



# Estimating Future Migration Flows Under Social and Environmental Scenarios Taking Into Account Interactions: Insights From a Survey Among Migration Scholars

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Scenario planning has been gaining popularity during the last decade as a tool for exploring how international migration flows might be affected by changing future circumstances. Using this technique, scholars have developed narratives that describe how flows might change depending on different developments in two of their most impactful and uncertain drivers. Current applications of scenario planning to migration however suffer from limitations that reduce the insights that can be derived from them. In this article, we first highlight these limitations by reviewing existing applications of scenario planning to migration. Then, we propose a new approach that consists in specifying different pathways of change in a set of six predefined drivers, to then ask migration scholars how each of these pathways might impact both migration flows and the other five drivers. We apply our approach to the case of migration pressure and demand from less developed countries to Europe until the year 2050. Results from our survey underscore the importance of a wide array of drivers for the future of migration that have so far not been considered in previous applications of scenario planning. They further suggest that drivers do not change independently from each other, but that specific changes in some drivers are likely to go hand in hand with changes in other drivers. Lastly, we find that changes in similar drivers could have different effects in sending and receiving countries. We finish by discussing how enhanced, quantified scenarios of migration between less developed countries and Europe can be formulated based on our results.

**Keywords:** international migration, migration drivers, scenarios, scenario planning, expert survey, climate change, social change

## INTRODUCTION

Since the 1990s, migration has been Europe's main engine of demographic growth—and indeed its sole since 2010 (Eurostat, 2021). As international migration has major implications for societies and economies, forward-looking analyses of migration form valuable tools for many domains of policymaking. In the fields of demography and economy, such forward-looking analyses have

traditionally consisted of migration forecasts or projections. These approaches consist in estimating the number of people that are expected to migrate between two countries or groups of countries given a continuation of past trends or as a function of selected variables (Disney et al., 2015; Raymer and Wiśniowski, 2018; Bijak et al., 2019). However, increasingly, researchers are becoming aware that past trends are often a poor indicator of future ones when it comes to assessing the strength and direction of future migration flows, as both are amenable to unpredictable factors such as wars and economic downturns (Bijak and Czaika, 2020; Vezzoli et al., 2021). Furthermore, statistical modeling often struggles to incorporate the type of structural drivers that are challenging to measure such as climate change or global power balances, forcing the analyst to omit features of the real world that can have an important impact on migration flows (Willekens et al., 2016).

Given the limitations inherent to projections and forecasts, scenario planning has been proposed as an alternative method for exploring the future of migration (OECD, 2009). Scenario planning refers to the set of methods developed in the 1950s by military intelligence that now form an integrated part of the field of future studies (Bradfield et al., 2005). One dominant approach within scenario planning is the Intuitive Logics approach, which consists in first identifying for a given outcome of interest the most impactful yet uncertain drivers of change, to then develop narratives (i.e., scenarios) that describe how changes in these drivers might lead to changes in the outcome of interest (Derbyshire and Wright, 2017). The goal of these narratives is not to predict the future, but to offer alternate, internally consistent, and equally plausible visions of it (Spaniol and Rowland, 2019). As such, the value of scenario planning lies in its ability to stimulate forward-thinking and inform strategic decision-making under changing circumstances (Wright et al., 2013).

While in some fields such as marketing and business studies, numerous studies have been published that reported on the use of scenario planning (Wilkinson and Kupers, 2015), in migration studies, applications of scenario planning are less common. As a preliminary step to the present work, we reviewed studies that applied scenario planning to migration. We derived seven studies, all of which applied the Intuitive Logics approach. While these studies make an important contribution by exploring new ways to think about the future of migration, a critical reading of this emerging body of literature also illustrates how previous approaches have been characterized by some recurring limitations. First, previous studies typically defined migration scenarios based on a narrow set of drivers, primarily within the economic and political domains. This approach limits the scope of the discussion on what factors might drive migration in the future and may overlook other relevant factors. Second, previous work insufficiently acknowledged possible interactions between drivers. This seems at odds with the more complex reality, where developments in one domain often trigger developments in other domains. Third, by concentrating on either the sending or the receiving context, previous migration scenario studies typically failed to address the differential impact that changes in a set of drivers might have across different contexts. Finally, and while it has been said that migration projections may be most useful when

combined with a qualitative scenario exercise (Vezzoli et al., 2021), so far, the literature has offered limited leads to establish such a connection between the approaches.

Our goal with this study is to stimulate further the use of scenario approaches in the context of migration studies by proposing a series of methodological innovations that aim at overcoming the limitations found in current applications of scenario planning. These innovations are inspired in part by previous applications of scenario planning to migration, and in part by work done in ecology and environmental studies, which have a much longer tradition of using scenario approaches (Sala et al., 2000; Van Vuuren et al., 2011; Nicholson et al., 2019).

Specifically, we aim to improve on current methods of migration scenario planning using results from a survey we conducted among migration scholars. Our approach consists in first specifying two pathways of change in a set of six predefined drivers. These do not just include drivers within the economic and political domains—as was often the case in previous studies—but also drivers within four other domains that are commonly included in conceptual frameworks on migration: demography, society, technology, and climate (de Haas and Fransen, 2018; Czaika and Reinprecht, 2020). In the survey, migration scholars were asked to assess the impact of each pathway of change, first on migration, and then on the other five drivers. This allowed us to assess both the direct and indirect impact of each driver on migration, and to answer the question of whether the change in one driver is likely to operate independently from the change in the other drivers. Throughout the survey, migration scholars were systematically asked to evaluate the impact of change in each driver separately for sending and receiving countries, allowing us to effectively assess how similar drivers may operate differently in each context. The result of this endeavor is a set of systematically quantified direct and indirect impacts of different pathways of change in six drivers on migration pressure and demand. In this study, less developed countries are considered as sending countries and European countries as receiving countries and the time horizon corresponds to the years 2021 until 2050.

The remainder of this article is structured as follows. First, in the Background section, we provide a brief overview of how previous studies used scenario planning to study the future of migration. Second, in the Materials and methods section, we provide the details of how we constructed our survey, how we selected our sample, and how we performed the analyses. Third, in the Result section, we present results about the direct impact of each scenario of change on migration pressure and demand, the interactions between drivers, and the possible indirect impacts of each scenario of change on migration. We end by discussing the main implications of our findings for the literature on migration scenario building.

## BACKGROUND

This study's main aim is to improve on current applications of scenario planning to migration. This ambition stems from insights from a systematic literature search that we performed as

part of previous work, the details of which are provided elsewhere (Boissonneault et al., 2020). This search yielded seven studies that applied scenario planning to migration<sup>1</sup>. A close reading of the method of these seven studies pointed to four main areas for improvement, which we will discuss in further detail below, and which have guided the approach of the current study.

Of the seven studies we obtained through our search, only one was published in a scientific journal (De Haas, 2011). The other six were published by the Organization for Economic Co-operation and Development (OECD) (OECD, 2009, 2016), other governmental organizations (The Government Office for Science, 2011; Szczepanikova and Van Crieking, 2018), or by research groups as working papers (Friedrich Ebert Stiftung, 2017; Acostamadiedo et al., 2020). Three studies involved the participation of migration scholars to identify drivers and build narratives, either through means of workshops (Szczepanikova and Van Crieking, 2018) (The Government Office for Science, 2011), or a survey (Acostamadiedo et al., 2020).

**Table 1** shows for each document the drivers and the corresponding directions of change that were selected to distinguish between scenarios in each study. It also shows how directions of change were combined with each other to form scenarios, as well as the regions to which they applied. It should be noted that the drivers and their directions of change are not the only elements that may enter the scenarios, as each scenario is supported by a narrative that may contain more elements. However, the drivers listed here and their corresponding directions of change are the only elements that were used to distinguish between the different scenarios presented in each study.

When we compare the approaches of the seven studies, we observe that so far, a limited number of drivers have been guiding the formulation of migration scenarios in the different studies. As seen in **Table 1**, all studies except one considered a total of two drivers [(OECD, 2016) considered three], and all considered two directions of change in each driver. This observation is not specific to applications of scenario planning in the field of migration *per se*, as similar strategies have been used in other fields as well (Derbyshire and Wright, 2017). However, among the different studies that applied scenario planning to migration, the same drivers and directions of change frequently reoccur, while other drivers remain largely absent. All studies but one (Friedrich Ebert Stiftung, 2017) used economic growth in either the country of origin or destination or economic convergence between countries of origin and destination as a driver to distinguish between scenarios. The studies further often considered drivers that fell within the political domain, such as the level of cooperation between countries and the change in immigration policies. In a few cases, studies considered drivers that fell within the societal domain by considering attitudes toward immigrants or the level of social development. In other words, although scenario planning methods aim to demonstrate how a multitude of different futures is still plausible, by frequently

selecting the same dimensions, previous studies in the field of migration have often formulated rather similar scenarios.

A second limitation concerned the way that studies combined the different directions of change in the selected drivers. We see that in most cases, studies considered one scenario for each unique combination of the different directions of change in the different drivers. By placing the two key drivers identified in **Table 1** along two axes, most studies thus considered four scenarios<sup>2</sup>. The implicit assumption behind this approach is that a given direction of change in one driver is equally likely to combine with both directions of change in the other driver. For example, the United Kingdom's Government Office for Science considered a first scenario that combines more inclusive and connected governance with high global economic growth, and a second scenario that combines it with low global economic growth. However, there are reasons to believe that these two combinations are not equally likely to materialize. After all, it seems highly unlikely that optimal international cooperation can be achieved in a context of increased economic inequality, as economic hardship is typically associated with social and political unrest. Thus, while the literature has recognized that the key drivers within the scenario framework are not independent (De Haas, 2011; Friedrich Ebert Stiftung, 2017), this example illustrates how in practice the interconnectedness has been insufficiently acknowledged in constructing the scenarios.

As a third limitation, previous studies seldom explicitly addressed the possibility that changes in similar drivers may have different impacts in sending and receiving countries. Instead, studies typically either considered the impact of one specific change in one country group only (either sending or receiving), or they simply considered the impact of global changes on migration flows, without specifying how these changes could affect sending or receiving countries differently. For example, one study considered how migration flows would change between OECD and non-OECD countries by considering the change in economic growth in OECD countries and the level of social development in non-OECD countries, while neglecting change in economic growth in non-OECD countries and the level of social development in OECD countries (OECD, 2009). Other studies considered the same kinds of change in the same driver in sending and receiving countries, implicitly assuming that sending and receiving countries will follow similar pathways of change in the future. For example, global economic convergence could be the result of economic growth in less developed countries, yet it could also follow from stagnated growth in more developed countries. However, these two developments can have different effects on migration pressure and demand in sending and receiving countries. In other words, previous studies insufficiently acknowledged that the main factors driving changes in the migration pressure in sending countries may be different from those that drive changes in the demand for migrants in receiving countries.

<sup>1</sup>Another review, from Sohst et al. (2020), found 17 studies about scenario planning and migration. However, their review also included studies that focused on other topics that may be relevant for migration, for example the labor market.

<sup>2</sup>As exceptions to the four scenarios rule we note the study performed by OECD (2009), which considered five scenarios, and the one by De Haas (2011) which considered two (De Haas, 2011).

**TABLE 1** | Overview of studies that applied scenario planning to migration, the drivers and directions of change they considered, and the resulting scenarios.

Reference	Driver 1	Directions of change	Region	Driver 2	Direction of change	Region	Scenarios
OECD, 2009	Economic growth	High vs. low	OECD countries	Social development	Advanced vs. Poor	Non-OECD countries	<ol style="list-style-type: none"> <li>1. High economic growth &amp; Advanced social development</li> <li>2. High economic growth &amp; poor social development</li> <li>3. High economic growth &amp; poor social development<sup>a</sup></li> <li>4. Stagnation &amp; High social development.</li> <li>5. Stagnation &amp; Low social development</li> </ol>
De Haas, 2011	Political processes	Openness, regional integration and democracy vs. Nationalism, xenophobia and autocracy	Northern and Southern Mediterranean countries	Economic development	Growth vs. Decline	Southern Mediterranean countries	<ol style="list-style-type: none"> <li>1. Openness, regional integration &amp; democracy &amp; Economic growth</li> <li>2. Nationalism, xenophobia &amp; autocracy &amp; Economic decline</li> </ol>
The Government Office for Science (2011) <sup>b</sup>	Economic growth	High vs. low	World	Political, social and economic governance	Inclusive and connected vs. Exclusive and fragmented	World	<ol style="list-style-type: none"> <li>1. High growth &amp; Inclusive &amp; Connected governance</li> <li>2. Low growth &amp; Inclusive &amp; Connected governance</li> <li>3. Low growth &amp; Exclusive &amp; Fragmented governance</li> <li>4. High growth &amp; Exclusive &amp; Fragmented governance</li> </ol>
OECD, 2016 <sup>c</sup>	Economic convergence	Convergence vs. divergence	OECD and non-OECD countries	Global co-operation	Co-operation vs. fragmentation	World	<ol style="list-style-type: none"> <li>1. Global co-operation &amp; Economic convergence</li> <li>2. Global fragmentation &amp; Economic convergence</li> <li>3. Global fragmentation &amp; Economic divergence</li> <li>4. Global co-operation &amp; Economic divergence</li> </ol>
Friedrich Ebert Stiftung, 2017	National immigration policies	Nations states are in charge vs. Nations states are not in charge	World	Attitudes toward immigrants	Migrants are seen as assets vs. Migrants are not seen as assets in host countries	World	<ol style="list-style-type: none"> <li>1. Nations states are in charge of national immigration policies &amp; Migrants are not seen as assets in host countries</li> <li>2. Nations states are not in charge of national immigration policies &amp; Migrants are not seen as assets in host countries</li> <li>3. Nations states are not in charge of national immigration policies &amp; Migrants are seen as assets in host countries</li> <li>4. Nations states are in charge of national immigration policies &amp; Migrants are seen as assets in host countries</li> </ol>
Szczepanikova and Van Criekinge, 2018	Economic convergence	Convergence vs. Divergence	Europe and rest of the world	Governance	Multilateral and inclusive vs. Bilateral/unilateral and exclusive	Europe and rest of the world	<ol style="list-style-type: none"> <li>1. Economic divergence &amp; Multilateral and inclusive governance</li> <li>2. Economic convergence &amp; Multilateral and inclusive governance</li> <li>3. Economic convergence &amp; Bilateral/unilateral and exclusive governance</li> <li>4. Economic divergence &amp; Bilateral/unilateral and exclusive governance</li> </ol>
Acostamadiedo et al., 2020 <sup>d</sup>	Economic convergence	Convergence vs. Divergence	Europe and rest of the world	International cooperation	Multilateralism vs. Unilateralism	Europe and rest of the world	<ol style="list-style-type: none"> <li>1. Unilateralism &amp; Economic convergence</li> <li>2. Multilateralism &amp; Economic convergence</li> <li>3. Unilateralism &amp; Economic divergence</li> <li>4. Multilateralism &amp; Economic divergence</li> </ol>

<sup>a</sup>Scenarios 2 and 3 in OECD (2009) were built along the same directions of change in the drivers economic growth and social development but differed from each other concerning the level of economic growth in BRIC countries (Brazil, Russia, India, and China).

<sup>b</sup>Although in The Government Office for Science (2011), drivers refer to the situation in the whole world, different scenarios are specified with respect to drylands and low-elevation coastal zones.

<sup>c</sup>This study considers the degree of openness in migration policies as a third driver which takes the value "Open migration policies" in scenario 1 and "Restrictive migration policies" in scenario 3.

<sup>d</sup>This study uses specialist input to provides an assessment of the likelihood that each scenario becomes reality as well as a quantification of migration flows under each scenario.

**TABLE 2** | Overview of scenarios of change within each domain, less developed countries.

Driver (including domain between parenthesis)	Alternate future name	Alternate future description
Demographic transition (Demography)	Alternate future A: Progress	Fertility rates in Asian, Latin-American and North-African countries continue to decline and reach levels similar to what is currently observed in Europe. In Sub-Saharan Africa, fertility rates approach replacement levels by 2050. Life expectancy steadily increases in Asian, Latin-American and North-African countries and at an accelerated pace in Sub-Saharan Africa, causing a shift toward an older population structure.
	Alternate future B: Stall	Fertility rates in Asian, Latin-American and African countries remain above those observed in Europe. Increases in life expectancy are weak across less developed countries. In many countries the population continues to grow—especially in Sub-Saharan Africa—and the population structure remains young.
Secularization (Society)	Alternate future A: Secularization	Despite persistent variation between them, countries follow a general trend toward more secularism. Some countries that had a state religion become secular. Younger generations increasingly value self-realization and become less family-oriented over time.
	Alternate future B: Conservatism	Rates of religious affiliation continue at similar levels over time and affect the majority of the population in many countries. Countries that had a state religion in 2020 continue to do so in 2050. The family and community are highly valued and affect all spheres of life. A re-evaluation of the national and cultural heritage causes stronger opposition to American and European values.
Political stability (Governance)	Alternate future A: Increased Stability	The Syrian war has definitely come to an end, the political situation in Iraq, Mali and other African and Asian countries has stabilized. Terrorist organizations have become less influential and few new conflicts arise.
	Alternate future B: Decreased Stability	The apparent stabilization of the late 2010s does not last long as new uprisings start to take place in different parts of the world during the 2020s and 2030s. Some are caused by people wanting more democratic and transparent institutions, similar to the Arab Spring of 2011, while others are linked to jihadi ambitions to form proto-states.
Economy	Alternate future A: Growth	Less developed countries increasingly benefit from globalization. Their financial sector experiences strong growth, and large companies hire workers at increasingly higher wages. Meanwhile, new legislations help reducing the share of informal, insecure jobs.
	Alternate future B: Stagnation	Less developed countries increasingly become victims of globalization. Competition between countries to attract businesses contributes to keeping wages low. Governments fail to propose legislations that would provide workers with more security and the informal sector continues to be the main source of employment in many countries.
Technology	Alternate future A: Boom	In developing countries, investments from China and the more developed world lead to an increased use of information and communication technologies, as well as automation in industries and businesses. This increased use of technology is supported by strong increases in educational attainment to the 2050 horizon.
	Alternate future B: Slump	Although a few countries like China manage to catch up, the technological gap between less and more developed countries has widened since 2020. While some investments are made, levels of educational attainment do not increase in a sustained way and fail to support the adoption of more optimal technologies in industries and businesses.
Climate change	Alternate future A: Mitigation	Countries take immediate and effective actions toward reducing their CO <sub>2</sub> emissions, which start decreasing globally by the end of the 2020s. In 2050 the earth is warmer by one degree, and although extreme meteorological events continue to be more frequent, the negative impact of global warming on humans and livelihoods stays manageable.
	Alternate future B: Intensification	Current efforts toward using cleaner sources of energy come to a halt and countries continue to rely on fossil fuels. Global temperatures are two degrees higher in 2050 compared to pre-industrial levels. Grave consequences are already felt by humans due to the rise of sea levels, decrease in agricultural output, loss of ecological services, and the increased frequency of extreme meteorological events.

Finally, few studies attempted to provide a quantification of the amount of change in migration flows associated with different scenarios. We could identify one study that provided a quantification of future migration flows under different scenarios (Acostamadiedo et al., 2020). In this study, the authors asked migration scholars to estimate the change in the number of migrants from the whole world to Europe under different scenarios of change in economic growth and the level of cooperation between countries. For example, respondents estimated that international migration to Europe would be highest in a scenario of economic divergence and multilateralism. However, based on these results, it remains unclear which elements of each scenario might lead to higher migration

flows. While it is not the main aim of scenario studies to provide quantitative predictions on the future of migration, the current disconnect between the different approaches forms an important limitation for studies that wish to combine quantitative projections with insights from scenario studies.

In the next section, we propose a new approach to building migration scenarios that address these four limitations. This is done by moving away from the Intuitive Logics approach that has dominated so far in applications of scenario planning to migration and by integrating practices found in other disciplines such as environmental and biological studies (Sala et al., 2000; Van Vuuren et al., 2011; Nicholson et al., 2019). Similar to many scenarios published in those disciplines, we rely on the opinion



of migration scholars to unravel causal mechanisms between drivers and the outcome of interest (Pereira et al., 2010) and pay particular attention to the interactions that might exist between different drivers (Nilsson et al., 2016; Van Soest et al., 2019).

## MATERIALS AND METHODS

### The Survey

We probed the opinion of migration scholars using hypothetical situations that depicted changes in migration drivers within six domains. These are the domains that commonly enter conceptual models in migration studies (de Haas and Franssen, 2018; Czaika and Reinprecht, 2020) and include: (1) Demography, (2) Society, (3) Governance, (4) Economy, (5) Technology, and (6) Climate change. Migration drivers within each domain were based on a recent review of the determinants of migration (Czaika and Reinprecht, 2020). To accommodate the different realities of sending and receiving countries, drivers within domains (1), (2) and (3) differed between sending and receiving countries but were the same within domain (4), (5), and (6) (Tables 2, 3, column 1). For each driver, two short storylines (henceforth *alternate futures*) were elaborated that described plausible changes in each driver (Tables 2, 3, columns 2 and 3). Each alternate future described opposite directions of change to allow to assess the maximum plausible extent to which migration might change as a result of a change in the selected drivers. Different alternate futures were elaborated for each driver for both sending and receiving countries, except for the driver climate change, for which we used the same storyline for both sending and receiving countries.

Respondents were instructed to consider as receiving countries the member states of the European Union together with Iceland, Norway, Switzerland, and the United Kingdom. These are referred to as European countries. All other countries except Canada, the United States, Israel, Australia, New Zealand, Japan, and South Korea were defined as sending countries, which are referred to as less developed countries.

The survey contained three parts. In the first part, information on the participant's main area of expertise was collected. Possible answers included the six domains identified above. In the second part, respondents were asked how much change in migration pressure and demand each alternate future would cause if they became reality. Assessments were made on a Likert scale that varied from  $-2$  (strong decrease) to  $2$  (strong increase) to ensure standardized responses. Migration scholars were instructed to consider the impact of each future assuming no change in the other drivers, allowing us to estimate the direct effect of each. They were asked to estimate changes in migratory pressure and demand in 2050 in comparison to the period preceding the COVID-19 pandemic, i.e., the year 2019. Then, in the third part, respondents were presented with a matrix in which each row represented a different alternate future and each column a different driver. For each driver, respondents were asked whether a given alternate future would lead to future A or B in this driver, or whether it would lead to no significant change. For example, migration scholars were asked whether an acceleration of demographic aging would either increase or decrease tolerance

toward immigrants in receiving countries or would not have a significant effect. This exercise was repeated concerning the impact of each alternate future on each driver [thus allowing for asymmetrical impacts between change in pairs of drivers (Nilsson et al., 2016)], and for both less developed and European countries. The full questionnaire is provided as **Supplementary Material**.

Ethical approval was not needed for this study as participants were not asked to share any personal information. Responses were stored in a database with anonymized identifiers linking the answers to the individual surveys. In the invitation that we sent to participate in the survey, we explicitly informed potential participants that by participating, they permitted us to use their answers for the study only. We also informed them that they could ask to be withdrawn from the survey at any time, in which case we would destroy any data that they might have provided.

### Data Collection

Data was collected online between March and May of 2021. The target group consisted of research scientists working in demographic research centers and university departments and specializing in migration. An initial list of 30 migration scholars was drafted based on the authors' professional networks. Each scholar was contacted individually by email and asked about their willingness to fill in the survey. They were also invited to provide suggestions for additional migration scholars who the authors could contact, which allowed us to contact 25 additional people. Scholars who accepted to participate were sent the survey in PDF format and were asked to fill in their answers in the same document and send it back.

Nineteen of the 55 migration scholars we contacted (35%) accepted to fill in the survey. Of these, all filled in all questions on the impact of alternate futures on migratory pressure and demand. In contrast, questions on the impact of alternate futures on the other five drivers were filled in by twelve to sixteen participants, depending on the alternate future. Participants were either active in the Netherlands (six), Germany, Belgium, Spain, and Poland (two each), or France, Finland, Estonia, and Switzerland (one each).

### Analysis

Answers concerning the impact of each alternate future on the other five drivers were averaged among all respondents and are presented alongside their standard deviations, as shown in Tables 4, 5. Values between  $-0.5$  and  $0.5$  can be interpreted as a negligible impact, between  $0.5/-0.5$  and  $1.5/-1.5$  as a significant but mild impact, and beyond  $1.5/-1.5$  as a strong impact.

Answers about how each alternate future might impact the other five drivers were collated in a matrix with rows representing the alternate futures and columns the impacted drivers. For each combination, we identified the most common answer and calculated the proportion of migration scholars that selected this answer, as shown in Figures 1, 2.

For each alternate future, we then summed the average values found in Tables 4, 5 that corresponded to each driver that it significantly impacted. We interpret this sum as the indirect impact of a given alternate future. For example, the majority of migration scholars may agree that in the context of less developed

**TABLE 3 |** Overview of scenarios of change within each domain, Europe.

Driver (including domain between parenthesis)	Alternate future name	Alternate future description
Population aging (Demography)	Alternate future A: Acceleration	Total fertility rates slightly decrease in comparison to their 2020 levels. Meanwhile, life expectancy starts increasing again. The result of these two trends is a stronger than anticipated process of population aging.
	Alternate future B: Deceleration	Total fertility rates gradually increase in comparison to their 2020 levels, reaching two children per woman in many countries. Meanwhile, increases in life expectancy continue to slow down and stop completely by 2050. Population aging continues but dependency ratios become more stable during the second half of the century.
Tolerance toward immigrants (Society)	Alternate future A: Increase	Younger generations increasingly recognize the value of migrants and see migration as a form of cultural enrichment. Acts of xenophobia and discrimination become more isolated.
	Alternate future B: Decrease	There is an increasingly widespread sentiment in Europe that migration should be reduced to a minimum. Encouraged by nationalism, acts of xenophobia and discrimination become more common.
International cooperation (Governance)	Alternate future A: Increase	European countries eventually agree on a single European policy on migration. Cooperation with neighboring countries like Turkey improves, leading to a better management of migration in general and asylum demands in particular.
	Alternate future B: Decrease	Negotiations regarding a single European migration policy are stalled, and countries increasingly work independently to manage migration at their borders. Meanwhile tensions arise between European countries concerning free movement of persons inside the Schengen area. The European Union fails to rally all countries at one discussion table and bilateral agreements are reached instead.
Economy	Alternate future A: Growth	Despite labor shortages in specific sectors, economic growth continues in European countries thanks to increases in productivity. Wages are high and unemployment rates remain low. The demand for labor remains strong throughout Europe until 2050.
	Alternate future B: Stagnation	Labor shortages initially continue and, coupled with the closure of many businesses in the context of the Covid-19 pandemic, lead to an important economic slowdown in Europe. Large companies transfer their activities to less developed countries where labor is more abundant and increasingly qualified. Unemployment rates gradually start increasing again and labor shortages slowly resorb to the 2050 horizon.
Technology	Alternate future A: Boom	Digital technology becomes widespread in all sectors of activity by 2050 and artificial intelligence is routinely relied upon in many sectors such as healthcare, manufacturing and agriculture. The increased use of automation in the industry causes a shift in labor demand toward more qualified workers.
	Alternate future B: Slump	The use of digital technology has progressed compared to 2020 but is still not widespread. Most sectors of industry still rely on suboptimal technology to resolve many problems and investments in research and development have declined compared to 2020.
Climate change	Alternate future A: Mitigation	Same as in <b>Table 1</b> .
	Alternate future B: Intensification	Same as in <b>Table 1</b> .

**TABLE 4 |** Mean expected change in the pressure to migrate from less developed countries associated with each alternate future within each driver (with standard deviations between parentheses).

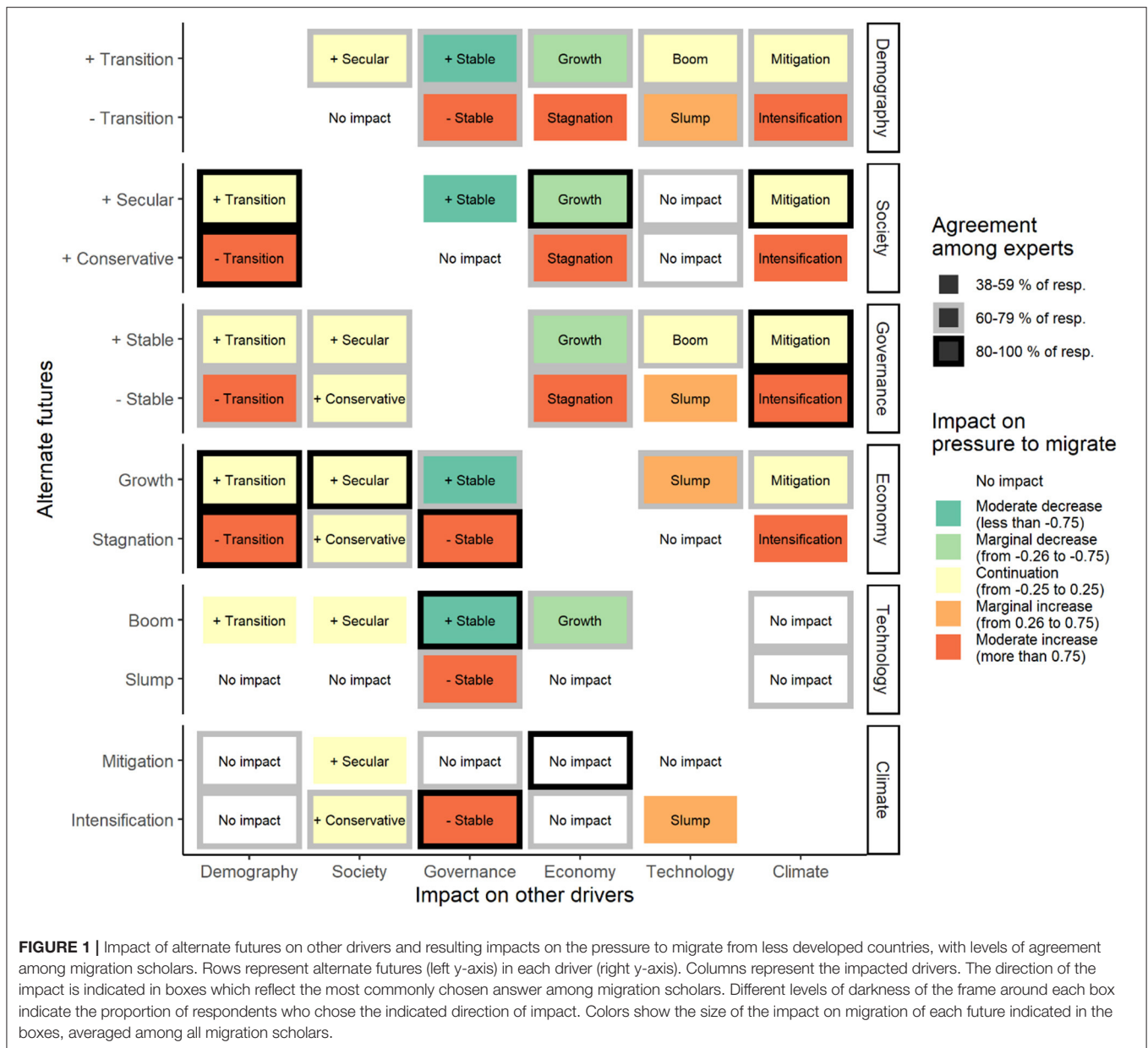
Driver	Future A	Future B
Demographic transition	Progress: -0.11 (1.05)	Stall: 0.95 (0.78)
Secularization	Secularization: 0.21 (0.79)	Conservatism: -0.05 (0.62)
Political stability	Increase: -0.84 (0.60)	Decrease: 1.11 (0.74)
Economic growth	Growth: -0.53 (1.12)	Stagnation: 0.84 (0.83)
Technological change	Boom: 0.00 (1.15)	Slump: 0.32 (0.67)
Climate change	Mitigation: 0.05 (0.71)	Intensification: 1.16 (0.76)

**TABLE 5 |** Mean expected change in the demand for migrants in Europe associated with each alternate future within each driver (with standard deviations between parentheses).

Driver	Future A	Future B
Population aging	Acceleration: 1.21 (0.54)	Deceleration: -0.11 (0.81)
Tolerance toward immigrants	Increase: 0.58 (0.61)	Decrease: -0.74 (0.73)
International cooperation	Increase: 0.28 (0.75)	Decrease: 0.05 (0.52)
Economic growth	Growth: 1.21 (0.71)	Stagnation: -0.84 (0.69)
Technological change	Boom: -0.47 (0.84)	Slump: 0.21 (0.63)
Climate change	Mitigation: 0.16 (0.5)	Intensification: 0.00 (0.75)

countries, an accelerated demographic transition (future A, demography) is likely to lead to secularization (future A, society) and increased political stability (future A, Governance). They might further agree that such an accelerated demographic transition is unlikely to lead to significant changes in the other drivers. Assuming that migration scholars have estimated that

secularization and increased political stability will cause the pressure to migrate to change, respectively, by 0.5 and -1.5 on average, the indirect impact of the alternate future describing an accelerated demographic transition on the pressure to migrate will be equal to -1. Results from this exercise are presented in **Figure 3**.



**FIGURE 1 |** Impact of alternate futures on other drivers and resulting impacts on the pressure to migrate from less developed countries, with levels of agreement among migration scholars. Rows represent alternate futures (left y-axis) in each driver (right y-axis). Columns represent the impacted drivers. The direction of the impact is indicated in boxes which reflect the most commonly chosen answer among migration scholars. Different levels of darkness of the frame around each box indicate the proportion of respondents who chose the indicated direction of impact. Colors show the size of the impact on migration of each future indicated in the boxes, averaged among all migration scholars.

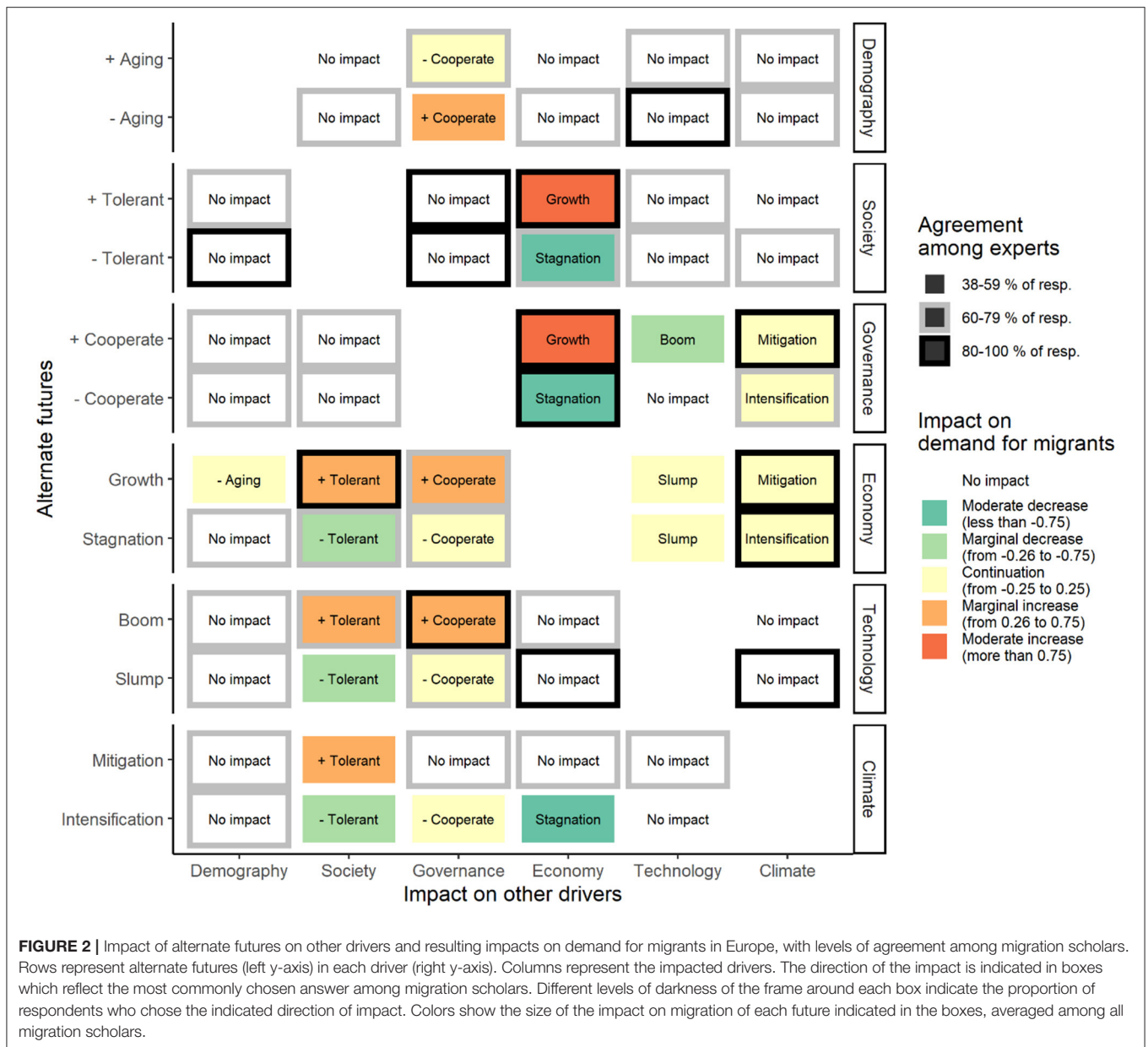
## RESULTS

### Mean Expected Change in Migration Pressure and Demand

Average expected values attributed by the survey participants are shown in **Table 4** concerning the impact of the different alternate futures on the pressure to migrate from less developed countries and in **Table 5** concerning the impact of these on the demand for migrants in Europe. Although values can theoretically vary from -2 (strong decrease) to 2 (strong increase), most figures lie between -1 and 1 and denote at most moderate decreases or increases in migration pressure and demand. Among less developed countries, participants expected an intensification of climate change and decreased political stability to have the largest

impact on the pressure to migrate to Europe. Change in the rate of economic growth was also considered as one of the factors with the largest impact on the pressure to migrate. It should be noted that—as some of the described futures seem to depict a greater deviation from current trends than their alternative—the strength of the impact of alternate futures in a singular domain can be asymmetrical. For instance, migration scholars expected that a stalled demographic transition would induce a moderate increase in the pressure to migrate, whilst they expected that further progress would induce little change. Likewise, migration scholars considered an intensification of climate change as potentially inducing a considerable increase in the pressure to migrate, whilst they considered that mitigation would induce almost no change. Respondents seemed to agree





**FIGURE 2 |** Impact of alternate futures on other drivers and resulting impacts on demand for migrants in Europe, with levels of agreement among migration scholars. Rows represent alternate futures (left y-axis) in each driver (right y-axis). Columns represent the impacted drivers. The direction of the impact is indicated in boxes which reflect the most commonly chosen answer among migration scholars. Different levels of darkness of the frame around each box indicate the proportion of respondents who chose the indicated direction of impact. Colors show the size of the impact on migration of each future indicated in the boxes, averaged among all migration scholars.

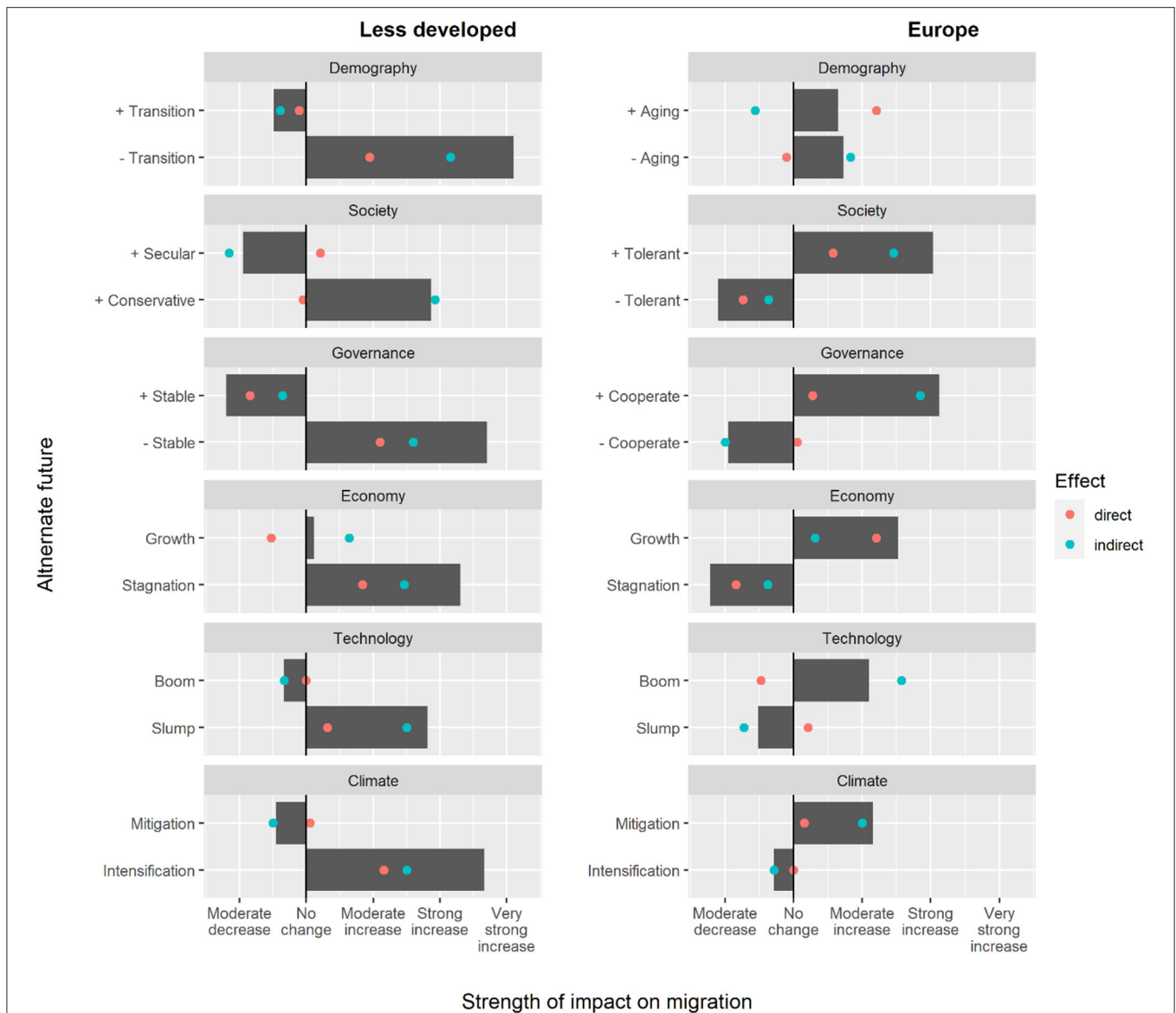
the least on the impact of economic growth and a technological boom on the pressure to migrate, as indicated by the larger standard deviations specific to these futures.

While political stability and climate change were considered the main drivers of change in the pressure to migrate from less developed countries, participants expected accelerated population aging and economic growth to have the largest impact on the demand for migrants in Europe. Thus, while previous migration scenarios often focused on the same factors in both countries of origin and destination, our results suggest that the same drivers may play different roles in sending and receiving countries. The standard deviations reported in **Table 5** were generally smaller than those in **Table 4**, indicating higher levels of agreement among scholars regarding the impact of the alternate

futures on the demand for migration in Europe as opposed to the pressure to migrate from less developed countries.

### Impact of Alternate Futures on Other Drivers

**Figure 1** presents an overview of the participants' assessments of the potential impact of alternate futures in each of our six selected drivers on the other five drivers, among less developed countries. Outcomes are presented for the impact that was the most often chosen by our sample of migration scholars. The level of darkness of the frames around the boxes indicates the level of agreement among them while the colors inside the boxes carry over information from **Tables 3, 4** about the strength of the



**FIGURE 3 |** Direct, indirect, and net impact on migration of each scenario in each driver. Direct impacts correspond to the values shown in **Tables 1, 2**. Indirect impacts are the row sums of the impacts shown in **Figures 1, 2**, which calculations are based on the exact values found in **Tables 1, 2**. The left hand part of the figure shows results about the pressure to migrate from less developed countries while the right one shows results about the demand for migrants in Europe. Dots are color-coded and represent direct and indirect effects. Bars represented net effects, which are the sum of direct and indirect effects.

impact on migration pressure and demand caused by changes in the drivers.

Among less developed countries, a high level of agreement was reached among migration scholars regarding the alternate futures within the societal domain. Specifically, respondents expected increased secularization to cause mitigation of global warming, an accelerated demographic transition, and economic growth. Increased conservatism, on the other hand, was expected to result in a stalled demographic transition. Participants expected a change in the level of political stability in less developed countries to have a significant impact on global warming, with

more stability leading to mitigation, and less stability to an intensification of climate change. In the economic domain, economic growth in less developed countries was expected to result in a faster demographic transition and increased secularization, whereas economic stagnation was expected to cause political instability. Participants further expected a technological boom to lead to more political stability, whereas intensified climate change was predicted to lead to more political unrest. For a few combinations of drivers, participants agreed that no significant impact could be expected. More specifically, mitigating climate change was expected to have little

impact on most other drivers. In general, the lowest degree of agreement between scholars was observed in the demographic and technological drivers.

**Figure 2** presents the same information as **Figure 1** but concerning European countries. Compared to the situation in less developed countries, migration scholars less often predicted that alternate futures in each driver would have a significant impact on the other drivers. The highest level of agreement was reached for combinations where no significant impact was expected. Still, some interesting interactions stand out. First, economic growth was expected to mitigate climate change and to increase tolerance toward migrants. Increased tolerance toward migrants was also expected to result in economic growth, indicating a bidirectional causality between the economic and societal drivers. Second, increased international cooperation was expected to lead to economic growth, whereas decreased cooperation would lead to economic stagnation. Third, participants expected increased international cooperation to mitigate global warming. Fourth, faster population aging was expected to decrease international cooperation. Finally, a technological boom was expected to favor increased international cooperation. Participants appeared to agree the least on the impact of climate change on other drivers.

### Direct, Indirect, and Net Impacts

As shown above, alternate futures in each driver may not only lead to direct changes in migration pressure or demand but may also cause changes in each of the other five drivers, this way indirectly affecting migration. **Figure 3** shows the size of both the direct (cyan dots) and indirect (red dots) impacts on the pressure to migrate from less developed countries (left panel), and the demand for migrants in Europe (right panel). The length of the bars corresponds to the sum of these two impacts, i.e., to the *net impact*.

We saw above that the futures “Decreased stability” regarding Governance and “Intensification” regarding Climate change were those that were considered to be likely to have the largest direct impact on the pressure to migrate from less developed countries to Europe. We see in **Figure 3** that these are also likely to induce large indirect impacts on the pressure to migrate, in part because these two drivers are linked to each other as we saw in **Figure 1**. However, other alternate futures were expected to affect the pressure to migrate mainly indirectly. This is the case for the future “Stalled demographic transition,” which anticipated an indirect impact on the pressure to migrate is the largest among all alternate futures. Since this alternate future was also expected to have a strong direct impact on the pressure to migrate, the resulting net impact is the strongest among all alternate futures. Other alternate futures have a strong net impact as a result of the fact that both direct and indirect impacts go in the same direction. This is the case for the future “Increased political stability,” the future “Economic stagnation,” and the future “Technological slump.” The anticipated direct and indirect impacts of other futures sometimes go in different directions. This is the case of the alternate future “Economic growth.” In yet other cases, the direct and indirect impacts are both weak, resulting in weak or moderate anticipated changes in

migration pressure (e.g., “Accelerated demographic transition,” “Technological boom”).

Concerning Europe, we saw above that our sample of migration scholars predicted changes in economic growth to have an important direct impact on the future demand for migrants. Consequently, alternate futures that are likely to affect the level of economic development are also expected to have the strongest indirect impacts on the demand for migrants. This is the case for the futures “Increased tolerance” and “Increased cooperation” regarding the drivers Society and Governance, respectively. These are both expected to lead to economic growth, and the indirect impacts of both of these futures are expected to lead to important increases in the demand for migrants. Futures within the driver Technology are expected to lead to relatively strong indirect impacts as well, this time through change induced in the drivers Society and Governance. However, these indirect impacts are expected to go in a different direction than their direct impacts, which results in mild net impacts. Indirect impacts associated with alternate futures in other drivers are otherwise moderate or weak.

## DISCUSSION

In this study, we aimed to stimulate further the use of scenario planning as a tool for analyzing the future of international migration. This was done by proposing a series of methodological innovations that aimed at addressing the shortcomings found in current applications of scenario planning in the context of migration and which we implemented through means of a survey among migration scholars.

The first shortcoming concerned the fact that past approaches have most of the time defined scenarios concerning change in only two drivers, usually related to the economic and political domains. To do better justice to the more complex reality that shapes international migration flows, here we did not just assess the impact of change in drivers within these two domains, but also within the demographic, societal, technological, and environmental domains. According to our survey results, drivers within the economic and political domains are indeed expected to play an important role in shaping future migration flows to Europe. For example, change in economic growth was expected to have the strongest direct impact on migration concerning the demand for migrants in Europe, as well as to play an important role by impacting migration demand via other drivers. Furthermore, changes in governance were expected to induce changes in migration pressure and demand that were among the strongest in both sending and receiving countries, especially after considering the role of their indirect impacts. However, according to our sample of migration scholars, these two drivers are far from being the only two forces that will drive migration pressure and demand in the future. In fact, among sending countries, all six drivers were thought to potentially have a strong impact on the pressure to migrate, especially in the case of “adverse” events like a stalled demographic transition or more conservative societies. Though previous migration scenarios often acknowledged the importance of such developments in

their narratives, the role of these drivers was less prominent as they were not systematically used to distinguish between the different narratives. In our study, the demand for migrants in European countries was believed to depend strongly on changes in the societal domain, i.e., whether societies will become more or less tolerant toward migrants. Although similar drivers were included twice in past scenario studies (De Haas, 2011; Friedrich Ebert Stiftung, 2017), they did not figure prominently in most.

Second, past approaches usually built four narratives for each combination between two directions of change in two drivers, implicitly assuming that change in each driver operates independently from the change in the other driver. As a result, as shown in **Table 1**, studies often considered scenarios of economic growth combined with decreased cooperation between countries, or of economic stagnation combined with increased cooperation. Our approach allowed us to show how likely it is, according to our sample of migration scholars, that a given change in a given driver leads to change in another driver and if so, which kind. In contradiction to assumptions made in past approaches, most migration scholars in our sample believe that economic growth in less developed countries is likely to lead to increased political stability and that economic stagnation is likely to lead to instability. Likewise, most migration scholars believe that economic growth in Europe could likely be linked with increased cooperation between countries and that stagnation could likely be linked with less cooperation. If we look at other drivers, we see that according to our sample of migration scholars, there is a strong connection among less developed countries between the level of secularism and the way that the demographic transition will further unfold and between the level of cooperation between European countries and the future pace of climate change. These results suggest that narratives found so far in the literature are based on developments that do not always appear equally likely. This conclusion challenges the stated goal of scenario planning which is to provide a set of equally plausible visions of the future (Amer et al., 2013). To align better with the goals of scenario planning, we suggest that future migration scenarios assess the likelihood that two drivers evolve in specific directions and that they take this information into account when building narratives.

Third, past studies provided an incomplete picture of how similar changes in the same drivers might impact sending and receiving countries differently. To remedy this, for each migration driver considered in this study, we systematically considered the potential impact of change therein on both the pressure to migrate from sending countries and the demand for migrants in receiving countries. This approach allowed us to explicitly acknowledge the fact that migration flows depend on different factors in both sending and receiving countries. To this end, we found for example that, according to our sample of migration scholars, an intensification of climate change could translate in a relatively strong increase in the pressure to migrate from less developed countries, but that the same change would barely affect the demand for migrants in Europe. Similarly, economic growth could contribute to an increased demand for migrants in Europe, while it would have little impact on the pressure to migrate from less developed countries. In sum, instead of formulating statements on the overall change in

migration flows, which are difficult to make because they depend on multiple factors in both sending and receiving countries, future studies could consider breaking down the forces that lead to changes in migration flows into those that operate in sending countries and those that operate in receiving countries.

Finally, our study was the first to our knowledge to systematically assess the relative impact of change in different drivers on migration, and it was also the first to our knowledge to provide a measure of how direct and indirect impacts might vary between drivers. We believe that this assessment might prove particularly useful for informing the debate on how policy can shape migration flows between countries (Haas et al., 2019). While past migration scenarios provided in-depth discussions of how different forces could lead to changes in different drivers and impact migration, it usually remained unclear what drivers should be targeted to steer flows. Based on our assessment, we suggest that to reduce the pressure to migrate from less developed countries, priority should be given to favoring progress in the demographic transition, as strong increases in the pressure to migrate are expected should a stall occur. Importantly, however, migration drivers should be addressed holistically as it was shown that they do not operate independently. In particular, a stall in the demographic transition, increased conservatism, lower political stability, economic stagnation, a technological slump, and faster climate change could have—according to our sample of migration scholars—strong reinforcing effects on each other and lead to strong increases in the pressure to migrate. In Europe, attention should be paid to changes in attitudes toward immigrants, how countries cooperate on questions relating to migration, and economic output, as these three factors are thought to both have a strong impact on the demand for migrants and strongly interact with each other.

The different innovations proposed in this article were mainly possible because of the fundamentally different approach we took at exploring the future of migration. Past migration scenarios were usually built by first identifying the most impactful yet uncertain drivers of migration, to then elaborate narratives that describe how these drivers could change and impact future flows. In a subsequent step, a quantification of the migration flows implied by these different narratives could be provided though, in practice, this was rarely done (Acostamadiedo et al., 2020). Here, we first sketched scenarios of change (i.e., alternate futures) in a set of six drivers, to then ask migration scholars to estimate their quantitative impact on migration. Although similar approaches can be commonly found in ecology (Pereira et al., 2010), to our knowledge, they had not been previously applied to study the future of migration. Without dismissing the way that scenario approaches have so far been applied to explore the future of migration, we believe that the field could benefit from exploring new ways of specifying scenarios, and that these could be enriched by applications of scenario methods in other fields. In particular, future studies could combine the different alternate futures described here and their corresponding impacts on migration pressure and demand to form migration scenarios that are richer, because they would include more drivers, more nuanced, because they would include the perspective of both sending and receiving countries, and more complete, because



they would consider the quantitative impact of changes in different drivers.

There are some substantive implications that can be drawn from our results. Our sample of migration scholars predicted that a stall in the demographic transition could lead to a large increase in the pressure to migrate from less developed countries, especially when considering interactions between drivers. While the average number of children per woman has now reached relatively low levels in most Asian, South American, and North African countries, in most sub-Saharan countries, fertility rates remain higher. Considering the stalls in fertility decline observed recently in several sub-Saharan countries (Kebede et al., 2019), the number of people intending to migrate from those countries to Europe could increase strongly, particularly in countries with already large populations such as Nigeria or the Democratic Republic of the Congo. Our sample of migration scholars further predicted that decreased political stability could strongly increase the pressure to migrate from less developed countries. Such decreased political stability has already been having an impact on migration from countries such as Syria, Venezuela, and, more recently, Ukraine. According to our results, this could be the case in the future in other countries such as Sri Lanka, for example. Finally, our sample of migration scholars predicted that an acceleration of global warming could increase strongly the pressure to migrate from less developed countries to Europe. This might be the case in those countries that are more vulnerable to droughts, such as Ethiopia or Somalia, or to flooding such as Bangladesh (McLeman, 2019). In contrast, further declines in the number of children per women and more stable political situations—as we have been witnessing in countries such as Turkey and Morocco, for example—could reduce the pressure to migrate from those to Europe. In sum, the assessments that we collected point toward a future reconfiguration of the migration flows recently observed from less developed countries to Europe if we were to witness specific changes in the social and environmental drivers of migration.

On the receiving end, we have seen that increased cooperation between countries and increased tolerance toward immigrants could increase the demand for immigrants in Europe. In contrast, increasing opposition to European integration and the eventual withdrawal of member states from the European Union (e.g., the 2020 “Brexit”) could reduce the demand for migrants in Europe. The effect of a failing integration on the demand for migrants could be compounded by raising anti-immigration ideologies (Gietel-Basten, 2016). Our sample of migration scholars further identified economic growth as an important determinant of the future demand for migrants to Europe. Diverging paths of growth between Southern and Northern European countries, as we have been witnessing during the last decade, could increasingly channel migrants toward specific countries such as Germany, the Netherlands, and Sweden, while deterring them from going to other such as Greece, Italy, or Spain. How economic growth influences the future of migration to Europe may depend on how countries agree to manage migration as onward migration—the migration of third country nationals from one country to another—continues to be a key factor shaping the European migration landscape (Della Puppa et al., 2021). In general,

however, respondents considered that changes in our set of drivers would have a greater impact on the pressure to migrate in sending countries than on the demand for migrants in Europe. Therefore, as previous studies underscored (Giménez-Gómez et al., 2019), it is in Europe’s interest to collaborate with sending countries if it wishes to better manage incoming flows.

Some limitations should be mentioned before we conclude. Our study, we argued above, improved on previous migration scenarios by considering a larger set of drivers. While it makes no doubt that considering six drivers instead of two provides a more complete background to assess changes in migration flows, migration remains a highly complex phenomenon that necessarily depends on many more factors. Also, the futures that we lined out for each driver necessarily represented simplified descriptions of reality; accordingly, the assessments made by the migration scholars were constrained by the way we presented them. For example, our scenario of economic growth in less developed countries assumed better jobs for the whole population. However, economic growth can follow from increased wealth among part of the population only. Furthermore, we sketched for each driver two futures, but there exists many more ways that things can evolve in the future within each driver. Our framework otherwise implicitly assumed linear change within each driver between now and the year 2050. However, things rarely change linearly and often, changes in migration flows are the result of shocks in underlying drivers (Curran et al., 2016; Gröger and Zylberberg, 2016). Recent examples of such shocks include the COVID-19 pandemic and the Russian invasion of Ukraine. While both have been having an important impact on migration, it remains unclear what the long-term consequences of these shocks will be.

Throughout this study, we considered European countries as receiving countries and less developed countries as sending countries. This dichotomy provided us with a convenient framework for exploring the future of migration under different scenarios but masked the important disparities that exist within each group. This variability expresses itself in terms of the number of immigrants that each country receives and emigrants they have. In Europe, in the year 2020, about half of all immigrants were registered in only four countries (Germany, Spain, France, and Italy) (Eurostat, 2022). The variation in terms of migration dynamics is even greater among what we labeled as less developed countries. While countries such as Morocco or Turkey continue to send large numbers of migrants to Europe, other such as Saudi Arabia or the United Arab Emirates send much fewer and actually receive more immigrants than most European countries (Azose and Raftery, 2019). The variability within the two groups of countries further expresses itself in terms of what the alternate futures we sketched may represent for each individual country. An economic stagnation in Ireland may for example have a much different consequence than one in Germany for their respective migratory balances (Green and Winters, 2010). Likewise, a two degree increase in global temperatures will have a much different consequence for a coastal country than for a more mountainous one, or for a country lacking infrastructure compared to a more developed one (Harrington et al., 2018; Russo et al., 2019).



Another limitation is linked to our relatively small and homogenous sample of migration scholars. Most scholars were working in demographic research institutes at the time of participating in our survey. Correspondingly, most of them considered themselves mostly knowledgeable in the demographic and societal determinants of migration, while few considered themselves mostly knowledgeable in the technological or environmental ones. Yet, these last two determinants might play an increasingly important role in shaping the future of migration (McLeman, 2019; Cattaneo et al., 2020). Scholars were active in nine different countries, the Netherlands being overrepresented. Because of the small sample, we could not assess the potential biases linked with the scholars' backgrounds or affiliations. Also, since we constrained our sample to migration scholars working in European research institutes, it remains an open question whether we would have obtained similar responses had we included migration scholars working in sending countries as well.

This study proposed ways to augment current applications of scenario planning to migration but unlike most of these, this study did not generate fully-fledged storylines describing the world at a future point in time. Based on our results, such storylines could be developed in subsequent work. These could be more complete than previous ones because they would rest on a larger number of drivers, would present a quantification of the change associated to each driver, would take into account interactions between drivers, and would explicitly consider the perspective of sending and receiving countries. Future migration flows remain notoriously difficult to predict. However, we believe that these difficulties can be managed as new methods are developed and added to the toolset of scenario building methods in migration studies.

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## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

MB and PJ conceived and designed the experiments, performed the experiments, analyzed and interpreted the data, contributed reagents, materials, analysis tools or data, and wrote the paper. Both authors contributed to the article and approved the submitted version.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fhumd.2022.897562/full#supplementary-material>

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