarity among the workers from different countries of origin. Not surprisingly, the impact also differs with company characteristics. In particular, studies from the United Kingdom (Nathan and Lee, 2013) and the Netherlands (Ozgen et al., 2013) suggest that firms which sell in international markets as opposed to domestically oriented ones benefit from the heterogeneity of the foreign-born workers.

An important gap in the literature is studies that look jointly at different types of diversity (e.g. Niebuhr and Peters 2020). One study from Denmark finds a positive association of diversity of education and gender diversity on firm innovations; while age diversity was found to have a negative effect on innovations (Østergaard et al. 2011), a finding echoed by Niebuhr and Peters (2020). Similarly, Garnero et al. (2014) confirms positive (negative) gains from educational (age) diversity for firm productivity and wages. This negative association is in line with the literature which has pointed out that disagreements can emerge between different generations, therefore introducing inefficiency into the innovation process. For the United States, Herring (2009) finds that state racial and gender diversity is associated with higher sales revenue, with both more customers and greater market share.

Finally, there is some evidence of an “optimal” level of diversity. For example, studies focusing on innovation suggest that diversity, typically measured by the fractionalization index based on the country-of-origin composition of the foreign-born, has a curvilinear relationship with regional patent applications (Ozgen et al. 2012; Dohse and Gold 2014). This finding suggests that as levels of diversity increase in European regions, the economic benefits increase until an optimal point is reached (that is around the mean level of diversity across NUTS 2 regions), beyond which additional diversity is associated with economic costs. This result is consistent with the theoretical suggestion that too much diversity may give rise to higher transaction costs, create social tensions both regionally and within workplaces (e.g. neighbourhood segregation or excess

co-location of country fellows in low-skilled services sectors), and reduce social capital. A comparison of recent studies however reveals an important point about the diversity-economic performance link. That is when polarisation and linguistic barriers are also taken into account the fractionalisation index in fact indicates positive impacts. This result suggests a consideration of several measures of diversity jointly in a specification to account for its different dimensions as explained in Section 2.2 (e.g. polarisation, communication barriers). This approach could help to single out the true effect of worker composition on economic outcomes.

With the help of matched employee-employer data, our knowledge of the dimensions of diversity and the motivations of immigrants is increased relative to what can be learned from area level studies. Accordingly, the economics literature shows that diversity advantages are not utilized symmetrically by all sectors due to the structural effects in different industries (e.g. the need or ability to benefit from diversity, patenting tendency of the sector, patentability of ideas, etc). Moreover, agglomeration benefits appearing in dense urban areas are also limited to certain types of firms, while the changing economic face of cities towards more high-tech, more diverse, richer in amenities and more capital-intensive, service sector-oriented firms also reinforces these asymmetries.²⁰

Another critical outcome based on the empirical findings is the importance of the enabling environment for the diversity of the workforce to contribute to economic outcomes. Individual level analyses demonstrate that workers cannot carry the productive externalities gained at diverse workplaces to their new jobs. However, the presence of an international workforce in a certain region or firm or team has been shown to produce positive innovative outputs. Furthermore, the effect of high-skill intensity of foreigners increases once they are employed in high-productivity diverse sectors, which is in line with the vast literature on the complementarity between skills and technology.

4.1. Policy Relevance and Future Research

Overall, the studies examined in this paper indicate that the economics of diversity literature places migration-induced diversity at the core of the analysis. Therefore, recognizing the heterogeneity of immigrants is an important first step towards understanding how to reap the benefits from worker diversity. The studies at the regional scale show that the compositional aspect of workers may lead to unprecedented outcomes in a positive sense and furthermore diversified groups of immigrants may contribute to regional innovation performance. Moreover, although assimilation of immigrants increases with the time they spend in the host country, they remain imperfect substitutes for natives. Therefore, to focus on the complementarity between foreigners and natives and to design policies that exploit that complementarity would benefit both populations and economies. Firm level studies demonstrate that diversity among foreign employees might increase firms' technological progress. However as reported in very few studies (hence this is a fruitful research area for the future) these productive externalities occur mostly in sectors where diverse skilled migrants cluster, such as R&D, manufacturing, and high-level

²⁰ An interesting research avenue to explore further is whether firms in different stages of their life cycle have varying preferences to employ a diverse workforce and different location choices with respect to density. Moreover, concerning the distance-decay and spatial network literatures, the role of a diverse foreign workforce as a source of knowledge spillovers would clarify the links between urban economics and immigration flows. However, these issues go beyond the scope of the discussion here.

services industries. Promoting recruitment of skilled talent from foreign countries would not only help to overcome the skill shortages in certain sectors, as well as in specialized types of employment through better matching possibilities, but also contribute to firms' innovation capacities when such talent is employed from a wide range of source countries.

The extent to which high skill-selective immigration policies benefit only more prosperous regions and hurt more lagging peripheral regions depends on various characteristics of regional economies as well as on policies. It is documented in the literature that high-skilled workers have stronger incentives to migrate when the skill premium is increasing with the average level of human capital of a destination (Giannetti, 2003). There are, however, local forces such as living cost differentials, trade costs, congestion and social costs that act as a counter-balance to this mobility. Policy makers, though, could benefit from adopting and promoting circular and temporary migration policies that are backed by the creation of necessary institutional and legal frameworks. The well-known brain-drain countries like China and India are today benefitting immensely from the knowledge spillovers from their out-migrating graduate students who left decades ago for education in the US. Therefore, it is vastly important for lagging-behind regions to create solid and attractive conditions for the high-skilled to invest back.

While the evidence suggests that the net effects of diversity on firms are positive, the studies measuring linguistic diversity have shown that communication barriers resultant from high linguistic diversity between workers can be detrimental for productivity (e.g. Dale-Olsen and Finseraas 2020, Lyons 2017). Policies aimed at reducing these barriers –through language training at the firm or region level or the requirement of greater language skills within firms' recruitment processes especially for communication-intensive tasks – could help to reduce these costs and further increase the net benefits of diversity.

The key message to take away from this review is that the heterogeneity of workers matters. Clearly, the migration process itself is a selective mechanism which stimulates people with certain characteristics to be more likely to move than others. Moreover, depending on the politico-economic circumstances of the countries of origin and destination, the cohort qualities and patterns may differ substantially. At the more refined spatial scales, the study shows that the diversity of foreign workers can be beneficial at both the firm and the regional levels to facilitate international, interregional and cross-firm knowledge spillovers and to increase productivity. In addition, with their talent and unique combination of diverse backgrounds foreign workers can increase firms' ability to innovate products and services. However, as presented in the summary of the findings section, the effect sizes at the firm level are significant, but small. Therefore, firms' main drivers of innovation remain firm scale, performance, external resources and institutions. However, we should not underestimate the importance of the diversity of people living and working in certain localities where they contribute to innovative outputs with their ideas and skills. From a methodological perspective, this review has shown the importance of moving beyond the notion of foreign workers as a homogenous group and has demonstrated the clear need to recognise their heterogenous characteristics. It has also shown that to analyse the complex and dynamic nature of migration and migration-induced diversity requires us to move beyond standard econometric techniques in order to convincingly address causality and measurement issues.

For future research, it is important to focus on the exact mechanisms through which diversity impacts upon productivity. This remains a challenge. The main restriction to explore such mechanisms further has been either absence of relevant *data*, which allows the researcher to observe managerial characteristics of the firms or *time* constraints for new research designs that combine qualitative and quantitative techniques, for example team-oriented firm-level studies. Distinguishing between the negative and positive impacts of diversity and exploring the conditions under which diversity appears to be beneficial should also be on the research agenda. Obviously, the improvement of the micro-level data resources and the availability of international comparisons of these data would clearly contribute to these efforts; therefore, this will also allow the investigation of the importance of cross-country institutional structures. Moreover, diversity research is predominantly concentrated in the developed countries. Since many developing countries have even higher levels of diversity a research priority should be to gain a greater understanding of the effects of diversity on economic outcomes in a variety of different geographical, economic and political settings. As our knowledge of the impacts of diversity improves, migration policies can be increasingly more influenced by scientific evidence rather than by common public perceptions.

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Appendix: Summary of the Findings (Categorised by spatial scale and sorted by diversity measure)

A1. Overview of Studies on The Impact of Cultural Diversity on Innovation

Author	Data	Year	Diversity measure	Outcome measure and effect
<i>Country, regional and inventor-level econometric studies</i>				
Chellaraj et al. (2008), U.S.	U.S. country, time series	1963-2001	Foreign graduate students as a percentage of total graduate students	Patent applications (+); Patent grant (+); Non-uni patent grants (+)
Hunt and Gauthier-Loiselle (2010)	49, U.S. States, panel data	1940-2000	Foreign graduate students as a percentage of population (in STEM ²¹ fields)	Patents per capita (+)
Stuen et al. (2012)	2,300 American science and engineering departments, panel data	1973-1998	Foreign graduate students as a percentage of total PhD enrolments	Publications (+) Citations ²² (+)
Crown et al. (2020)	Australian SA-3 regions, panel data	2007-2014	Foreign graduate students as a percentage of regional population	Patent applications per 10,000 (+) Citation-weighted patent applications per 10,000 (+)
Blit et al. (2020)	98 Canadian cities, panel data	1981-2006	Foreign graduates students as a percentage of regional population	Patents per capita (+)
Ozgen et al. (2012)	170 EU NUTS2 regions, panel data	1991-1995 & 2001-2005	Nationality fractionalisation	Patent applications per million inhabitants (+)
Bratti and Conti (2014)	103 Italian NUTS3 regions, panel data	2003-2008	Nationality fractionalisation	Patent applications (-)
Dohse and Gold (2014)	200 EU NUTS 0, 1 or 2 regions, panel data	2005-2010	Nationality Shannon index	Patent applications (+)

²¹ STEM is an abbreviation for science technology engineering and mathematics fields.

²² Both effects are fragile to instrumental variables estimation, yet the authors acknowledge that their instrument is statistically not strong enough to isolate the variation in the number of international students and the regional composition of those students.

Author	Data	Year	Diversity measure	Outcome measure and effect
Ferrucci and Lissoni (2019)	ICRIOS-PatStat and WIPO-PCT patent data at European level, repeated cross-section	1990-2010	Nationality fractionalisation	Citations received per patent (+)
Nathan (2015)	70,007 inventors in about 200 UK Travel to Work Areas, 3-waves panel data	1993-2004	Birthplace & ethnicity fractionalisation of inventors	Patents (+) Patent counts ²³ (+)
Akcigit et al. (2017)	State level analysis of US patenting	1880-2000	Foreign-born expertise index	Log of number of patents (+) Log of number of citations (log of 1+ citations) (+)
Moser et al. (2018)	USPTO patent data by inventors, repeated cross-section	1940-1960	Dummy variable which takes value 1 if there is at least one inventor who is a German Jewish émigré by tech class	Number of patent applications by class (+) (in chemistry field)
Borjas et al. (2018)	US data for mathematics departments at advisor level, panel data	1939-2010	Interaction term (two dummy variables; i) year 1989 & beyond; ii) Chinese-American advisors)	Number of papers published (+) (by pre-existing Chinese-American academics)
Kerr and Kerr (2018)	USPTO patent data by inventors, panel data	1975-2009	Foreign inventors by ethnicity as a percentage of total inventors residing in the US	Collaborative patents (+) (Dummy=1 if patent is collaborative: includes at least one foreign inventor)
<i>Firm-level econometric studies</i>				
Østergaard et al. (2011)	1,648 Danish firms with linked employee data, cross-section	2006	Nationality Theil index of ethnic diversity;	Any innovation (0)

²³ In this study the patent count is referred as: “count of the number of times an inventor engages in patenting during a given 4-year period”.

Author	Data	Year	Diversity measure	Outcome measure and effect
McGuirk and Jordan (2012)	Two pooled cross-sectional surveys of Irish businesses in 26 counties, total sample about 1000 observations	1996, 2002	Nationality fractionalisation	Product innovation (+), Process innovation (-)
Brunow and Stockinger (2013)	About 12,000 German establishments, 5-waves panel data	2000-2009	Nationality fractionalisation (of high-skilled foreigners)	Improvement (+), Adoption (+), Introduction (+), Process innovation (+)
Ozgen et al. (2013)	4582 Dutch firms, cross-section	2002	Birthplace fractionalisation; & Total number of countries present in a firm	Any innovation (+), Product innovation (+), Process innovation (0) (for both diversity measures)
Ozgen et al. (2014)	2,800 Dutch firms and 16,000 German, panel data	1999-2006	Birthplace fractionalisation	Product innovation (+), Process innovation (0)
Parrotta et al. (2014a)	About 12,000 Danish firms, pooled over 9 years	1995-2003	Birthplace fractionalisation (weighted)	Any innovation (+) Patent applications (+) (dummy variable taking value 1 if firm applied for patent)
Lee (2015)	2000 UK firms, cross-section	2004-2005	Birthplace fractionalisation; & Ethnic-ownership dummy	Innovation (0)

* The NUTS classification is a hierarchical system for geographically disaggregating the economic and administrative territory of the EU countries. *Note:* The symbols +, - and 0 indicate the conclusion drawn from the most representative regression of the study. + indicates a positive statistically significant effect; - a negative statistically significant effect and 0 indicates that the estimated effect is statistically insignificant.

A2: Overview of Studies on The Impact of Diversity on Wages and Labour Markets

Author	Data	Year	Diversity measure	Outcome measure and effect
<i>Country, regional and inventor-level econometric studies</i>				
Ottaviano and Peri (2006)	160 U.S Metropolitan Statistical Areas, 3-waves panel data	1970-1990	Birthplace fractionalisation	Native wage (+)
Longhi (2013)	UK Local Authority Districts, panel data	2002-2007	Birthplace fractionalisation	Wage (0)
Ehrl and Monasterio (2017)	Individuals and municipalities in the Brazilian State of Rio Grande do Sul, panel data	1920-2013	Birthplace fractionalisation; & Share of workers with non-Iberian background	Wages (+) (in the local labour market)
Sparber (2009)	U.S. Census at state-industry level, panel data	1980-2000	Racial fractionalisation	Wages ²⁴ (+) (weighted average)
<i>Firm-level/individual-level econometric studies</i>				
Niebuhr and Peters (2020)	Around 10,000 German establishments, panel data	2000-2008	Birthplace fractionalisation	Wages (0) (Entry wages)
Ozgen and van Ommeren (2020)	50,000 Dutch young employees, panel data	2004-2008	Birthplace fractionalisation	Wage growth (+)
Grinza et al. (2018)	555,963 workers and 9,430 firms in Belgium, panel data	1999-2010	Birthplace fractionalisation ²⁵	Wages (-) (Average log hourly wage of firms)

²⁴ Where numbers of workers per industry per state are the weights proxy for labour productivity.

²⁵ Their index is constructed as average Euclidean distance based on the difference between the Human Development Index in Belgium and other countries.

Author	Data	Year	Diversity measure	Outcome measure and effect
Cooke and Kemeny (2017)	Employee-employer U.S data, 28,950,000 individuals and 1,026,00 firms, panel	1991-2008	Birthplace fractionalisation	Wages (+) (for sub-group of workers who solve complex problems)
Kemeny and Cooke (2017)	Employee-employer U.S data, 33,550,000 individuals and 1,193,000 firms, panel data	1991-2008	Birthplace fractionalisation	Wage (+) (Stronger effect in cities with more inclusive social & education institutions ²⁶)
Malchow-Møller et al. (2012)	Employee-employer Danish data, 1,710,797 individuals and 66,178 firms, panel data	1993-2004	Share of foreign-born workers in firms	Wages (-) (the effect originates from low-skilled immigrants)
Foged and Peri (2016)	97 Danish municipalities, panel data	1988-2008	Share of employed immigrants from refugee-country	Wages (+) Employment (0) Occupational complexity (+) Task intensity (+) Occupational mobility (+)

²⁶ Institutions are the system of formal and informal rules and norms facilitating this coordination, strengthening trust, and reducing defection so as to enable interactions among a diverse and specialized population.

A3: Overview of Studies on The Impact of Diversity on Productivity²⁷

Author	Data	Year	Diversity measure	Outcome measure and effect
<i>Country and regional econometric studies</i>				
Fassio et al. (2019b)	16 industries in the manufacturing sector in France, Germany & the UK, panel data	1994-2007	Shannon index of linguistic diversity	TFP (+) (only for the services sector)
Kahane et al. (2013)	NHL data for Europe and North America, yearly season, panel data	2001-2008	Birthplace fractionalisation	Percentage of wins (+) Percentage of points (+) Goal difference (+)
Kerr (2008)	USPTO patent data at individual level, patent data	1985-1997	Effective quotas for immigrants by U.S. immigration quotas	Manufacturing output in millions of 1987 U.S. dollars (+)
<i>Firm-level and individual level econometric studies</i>				
Parrotta et al. (2014b)	Around 28,000 Danish firms, panel data	1995-2005	Birthplace fractionalisation	TFP (-)
Trax et al. (2015)	11,343 Germany establishments and regions, panel data	1999-2008	Nationality fractionalisation (in a plant or a region); & Share of foreigners in a plant	TFP (+) for nationality fractionalisation TFP (0) for share of foreigners
Dale-Olsen and Finseraas (2020)	Norwegian firms, panel data	2001-2012	Linguistic fractionalisation	TFP (-)

²⁷ TFP refers to Total Factor Productivity.