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# Estimating international migration flows for the Asia-Pacific region: Application of a generation–distribution model

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## Abstract

Flows of international migration are needed in the Asia-Pacific region to understand the patterns and corresponding effects on demographic, social, and economic change across sending and receiving countries. A major challenge to this understanding is that nearly all of the countries in this region do not gather or produce statistics on flows of international migration. The only information that are widely available represent immigrant population stocks measured at specific points in time—but these represent poor proxies for annual movements. In this paper, we present a methodology for indirectly estimating annual flows of international migration amongst 53 populations in the Asia-Pacific region and four macro world regions from 2000 to 2019 using a generation–distribution framework. The estimates suggest that 27–31 million persons from the Asia-Pacific region have changed their countries of usual residence during each year in the study. Southern Asia is estimated to have had the largest inflows and outflows, whilst intra-regional migration and return migration were highest in Eastern, Southern, and South-Eastern Asia. India, China, and Indonesia were estimated to have had the largest emigration flows and net migration losses. As a first attempt to estimate international migration flows in the Asia-Pacific region, this paper provides a basis for understanding the dynamics and complexity of the large-scale migration occurring in the region.

**Keywords:** international migration, Asia-Pacific region, migration estimation, migration data

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## 1. Introduction

International migration is believed to be increasing and thriving in the Asia-Pacific region yet evidence of the annual movements and origin–destination corridors remain largely unknown because the data are not collected or made accessible (Iredale, Guo and Rozario 2003; Hugo 2005; Skeldon 2006; Charles-Edwards et al. 2016). The main weaknesses across the region are thought to be in the ‘registration of foreign workers, estimates of unauthorized migration, measurement of return migration, estimating the number of nationals abroad, the public availability of migration statistics and institutional cooperation’ (Huguet 2008: 231). Moreover, migration in the Asia-Pacific region is thought to be different from elsewhere in the world, characterised by ‘strict control of foreign workers, prohibition of settlement and family reunion, and denial of worker rights (especially for less-skilled personnel)’ (Castles 2009: 451). The absence of data has resulted in relatively little research on the patterns and consequences of international migration in the Asia-Pacific region, which is surprising considering the region contains over three-fifths of the world’s population.

In this paper, we develop a method for indirectly estimating annual flows of international migration in the Asia-Pacific region. Annual flows of immigration and emigration are particularly useful as inputs to demographic accounts of population change and for assessing policies on international migration. Further, annual migration flows represent persons changing their country of residence, in line with the United Nations’ Recommendations (1998, 2020c). While widely available, net migration totals are generally not useful for informing policies on migration, which are predominately targeted towards foreign citizens entering countries (i.e. immigration). Moreover, net migration represents the difference between immigration and emigration, and often includes some residual error from other demographic measures if measured indirectly. Finally, in comparison to five-year estimates from immigrant stock data by Abel (2018) and Azose and Raftery (2019), annual flows avoid the problem of missing repeat or return migrations, and may even have different spatial patterns depending on the types of moves predominant in each country (Rogerson 1990).

In this paper, the estimation focuses on how many people moved from, to, and amongst 53 Asia-Pacific populations between 2000 and 2019. In addition, we provide estimates from and to four macro world regions representing Rest of Asia, Africa, Europe, and Central and South America for comparison and to ensure the total flows from and to each country are provided. To produce the estimates, a two-step generation–distribution model is proposed. The first step results in estimates of emigration, relying on the strong relationships known to exist between international migration and population size, economic development, and population age–sex compositions. The second step distributes the estimated emigration flows across destination countries based on information about migrant population stocks and trade flows.

Estimates of international migration are needed in Asia Pacific to understand how countries are connected and affected by migration. They are also needed to assess current migration policies and their effectiveness. There are two main contributions provided in this study. First, we present a framework for estimating international migration flows in the near absence of reported data and outline the necessary steps to produce such

estimates. Second, by providing a set of estimates, there is now a means of enquiry for public discourse and assessing both reported data on population change and migration, including the spatial patterns. Much of the literature on migration trends in the Asia-Pacific region is largely based on immigrant population stocks, foreign worker statistics, or qualitative evidence (see, e.g. [Asis 2006](#); [Skeldon 2006](#); [Liu-Farrer and Yeoh 2020](#)). Our estimates may support, verify or query such evidence. Thus, the framework for estimation described in this paper address a fundamental gap in our knowledge by providing an invaluable basis for understanding the dynamics and complexity of migration in a major and diverse region of the world.

## 2. Background

People who undertake international migration do so for many reasons. For persons who have the capacity to act independently and to make their own choices, these include aspirations for education and human capital development, seeking employment or improved working conditions, reuniting with family members, or seeking new experiences and different lifestyles ([Goldin, Cameron and Balarajan 2011](#); [De Haas et al. 2020](#)). For persons without agency, the reasons include escaping persecution, harm, or dire economic or environmental conditions. To better understand the motives of people migrating, however, we first need some basic information about the levels and directions of the migration patterns themselves. Unfortunately, this basic information is largely non-existent for most countries in the world and this greatly limits our ability to conduct migration research ([Willekens et al. 2016](#)).

The levels of temporary and undocumented migration are thought to have increased substantially across the Asia-Pacific region, making it even more difficult to identify migrants for data collection ([Boucher and Gest 2018](#)). The Organisation for Economic Cooperation and Development ([OECD 2019](#)), for example, found the average length of stay of temporary migrants in this region is five years, which led them to call urgently for more research on this fast-growing movement of people across the region.

There are several reasons for the near-complete absence of migration flow data in the Asia Pacific region. First, no consensus across national statistical offices exists on what exactly is a ‘migration’ and how it should be measured, so comparative analyses of the data that are available suffer from differing national definitions and coverage levels. This is particularly the case for a large proportion of migrants in Asia where permanent migration pathways are restricted and temporary and undocumented flows represent dominant forms of migration ([Skeldon 2006](#); [Liu-Farrer and Yeoh 2020](#)). Temporary migrants moving across Asia are often caught between having regular and irregular migration statuses due to a sudden loss of employment and financial difficulties in returning to their country of origin ([Pietsch 2015](#); [Asis and Battistella 2018](#)). Second, the event of migration is rarely measured directly. Often it is inferred from a comparison of places of residence at two points in time or from a change in residence recorded by a population or migration registration system. The challenge is compounded because of the difficulties of identifying international migrants and the use of different or multiple methods of data collection ([Bilsborrow et al. 1997](#); [De Beer et al. 2010](#)). There may be non-participation of

immigrants themselves in the process of data collection, many of whom prefer not to report their status with government agencies out of fear of being returned to their country of origin. Finally, there may be issues with the production of migration data by statistical agencies that include lack of conformity to international standards, inadequate level of disaggregation, and inflexibility in data made available for public use (Huguet 2016).

To further complicate the problem, official statistics on migration may come from a variety of data sources, such as population registers, registers of foreigners, border statistics, pension or tax registers, population censuses, or surveys (Kelly 1987; Bilsborrow et al. 1997; Poulain, Perrin and Singleton 2006; Kupiszewska and Nowok 2008)—and these different sources vary in their ability to document migration flows, as well as how they measure the flows themselves. Issues of incomparability in reported migration statistics have a long-standing history (Kraly and Gnanasekaran 1987; Simmons 1987). Information on emigration and irregular migration is particularly problematic because the migrants have either left the country gathering the data or because the nature of the movements is not documented (Asis and Battistella 2018). In other words, populations rarely have incentives to report their departures in comparison to arrivals, and persons who migrate irregularly may have weak legal status and are thus less likely to engage with administrative authorities. Moreover, administrative authorities tend to focus on particular types of migration, e.g. labour, education, family reunification, and they may not have the capacity or official channels to communicate their data with other agencies to form a comprehensive picture of migration.

To measure migration or migrant populations, many countries rely on data sources that are less accurate (e.g. surveys) or infrequent over time (e.g. population censuses). While easier and cheaper to employ, practically all surveys are inadequate for capturing the details needed for analysing migration flows due to their relatively small sample sizes, combined with the fact international migration is a relatively rare event. Censuses occur only periodically and are generally only able to count immigration through questions on place of residence one year or five years ago. Emigrants are generally not counted by censuses because they are no longer present in the population of interest. While not suitable for flows, both surveys and censuses can be used for gathering information on immigrant populations and their characteristics, provided they represent a reasonably large proportion of the population and their locations within the country are known.

To overcome the problems associated with inadequate and missing data, there are numerous examples of research on estimating international migration flows (see, e.g. Poulain 1993; Raymer 2008; De Beer et al. 2010; Raymer et al. 2013; Wiśniowski et al. 2016; Abel 2018; Fiorio et al. 2021). Estimating flows provides a way to augment or overcome data limitations. In the Asia-Pacific region, where levels of temporary and undocumented migration are considered to be high compared to other world regions, estimates can assist in understanding the demand for basic human rights and protections (Asis 2006). Most of the research on estimating migration has focused on particular countries, independent of others (e.g. Hugo 2014). For research on estimating migration within a system of countries, we can draw from recent research on European Union (EU) and European Free Trade Association (EFTA) countries. For instance, Poulain (1993) and De Beer et al. (2010) apply optimisation to harmonise origin–destination-specific flows reported by sending and receiving countries. Raymer (2008) and Raymer, De Beer and

Van der Erf (2011) showed how spatial interaction models could be applied to model international migration flows in a hierarchical manner. Raymer et al. (2013) and Wiśniowski et al. (2013, 2016) extended these ideas by developing Bayesian statistical models for incorporating covariate data and various forms of prior information, including expert judgements to provide probabilistic estimates of migration by origin, destination, age, and sex. Finally, Abel (2013, 2018) and Abel and Sander (2014) developed a methodology to convert immigrant stock data by country of birth into international migration transitions for all countries in the world. This methodology is conceptually different from the ones above since it relies on immigrant population data and demographic accounting as bases for estimation (see also Dennett 2016; Azose and Raftery 2019). Our study adds to the literature in two ways. First, we estimate annual migration flows in a region where hardly any consistent or reliable information on migration flows are available. Second, we apply a generation–distribution multiplicative model framework, which increases control of the estimation process. This hierarchical approach, to our knowledge, has not been attempted to estimate international migration flows.

### 3. Generation distribution model

In this study, we present the model framework used to estimate an annual time series of migration flows amongst 53 Asia and Pacific countries and areas. The list is based on the UN's Standard Country or Area Codes for Statistical Use (United Nations 2011). Countries in the Central and West Asia are not included as they are geographically far from the Pacific Ocean. In addition, some small Oceania countries are excluded due to data limitations. Taiwan, the USA, and Canada are included because of their geographic locations and importance to migration connections with Asia-Pacific populations. We also include the following four broad world regions for migration from and to areas outside the Asia-Pacific region: Rest of Asia, Europe, Africa, and South and Central America. A full list of the 57 countries or regions and their codes is presented in Table 1, along with their 2000 and 2017 populations and percentages of immigrants and emigrants residing abroad.

In Table 2, immigrant populations in the Asia-Pacific region and Rest of World, defined as persons living outside their country of birth, are presented for the years 2000 and 2017. According to these data from the World Bank, the growth in the world's immigrant population grew by 54 per cent in 17 years, from 167 million persons to 257 million persons. Immigrants originating from the Asia-Pacific region increased by 77 per cent, whereas those originating from Rest of World increased by 45 per cent. The fastest growth occurred amongst persons born in the Asia-Pacific region and living in Rest of the World (170 per cent increase). Although we do not know when these persons migrated exactly, there was clearly an increase in the movements from the Asia-Pacific region relative to Rest of World.

Motivated by Willekens and Baydar (1986) and Willekens (1994), we develop a generation–distribution model to estimate origin–destination-specific migration flows for 53 Asia-Pacific populations and four non-Asia-Pacific regions between 2000 and 2019. Figure 1 illustrates our overall model framework which includes three major steps. First,

Table 1. Population sizes (in thousands) and percentage immigrants and emigrants by country and regions, 2000 and 2017

| Region   | Code/country or area | Population |           | Immigrants (per cent) |       | Emigrants (per cent) |       |
|----------|----------------------|------------|-----------|-----------------------|-------|----------------------|-------|
|          |                      | 2000       | 2017      | 2000                  | 2017  | 2000                 | 2017  |
| E Asia   | CHN China            | 1,290,551  | 1,421,022 | 0.03                  | 0.06  | 0.46                 | 0.74  |
|          | HKG Hong Kong        | 6,606      | 7,306     | 34.90                 | 39.20 | 10.42                | 14.91 |
|          | MAC Macao            | 428        | 623       | 52.91                 | 55.18 | 23.77                | 24.88 |
|          | PRK DPR Korea        | 22,929     | 25,430    | 0.14                  | 0.18  | 0.32                 | 0.43  |
|          | JPN Japan            | 127,524    | 127,503   | 1.29                  | 1.72  | 0.57                 | 0.65  |
|          | MNG Mongolia         | 2,397      | 3,114     | 0.31                  | 0.64  | 1.29                 | 2.27  |
|          | KOR Rep. Korea       | 47,379     | 51,096    | 0.49                  | 2.16  | 4.13                 | 4.43  |
|          | TWN Taiwan           | 21,967     | 23,675    | 2.08                  | 3.16  | 0.39                 | 0.41  |
|          | BRN Brunei Dar.      | 333        | 424       | 28.61                 | 24.88 | 13.58                | 10.92 |
|          | KHM Cambodia         | 12,155     | 16,009    | 1.15                  | 0.46  | 3.78                 | 6.69  |
| S-E Asia | IDN Indonesia        | 211,514    | 264,651   | 0.13                  | 0.13  | 1.19                 | 1.71  |
|          | LAO Laos             | 5,324      | 6,953     | 0.33                  | 0.62  | 12.20                | 18.93 |
|          | MYS Malaysia         | 23,194     | 31,105    | 5.77                  | 10.07 | 5.22                 | 5.66  |
|          | MMR Myanmar          | 46,720     | 53,383    | 0.18                  | 0.12  | 2.62                 | 6.13  |
|          | PHL Philippines      | 77,992     | 105,173   | 0.32                  | 0.17  | 4.08                 | 5.61  |
|          | SGP Singapore        | 4,029      | 5,708     | 30.26                 | 36.59 | 4.81                 | 5.96  |
|          | THA Thailand         | 62,953     | 69,210    | 2.04                  | 5.16  | 1.07                 | 1.45  |
|          | TLS Timor-Leste      | 884        | 1,243     | 1.05                  | 0.59  | 16.77                | 3.08  |
|          | VNM Viet Nam         | 79,910     | 94,601    | 0.07                  | 0.10  | 2.39                 | 3.10  |
|          | AFG Afghanistan      | 20,780     | 36,296    | 0.29                  | 0.66  | 22.17                | 13.91 |
| S Asia   | BGD Bangladesh       | 127,658    | 159,685   | 0.67                  | 0.94  | 4.26                 | 4.74  |

Continued

Table 1. Continued

| Region | Code/country or area  | Population |           | Immigrants (per cent) |       | Emigrants (per cent) |        |
|--------|-----------------------|------------|-----------|-----------------------|-------|----------------------|--------|
|        |                       | 2000       | 2017      | 2000                  | 2017  | 2000                 | 2017   |
|        | BTN Bhutan            | 591        | 746       | 5.02                  | 6.46  | 20.34                | 6.52   |
|        | IND India             | 1,056,576  | 1,338,677 | 0.60                  | 0.39  | 0.75                 | 1.25   |
|        | IRN Iran              | 65,623     | 80,674    | 4.02                  | 3.05  | 1.27                 | 1.53   |
|        | MDV Maldives          | 279        | 496       | 9.31                  | 12.57 | 0.44                 | 0.60   |
|        | NPL Nepal             | 23,941     | 27,633    | 2.84                  | 1.76  | 4.08                 | 7.78   |
|        | PAK Pakistan          | 142,344    | 207,906   | 2.94                  | 1.59  | 2.39                 | 3.03   |
|        | LKA Sri Lanka         | 18,778     | 21,128    | 0.21                  | 0.18  | 5.23                 | 8.37   |
|        | ASM American Samoa    | 58         | 56        | 41.71                 | 41.27 | 5.52                 | 3.42   |
|        | AUS Australia         | 18,991     | 24,585    | 22.83                 | 28.66 | 2.03                 | 2.25   |
|        | COK Cook Islands      | 18         | 18        | 15.08                 | 16.34 | 108.65               | 125.87 |
|        | FJI Fiji              | 811        | 877       | 1.37                  | 1.38  | 16.27                | 24.54  |
|        | PYF French Polynesia  | 241        | 276       | 10.94                 | 9.67  | 1.79                 | 0.69   |
|        | GUM Guam              | 155        | 164       | 45.96                 | 45.91 | 1.81                 | 1.33   |
|        | KIR Kiribati          | 84         | 114       | 2.14                  | 2.18  | 4.76                 | 3.76   |
|        | MHL Marshall Islands  | 51         | 58        | 3.32                  | 5.05  | 13.77                | 13.67  |
|        | FSM Micronesia        | 107        | 111       | 0.98                  | 0.87  | 15.75                | 19.04  |
|        | NRU Nauru             | 10         | 11        | 21.36                 | 11.09 | 15.56                | 22.32  |
|        | NCL New Caledonia     | 217        | 277       | 21.45                 | 23.88 | 2.28                 | 1.70   |
|        | NZL New Zealand       | 3,859      | 4,702     | 16.72                 | 21.54 | 12.70                | 16.31  |
|        | NIU Niue              | 2          | 2         | 22.24                 | 32.88 | 302.79               | 340.53 |
|        | MNP N Mariana Islands | 57         | 57        | 67.21                 | 36.77 | 4.83                 | 4.79   |

Continued



Table 1. Continued

| Region    | Code/country or area | Population |           | Immigrants (per cent) |       | Emigrants (per cent) |        |
|-----------|----------------------|------------|-----------|-----------------------|-------|----------------------|--------|
|           |                      | 2000       | 2017      | 2000                  | 2017  | 2000                 | 2017   |
|           | PLW Palau            | 19         | 18        | 29.92                 | 27.33 | 21.01                | 14.78  |
|           | PNG Papua New Guinea | 5,848      | 8,438     | 0.43                  | 0.36  | 0.08                 | 0.06   |
|           | WSM Samoa            | 174        | 195       | 3.26                  | 1.93  | 54.19                | 61.71  |
|           | SLB Solomon Islands  | 413        | 636       | 0.90                  | 0.31  | 0.67                 | 0.65   |
|           | TKL Tokelau          | 2          | 1         | 15.42                 | 35.32 | 133.29               | 170.77 |
|           | TON Tonga            | 98         | 102       | 1.06                  | 1.06  | 47.69                | 60.62  |
|           | TUV Tuvalu           | 9          | 11        | 1.48                  | 1.16  | 27.97                | 28.79  |
|           | VUT Vanuatu          | 185        | 285       | 0.74                  | 0.80  | 3.47                 | 2.49   |
|           | WLF Wallis + Futuna  | 15         | 12        | 13.42                 | 8.65  | 50.40                | 96.95  |
| N America | CAN Canada           | 30,588     | 36,732    | 18.00                 | 20.94 | 3.76                 | 3.56   |
|           | USA United States    | 281,711    | 325,085   | 11.77                 | 14.43 | 0.71                 | 0.87   |
| Other     | ROA Rest of Asia     | 239,905    | 337,571   | 6.73                  | 9.57  | 5.83                 | 5.03   |
|           | AFR Africa           | 820,062    | 1,258,597 | 0.16                  | 0.17  | 1.14                 | 1.41   |
|           | EUR Europe           | 723,476    | 743,284   | 3.34                  | 5.02  | 2.51                 | 2.56   |
|           | SCA S + C America    | 521,781    | 636,125   | 0.49                  | 0.48  | 4.02                 | 4.87   |
| Total     |                      | 6,150,308  | 7,559,870 | 1.84                  | 2.23  | 1.84                 | 2.23   |

Sources: United Nations (2019a,b), Taiwan Ministry of the Interior (2020), and Taiwan National Immigration Agency (2020).

Note: Other South and Other North categories are excluded.

**Table 2.** Immigrant populations (in millions) in the Asia-Pacific region and Rest of World, 2000 and 2017

| Year | Region of birth | Region of residence |               |       |
|------|-----------------|---------------------|---------------|-------|
|      |                 | Asia-Pacific        | Rest of World | Total |
| 2000 | Asia-Pacific    | 33.5                | 12.8          | 46.2  |
|      | Rest of World   | 33.2                | 87.6          | 120.8 |
|      | Total           | 66.7                | 100.4         | 167.1 |
| 2017 | Asia-Pacific    | 47.5                | 34.5          | 82.0  |
|      | Rest of World   | 43.2                | 132.0         | 175.2 |
|      | Total           | 90.7                | 166.5         | 257.2 |

Sources: World Bank (Özden et al. 2011, 2017).

Note: Other South category is excluded.

we use a predictive model to generate the total emigration rates from each origin  $i$  based on parameters estimated from a regression applied to harmonised European migration rates. Estimated emigration flows,  $n_{i+}$ , are obtained by multiplying the estimated rates by mid-year population totals for each country. Second, for each origin country, emigrants are distributed according to estimated probabilities of migration to each Asia-Pacific country (53 countries in total) and four world regions,  $p_{j/i}$ . The probabilities are based on bilateral data on immigrant population stocks by country of birth or citizenship and international trade. By multiplying  $n_{i+}$  and  $p_{j/i}$ , we obtain a set of origin–destination-specific migration flow estimates  $n_{ij}$  for the Asia-Pacific region.

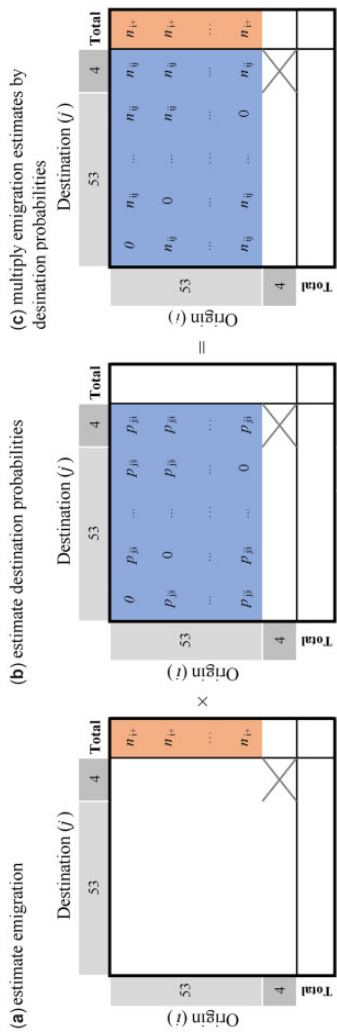
Third, the estimates are refined by (1) estimating flows from world regions outside the Asia-Pacific region using the proportions found in the immigrant population stock and trade data; (2) strengthening the correlations between total immigration and emigration over time using an iterative proportional fitting (IPF) procedure; and (3) adjusting any implausible estimates and replacing the estimates with reliable observed data where possible. For each year, the resulting matrix of estimated migration flows is comprised of 3,180 possible origin–destination migration cells, excluding the diagonal elements and flows between four world regions (i.e.  $57 \times 57 - 57 - 12$ ).

The migration estimation framework described above is similar to the hierarchical multiplicative models used in Raymer (2008) and Raymer, De Beer and Van der Erf (2011). The major difference between migration in Europe and Asia Pacific is the availability of data. Thus, our approach differs because of the much more severe missing data situation and increased reliance on auxiliary information.

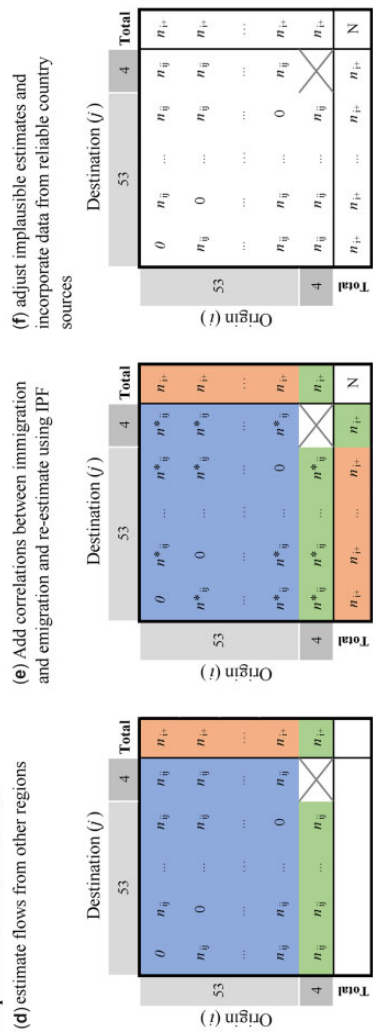
### 3.1 Input data

As a basis for estimation, nine datasets were gathered from publicly available sources (see Online Appendix Table A.1). The first data set represents harmonised migration flows amongst 30 European countries from 2002 to 2008 estimated in the Integrated Modelling

**Steps 1 and 2. Generation and distribution estimation**



**Step 3. Refinement of estimates**



**Figure 1.** Generation–distribution model framework used to estimate international migration in the Asia-Pacific region. Note: Uncertainty of the estimates is generated in Step a.

of European Migration (IMEM) project (Raymer et al. 2013). This is the only data set that we are aware of that contains a consistent and complete set of annual international migration flow estimates (There is an ongoing research project to extend these estimates and include other data sources but the results have not been peer-reviewed (Del Fava, Wiśniowski and Zagheni 2019). Also, United Nations Population Division (2015) publishes International Migration Flows to and from Selected Countries Database (IMFSCD) with yearly bilateral flows from and to 45 prominent, mostly European, immigrant-receiving countries (United Nations 2015). Note that the definitions underlying migration flows in IMFSCD differ depending on the country reporting the data (Abel and Cohen 2019; Raymer, Guan and Ha 2019).) The advantage of the IMEM project estimates over reported data is that the flows have been benchmarked to the definition recommended by the United Nations (1998) and there is no missing information. Specifically, a migrant is defined as ‘a person who moves to a country other than that of his or her usual residence for a period of at least a year (12 months)’ (p. 10). Flows obtained from national statistics offices or international agencies such as Eurostat, on the other hand, are based on the country-level statistics, which are not comparable with other countries’ reports (Nowok, Kupiszewska and Poulain 2006). We use the IMEM estimates and their associations with a range of predictor variables as a basis for generating migration flows from each country in the Asia-Pacific region (see Section 3.2). A second advantage of the IMEM estimates is that they are probabilistic, that is, they are in the form of probability distributions of the ‘true’, unobserved migration flows. In this work, we use this information to approximate uncertainty in the emigration flows for Asia-Pacific countries (Step a in Fig. 1).

The variables used as predictors in the generation (emigration rate) model include population size, Gross Domestic Product (GDP) per capita, percentage foreign-born population, old-age dependency ratio, percentage urban population, and female life expectancy. These variables have been used previously to estimate international migration flows (see, e.g. Raymer et al. 2013; Abel, Raymer and Guan 2019; Raymer, Guan and Ha 2019). The variables were collected for all 53 Asia-Pacific populations and the 30 European populations for annual time periods wherever possible.

Country-specific population data were sourced from the United Nations World Population Prospects 2019 database (United Nations 2019b). Specifically, we used the mid-year population counts between 1999 and 2018 as a time-lagged population variable for 2000–19. A dummy variable for countries with less than 6 million persons was also created to distinguish between large and small populations based on the 2018 population sizes. GDP per capita data, measured in terms of current US dollars, were obtained from the World Bank World Development Indicator database and the United Nations National Accounts Estimates of Main Aggregates (World Bank 2020; United Nations 2020b). The GDP per capita values for Taiwan, French Polynesia, and Wallis and Futuna Islands were obtained from International Monetary Fund (2020) and the Secretariat of the Pacific Community (2010, 2015, 2018).

Immigrant population percentages were calculated by dividing immigrant population stock counts obtained from the United Nations Migrant Population database by the mid-year population counts from the United Nations World Population Prospects 2019 database (United Nations 2019a,b). Immigrant population stock data are only available in 1995, 2000, 2005, 2010, 2015, and 2019. The totals for the years in between these dates are

estimated by linear interpolation. Note that the Migrant Population database mixes three definitions of immigrants. In the majority of countries, immigrants are defined as the population born in another country (i.e. foreign-born). The second immigrant definition is persons who do not have national citizenship (i.e. foreign citizens). Finally, for North Korea, immigrant populations are imputed based on data from Eastern Asia ([United Nations 2019a](#)). Immigrant population data for Taiwan are obtained from the Ministry of the Interior, defined by nationality ([Taiwan Ministry of the Interior 2020](#)).

Old-age dependency ratios are used to capture the age composition and variations in ageing across countries. For most countries, these data were sourced from the World Bank World Development Indicator database ([World Bank 2020](#)). For Taiwan, Cook Islands, Niue, and Tokelau, the information was sourced from their national statistics offices ([Taiwan Department of Household Registration 2019](#); [Cook Islands Ministry of Finance and Economic Management 2019](#); [Statistics Niue 2019](#); [Government of Tokelau 2020](#)). No old-age dependency ratios were reported for American Samoa, Marshall Islands, Northern Mariana Islands, Nauru, Palau, Tuvalu, Wallis and Futuna Islands, and Liechtenstein. Data on the percentage of urban population were obtained from the United Nations World Urbanization Prospects dataset ([United Nations 2018](#)). These numbers are used to capture the degree of urbanisation and economic development in each country. Female life expectancy at birth ( $e_0$ ) was obtained from the World Bank World Development Indicator database ([World Bank 2020](#)) to proxy health status and socioeconomic development.

All variables were available for the 30 European populations, whereas missing values existed in certain years and populations for the 53 Asia-Pacific populations. Missing values mostly occurred in small Oceania countries for the variables of GDP per capita (4.7 per cent among all populations and years missing), old-age dependency ratio (15.2 per cent) and female life expectancy (14.5 per cent). The rate of missing values across all six variables is considered very low at only 5.7 per cent (see, e.g. [Manly and Wells 2015](#) for guidance). To address the multivariate incomplete data, we applied multiple imputation with the bootstrapping-based ‘Amelia II’ package in R ([Honaker, King and Blackwell 2011](#)). The input for the imputation model includes the six variable values from 2002 to 2008 for the 30 European populations and 2000–19 for the 53 Asia-Pacific populations. The observed values were kept the same and only missing values were filled in the imputed dataset. Alternatively, we could have applied linear interpolation or assume fixed values within countries, depending on the number of missing values. However, we reasoned that multiple imputation provided the best approach to tackle the missing values and, since it was model-based, allowed the inclusion of additional variation into the estimates for small populations.

Finally, two bilateral datasets were gathered for the purpose of distributing emigrants across destination countries and world regions. The immigrant stock data were sourced from the United Nations Migrant Population database ([United Nations 2019a](#)), [Taiwan Ministry of the Interior \(2020\)](#), and [Taiwan National Immigration Agency \(2020\)](#). For the United Nations immigrant stock data, there are many missing cell values. We simply assumed zeros for these cells because only the proportion from each origin was required. Trade flows were downloaded from the United Nations Comtrade database ([United Nations 2020a](#)) and [Taiwan Bureau of Foreign Trade \(2020\)](#). The trade values represent all commodities in US dollars averaged by the values reported by sending country and receiving country for each country-to-country corridor.

### 3.2 Model specification

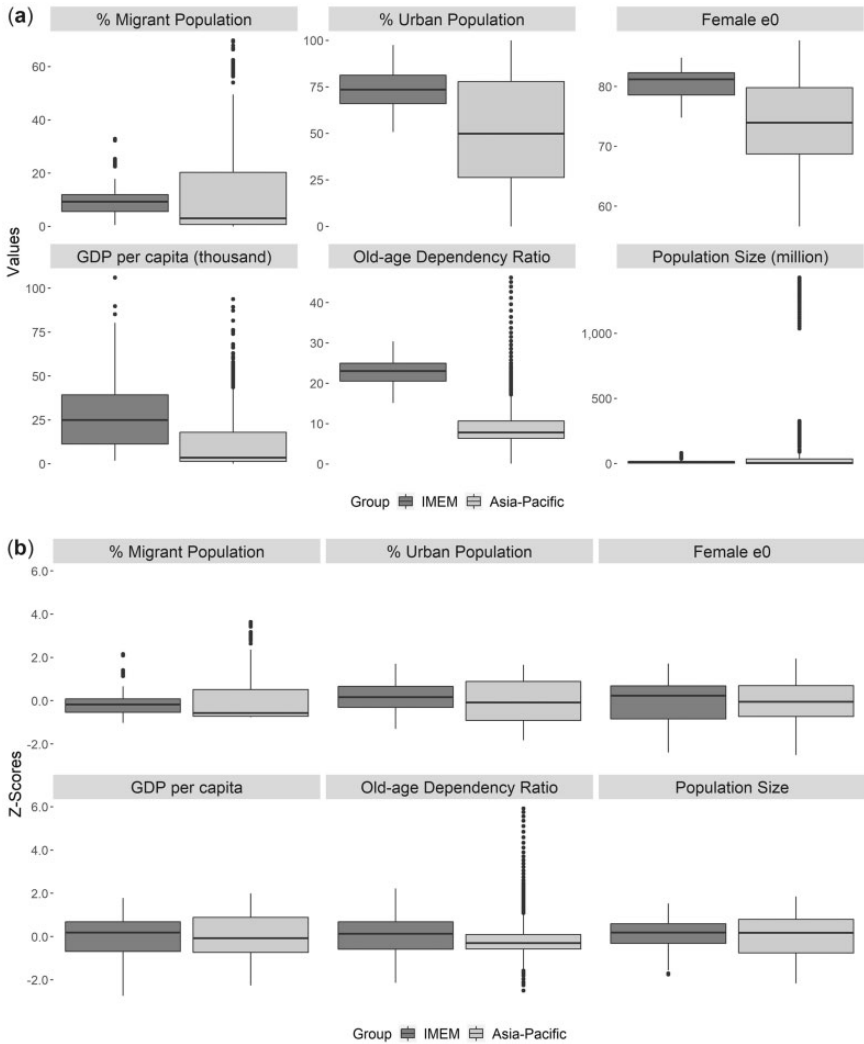
As outlined in Fig. 1, there are three main steps in our model framework. The calculations described below were performed using the R statistical software version 3.6.3 (Team RC 2013). The R code and estimates are available for download at <https://doi.org/10.5281/zenodo.6837140>.

In the first step, we estimate annual emigration rates from each Asia-Pacific origin based on relationships found between covariates and emigration rates from EU/EFTA countries. The emigration rates for European countries were calculated using emigration flows from the harmonised IMEM dataset (Raymer et al. 2013) and mid-year population counts in the United Nations World Population Prospects database (United Nations 2019b). The IMEM data are model-based estimates in form of probability distributions of the ‘true’ flows, where the model integrates (i) reported data from both receiving and sending countries, (2) a spatial interaction regression model for estimating missing flow data, and (3) expert judgements on the effects of measurement and undercount.

To account for uncertainty, we drew 1,000 of the estimates from the IMEM posterior distributions and used them as a basis for estimating the distribution of emigration rates for Asia-Pacific countries. While we know Asia-Pacific migration is fundamentally different from European migration, we assume the relationships between migration and covariates operate in similar ways. To support this assumption, we tested a range of regression models. In the end, we used population size, GDP per capita, percentage immigrant population, old-age dependency ratio, percentage of urban population, female life expectancy at birth, and a dummy variable for small populations to predict log-transformed emigration rates. In Fig. 2a, we present the distributions of the covariates for 30 EU/EFTA countries and those for 53 Asia-Pacific countries (without missing values). Clearly, across the six variables, the European data have different means and distributions than the Asia-Pacific data. The variables also tend to be right skewed. This is due to the wider range of demographic, social, and economic conditions in Asia Pacific. For example, the largest population in the EU/EFTA in 2019 was Germany with 83.5 million persons; in the Asia-Pacific region, it was China with 1.43 billion, followed closely by India with 1.37 billion.

To overcome the comparability issues between European and Asia-Pacific data, we log-transformed the covariates and converted them into Z-scores. This transformation made the data more comparable and allowed us to assume similar relative relationships between emigration rates with each covariate in the EU/EFTA region and those in the Asia-Pacific region. Note, to ease the computational burden, the missing covariate values for Asia-Pacific countries were imputed 100 times and randomly applied to the 1,000 regression models based on IMEM data. Also, the standardised covariates were imputed instead of the original values to avoid unreasonable negative values. The EU/EFTA and Asia-Pacific distributions of the median standardised covariates (natural logarithm) by year and country are presented in Fig. 2b.

Standardising the covariate data for EU/EFTA and Asia-Pacific countries helped to make them more comparable and allowed the application of a predictive model to estimate emigration rates. Specifically, the following least squares regression model was applied to first predict log emigration rates ( $r_i$ ) for EU/EFTA countries:



**Figure 2.** (a) Box plots of variables used in generation model for predicting emigration rates: original values. (b) Box plots of variables used in generation model for predicting emigration rates: standardised natural logarithms.

$$\begin{aligned}
 \ln r_i(t)^{[m]} = & \beta_0^{[m]} + \beta_1^{[m]} * Z_{\ln POP_i(t-1)} + \beta_2^{[m]} * Z_{\ln GDP_i(t-1)} + \beta_3^{[m]} * Z_{\ln MP_i(t-1)} \\
 & + \beta_4^{[m]} * Z_{\ln DR_i(t-1)} + \beta_5^{[m]} * Z_{\ln UP_i(t-1)} + \beta_6^{[m]} * Z_{\ln Fe0_i(t-1)} \\
 & + \beta_7^{[m]} * SMALL_i(t-1) + \varepsilon,
 \end{aligned}$$

where  $i$  denotes an origin country,  $t$  denotes year, and  $m = 1, 2, \dots, 1,000$  denotes a sample from the distribution of the IMEM true flows. The independent variables  $Z_{\ln POP_i(t-1)}$ ,  $Z_{\ln GDP_i(t-1)}$ ,  $Z_{\ln MP_i(t-1)}$ ,  $Z_{\ln DR_i(t-1)}$ ,  $Z_{\ln UP_i(t-1)}$ , and  $Z_{\ln Fe0_i(t-1)}$  represent standardised natural logarithms of population size, GDP per capita, percentage immigrant population, old-age dependency ratio, percentage urban population, and female life expectancy, respectively.  $SMALL_i(t-1)$  is an indicator variable for small/large populations, where populations greater than one million are given the value of 1. All variables are time-variant with  $t-1$  denoting a time-lagged variable by one year.

In Fig. 3 (see also Online Appendix Table A.2), 80 percentile credible intervals for the estimated parameter values are presented for the model based on 1,000 samples of the IMEM emigration flows. Overall, 63 per cent of the total variance in log emigration rates for IMEM countries can be explained by the seven covariates. As demonstrated by the credible intervals in Fig. 2, all variables are associated with the migration rate, except for the percentage urban population. Small populations are associated with higher emigration rates. GDP per capita and percentage immigrant population have positive associations, implying more developed countries and those with larger immigrant populations exhibit higher emigration rates. The variables representing old-age dependency ratios and female life expectancy at birth, on the other hand, exhibited negative associations.

To obtain estimates of emigration from Asia-Pacific populations, we multiply the coefficients estimated in each of the 1,000 models to standardised natural logarithms of the corresponding Asia-Pacific variable values. The 2000–19 mid-year population counts are then used to translate emigration rates to emigration flows.

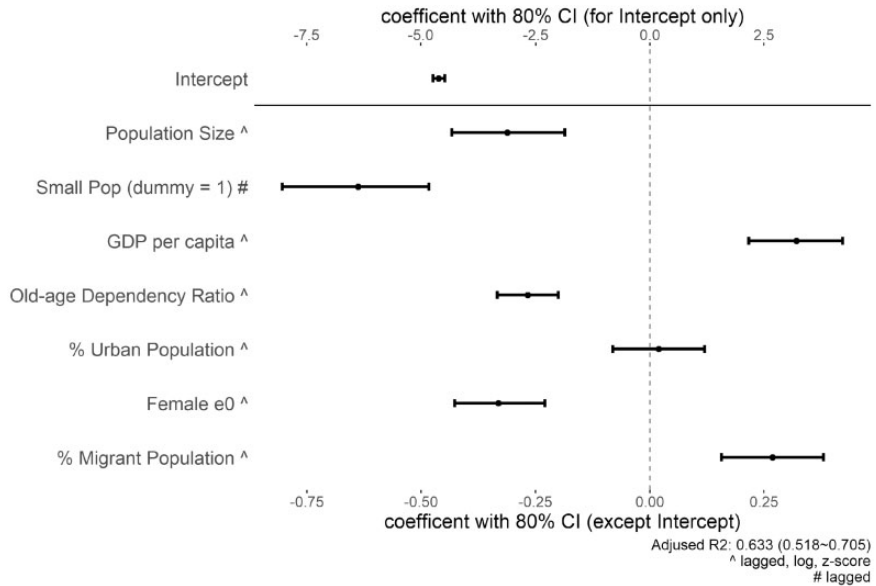


Figure 3. Estimated parameters from generation model to predict log emigration rates, with 80 per cent CI.



The second step of the model framework is to distribute the estimated emigration flow distributions to 57 destinations based on their bilateral relationships observed in the immigrant population stock and trade flow data. To do this, shares in immigrant population stock and bilateral trade were used to estimate the proportion to destination  $j$  from each origin  $i$ :

$$p_{j/i}^k = \frac{x_{ij}^k}{\sum_j x_{ij}^k},$$

where  $p_{j/i}^k$  is the probability of emigration to destination  $j$  conditioned on the origin being  $i$  for each auxiliary information source,  $x^k$  ( $k =$  immigrant stock, gross migrant stock, trade). When  $k =$  immigrant stock,  $x_{ij}^k$  is the reported number of immigrants living in region  $j$  who originated from region  $i$ . When  $k =$  gross migrant stock,  $x_{ij}^k$  includes both the reported number of immigrants living in region  $j$  who originated from region  $i$  and immigrants living in region  $i$  who originated from region  $j$ . This variable increases the possibility for counterflows to occur in the estimates, which are not visible in the birthplace-specific immigrant stock data. When  $k =$  trade,  $x_{ij}^k$  is the reported trade flow from region  $i$  to region  $j$ . In Tables 3–5,  $p_{j/i}^k$  values are presented for immigrant stock and trade flow data for India (2019), Australia (2008), and New Zealand (2013), ranked by the relative importance of destinations. Here, for the top destinations as reported in the immigrant stock data, we see that 53.4 per cent of India’s emigrants were living in Rest of Asia in 2019, 47.8 per cent of Australia’s emigrants were living in Europe in 2008 and 77.5 per cent of New Zealand’s emigrants were living in Australia in 2013.

In distributing migration flows across destinations, we average the ‘gross migrant stock’ and trade values to represent  $p_{j/i}^k$ . In Step c, we multiply the average  $p_{j/i}^k$  proportions representing 57 destinations by the 53 estimated Asia-Pacific emigration counts from 2000 and 2019 (Step a). For the averaging, we use the gross migration stock, which is the sum of bilateral stocks, instead of immigrant stock to increase the size of the counter flows. The birthplace nature of the data often results in one-directional flows, i.e. we know how many persons born in China live in other countries but we do not know how many returned to China. The  $p_{j/i}^k$  values for India, Australia, and New Zealand are presented in Tables 3–5, along with corresponding reported immigrant stock and trade flow percentages. Since there were no clear patterns in the distributional shares, we decided that average of the gross migrant stock and trade would provide the most conservative approximation. For example, Australia reported sending 22 per cent of migrants to Europe in 2008; the corresponding percentages for the immigrant stock and trade were 47.8 per cent and 10.4 per cent, respectively. Here, the average worked well. However, this was not true for all cases. For example, New Zealand reported sending 54.8 per cent of migrant to Australia in 2013. In this case, the gross migrant stock (36.8 per cent) provided the best approximation.

Step 3 in the model framework focuses on refining the estimates produced by combining Steps 1 and 2. In Step d, we add estimates of emigration flows from the four world regions, namely Europe, Africa, South and Central America, and the Rest of Asia. To do this, we assume, for each destination column, that the ratio of (1) migration from each

**Table 3.** Percentage shares of immigrant population stocks and trade ( $p_{ij}^k$ )—India as the origin ( $i$ ), 2019

| Source ( $k$ )       | Destinations ( $j$ ) |      |      |      |     |     |     |     |     |     |     |     |      |     |     |       |
|----------------------|----------------------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-------|
|                      | ROA                  | USA  | PAK  | EUR  | CAN | AUS | NPL | MYS | SGP | AFR | NZL | BTN | BGD  | JPN | MMR | Other |
| Immigrant stock      | 53.4                 | 15.2 | 9.1  | 8.5  | 4.1 | 3.2 | 2.5 | 0.8 | 0.7 | 0.6 | 0.4 | 0.3 | 0.2  | 0.2 | 0.2 | 0.7   |
| Gross migrant stock  | 41.4                 | 11.8 | 11.8 | 6.6  | 3.1 | 2.5 | 4.3 | 0.7 | 0.6 | 0.5 | 0.3 | 0.2 | 13.9 | 0.1 | 0.3 | 1.9   |
| Trade                | 16.4                 | 16.7 | 0.7  | 19.8 | 1.0 | 1.2 | 2.3 | 2.0 | 2.7 | 8.2 | 0.1 | 0.2 | 2.7  | 1.6 | 0.3 | 24.0  |
| Average <sup>a</sup> | 28.9                 | 14.2 | 6.2  | 13.2 | 2.1 | 1.9 | 3.3 | 1.4 | 1.7 | 4.3 | 0.2 | 0.2 | 8.3  | 0.9 | 0.3 | 13.0  |

Note: row totals may not add up to 100 due to rounding.

<sup>a</sup>Average of Trade and Gross Migrant Stock rows. Numbers may not add up due to rounding.

**Table 4.** Percentage shares of immigrant population stocks and trade ( $p_{ij}^k$ )—Australia as the origin ( $i$ ), 2008

|                      | Destinations ( $j$ ) |      |      |     |     |      |     |     |     |     |     |     |     |      |     |       |
|----------------------|----------------------|------|------|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|------|-----|-------|
|                      | EUR                  | USA  | NZL  | CAN | PNG | JPN  | ROA | HKG | IDN | SGP | AFR | SCA | MYS | CHN  | KOR | Other |
| Immigrant stock      | 47.8                 | 15.4 | 13.3 | 4.3 | 2.1 | 2.0  | 2.0 | 1.9 | 1.8 | 1.7 | 1.6 | 1.1 | 1.0 | 0.9  | 0.7 | 2.4   |
| Gross migrant stock  | 43.6                 | 2.6  | 9.2  | 1.0 | 0.2 | 0.8  | 4.3 | 1.6 | 1.3 | 1.0 | 5.7 | 2.0 | 2.1 | 5.4  | 1.3 | 17.9  |
| Trade                | 10.4                 | 5.5  | 3.7  | 0.7 | 0.7 | 22.6 | 7.7 | 1.2 | 1.8 | 2.3 | 1.5 | 1.5 | 1.8 | 17.0 | 8.7 | 12.9  |
| Average <sup>a</sup> | 27.0                 | 4.1  | 6.5  | 0.9 | 0.5 | 11.7 | 6.0 | 1.4 | 1.6 | 1.7 | 3.6 | 1.8 | 2.0 | 11.2 | 5.0 | 15.4  |
| Reported share       | 22.0                 | 7.2  | 11.3 | 2.9 | 0.5 | 3.9  | 4.5 | 3.9 | 3.1 | 7.3 | 1.7 | 1.6 | 3.7 | 5.9  | 3.1 | 17.4  |

Note: row totals may not add up to 100 due to rounding.

<sup>a</sup>Average of Trade and Gross Migrant Stock rows. Numbers may not add up due to rounding.

Table 5. Percentage shares of immigrant population stocks and trade ( $\rho_{ijt}^k$ )—New Zealand as the origin (*i*), 2013

|                      | AUS  | EUR  | USA | CAN | AFR | SGP | JPN | COK | HKG | KOR | MYS | PNG | SCA | THA | WSM | Other |
|----------------------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Immigrant stock      | 77.5 | 12.3 | 4.6 | 1.4 | 0.6 | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.7   |
| Gross migrant stock  | 36.8 | 25   | 3.2 | 1.2 | 4.3 | 0.5 | 0.8 | 0.9 | 0.6 | 1.8 | 1.1 | 0.2 | 0.6 | 0.6 | 3.2 | 19.2  |
| Trade                | 16.8 | 11.5 | 8.8 | 1.2 | 3.6 | 2.1 | 6.3 | 0.2 | 1.5 | 3.4 | 2   | 0.5 | 3.3 | 1.5 | 0.3 | 37    |
| Average <sup>a</sup> | 26.8 | 18.2 | 6.0 | 1.2 | 4.0 | 1.3 | 3.6 | 0.6 | 1.1 | 2.6 | 1.6 | 0.4 | 2.0 | 1.1 | 1.8 | 28.2  |
| Reported share       | 54.8 | 17.3 | 4.2 | 2.4 | 0.8 | 0.5 | 1.4 | 0.4 | 0.5 | 1.9 | 0.8 | 0.3 | 1.3 | 0.6 | 0.7 | 12.1  |

Note: row totals may not add up to 100 due to rounding.

<sup>a</sup>Average of Trade and Gross Migrant Stock rows. Numbers may not add up due to rounding.

world region to (2) total migration from Asia-Pacific countries was the same as the average of two ratios:

- (1) immigrant population stocks from world regions to total immigrant population stocks from Asia-Pacific countries and
- (2) trade from world regions to trade from Asia-Pacific countries.

Specifically, the ratios are obtained as follows:

$$\frac{n_{oj}}{\sum_{i \in AP} n_{ij}} = 0.5 * \left( \frac{M_{oj}}{\sum_{i \in AP} M_{ij}} + \frac{T_{oj}}{\sum_{i \in AP} T_{ij}} \right),$$

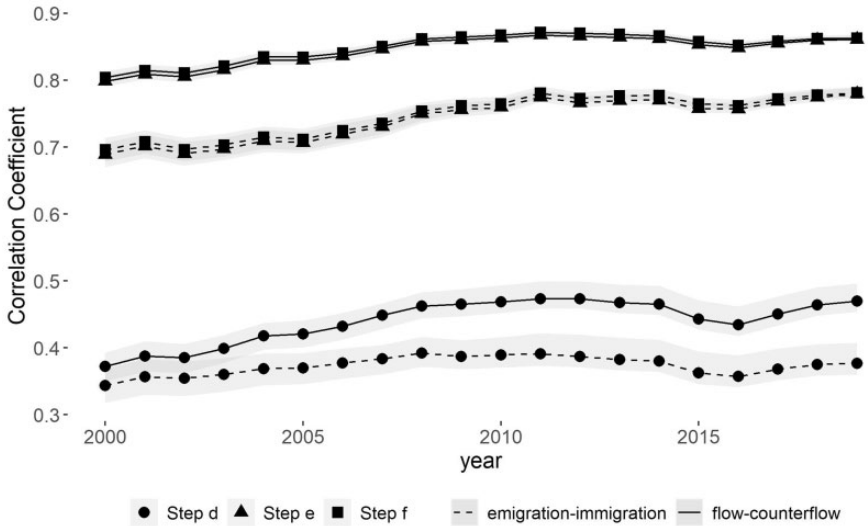
where  $n$  denotes migration flows,  $M$  denotes gross migrant population stock and  $T$  denotes trade. The subscript  $o$  denotes world region origin. Subscripts  $i$  and  $j$  denote an Asia-Pacific origin and destination. To calculate the estimated migration flows from each world region to each Asia-Pacific country, we multiply the average ratios to the sum of the Asia-Pacific destination flows obtained in Step b, i.e.

$$n_{oj} = \sum_{i \in AP} n_{ij} * 0.5 * \left( \frac{M_{oj}}{\sum_{i \in AP} M_{ij}} + \frac{T_{oj}}{\sum_{i \in AP} T_{ij}} \right).$$

The result of this process produced the first set of complete estimates for the  $57 \times 57$  origin–destination-specific migration flow tables for each year between 2000 and 2019. Note, we did not attempt to estimate the international migration flows amongst the four world regions.

Step e involves assessing and, if necessary, strengthening the correlations between totals of immigration and emigration. The notion that flows of emigration should be highly correlated with flows of immigration is well documented. Indeed, [Tobler \(1995\)](#) proposed it as an additional ‘law’ of migration. In [Fig. 4](#), correlation coefficients are presented with the solid dot line representing the correlation index for median total immigration and emigration and the dashed dot line representing correlation index for median origin–destination-specific flows and counter-flows. For the set of estimated flows resulting from Step d, the two correlation coefficients are both lower than 0.48, suggesting a relatively weak correlation between immigration and emigration.

To strengthen the correlations between immigration and emigration, we first created a table that assumed perfect correlation between total immigration and total emigration for each Asia-Pacific country. In other words, we force the column totals,  $n_{+j}$ , to equate the row totals,  $n_{i+}$ , in the migration tables. IPF is then used to force the  $n_{ij}$  estimates to fit the perfectly correlated margins, whilst maintaining the origin–destination interaction association structures. We repeated this procedure for each of the 1,000 samples of estimated emigration flows. Note, however in the IPF process, marginal constraints for the four world regions were not imposed. For example, the flow from Afghanistan to the Rest of Asia is constrained by the total emigration flow from Afghanistan but not the total immigration flow to the Rest of Asia. Next, the estimates obtained from Step d are averaged with the estimates assuming perfect correlation in the margins. As demonstrated in [Fig. 4](#),



**Figure 4.** Correlation of coefficients with 80 per cent prediction intervals.

this results in correlation indices between 0.69 and 0.78 for the flows/counter-flows and 0.80–0.87 for total emigration/immigration.

Next, emigration and immigration rates were examined to check if the correlated estimates are reasonable in relation to each country's population growth. Annual emigration and immigration rates for the 53 Asia-Pacific populations, summarised over 2000–19, are plotted in Fig. 5. In general, the estimated emigration rate levels are considered reasonable, with the highest rate around 3 per cent for Tokelau. The estimated immigration rates, however, are considered unrealistically too high for Hong Kong, Macao, Singapore, and some Pacific Island states (i.e. above 5 per cent). We also compared our estimated median net migration rates for 2019 with the [United Nations \(2019b\)](#) net migration statistics for the 2015–20 period. Our estimates for Hong Kong, Macao, and Singapore vary substantially from the United Nations estimates: 7.6 per cent versus 0.4 per cent, 6.3 per cent versus 0.8 per cent, and 4.3 per cent versus 0.5 per cent, respectively.

Finally, in Step f, estimates with implausible migration levels are adjusted. This included the total immigration estimates for Hong Kong, Macao, and Singapore. Here, the net migration rates from United Nations (2019) World Population Prospects were used to recalculate the immigration rates (see Fig. 5). This resulted in the reduction of 2019 immigration median levels for Hong Kong from 618 thousand (8.3 per cent) to 81 thousand (1.1 per cent), Macao from 48 thousand (7.5 per cent) to 8 thousand (2.0 per cent), and Singapore from 287 thousand (5.0 per cent) to 65 thousand (1.1 per cent). Also, flow estimates were replaced for a few countries that provided relatively good and complete data. Specifically, replacements were made for migration to/from Australia, Canada, South Korea, and New Zealand using data from the United Nations and national statistics offices ([United Nations 2015](#); [ABS 2020](#); [Statistics New Zealand 2020](#); [Statistics](#)

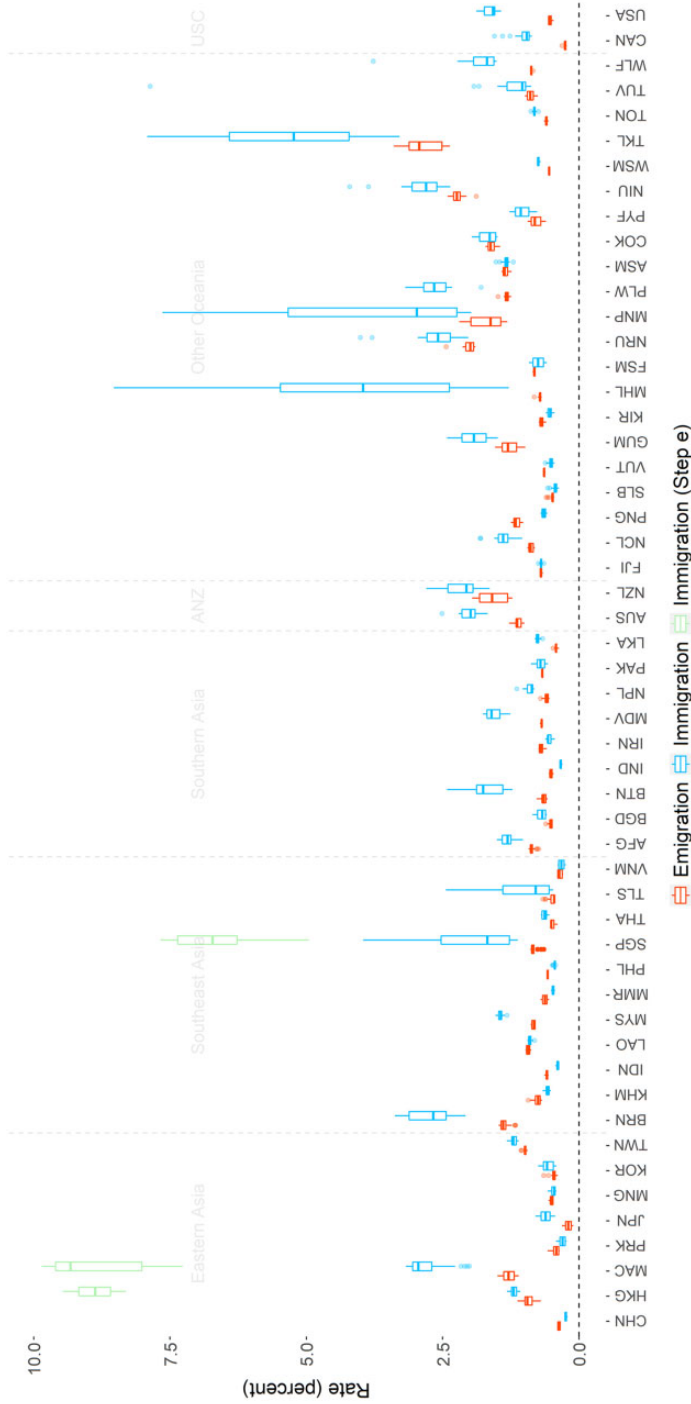


Figure 5. Emigration and immigration rates for Asia-Pacific countries summarised over 2000–19 (truncated at 10 per cent).

Korea 2020; Statistics Canada 2020b). (Australia defines immigrants and emigrants as persons who stay in or leave Australia for 12 months or more over a 16-month period (ABS 2020). New Zealand defines immigrants and emigrants as permanent and long-term arrivals or departures who arrived for a continuous stay of 12 months or more or departed for 12 months continuously or more (Statistics New Zealand 2020). South Korea defines immigrants and emigrants as persons who have continuously resided in or left the country for more than one year (Statistics Korea 2020). Canadian immigration and emigration statistics are recorded separately for permanent (including citizens) and temporary residents (Statistics Canada 2020a,b), with no clear measurement on the duration of residence and only net migration numbers are provided for temporary migrants.)

Besides statistics that are available from the statistical offices of Australia, New Zealand, Canada, and Korea, the international ILO and UNESCAP agencies provide labour migration flow data for some Asia-Pacific countries. Note, these flows represent subsets of total emigration or immigration. In Fig. 6a and b, our estimates of emigration and immigration, respectively, with 80 per cent prediction intervals are compared with reported flow data from ILMS (<https://ilostat.ilo.org/topics/labour-migration/>) and UNESCAP (UN Labour Migration Outflow Database, <https://sitreport.unescapsdd.org/labour-migration-outflow>) databases. UNESCAP only contains outflows of labour (Fig. 6a) under the definition of nationals employed abroad. For some countries, there could be more than one type of statistic because the definitions differ for different data collecting agencies (UNESCAP outflows mostly agree with nationals employed abroad (green line) retrieved from ILMS in Indonesia, Myanmar, Philippian Cambodia, Sri Lanka, and Thailand. These countries are likely to submit the same data to both ILO and the UN). Although most estimated flows appear to be higher than reported values for both emigration and immigration, the trends over time are often parallel, particularly for emigration from Laos, Pakistan, and Vietnam and immigration to Malaysia, Thailand, and Vietnam. Additionally, the gap between estimated and reported values is likely due to incomplete coverage of total migration (e.g. returning nationals not included). On the other hand, reported emigration flows from Fiji, Sri Lanka, the Philippines, and Samoa in Fig. 6a are considerably higher than our estimates, which could reflect the inclusion of international short-term movements.

To compare the effects of the refinement steps (d, e, and f) on the estimates, we present the 2019 median flow estimates in Online Appendix Table A.3. The emigration rates from our final set of estimates (Step f) among 53 Asia-Pacific countries range from 0.1 per cent to 3.4 per cent over the 20-year period, compared to 0.2 per cent to 3.5 per cent among 30 European countries used in step a.

## 4. Results

In applying the generation–distribution model outlined in Fig. 1, we obtained a time series of estimated origin–destination-specific tables of migration representing flows amongst 53 Asia-Pacific countries and four world regions from 2000 to 2019. In 2000, our median estimates show that 27.0 million persons (0.70 per cent of Asia Pacific population) changed their country of usual residence within and beyond the Asia-Pacific region.

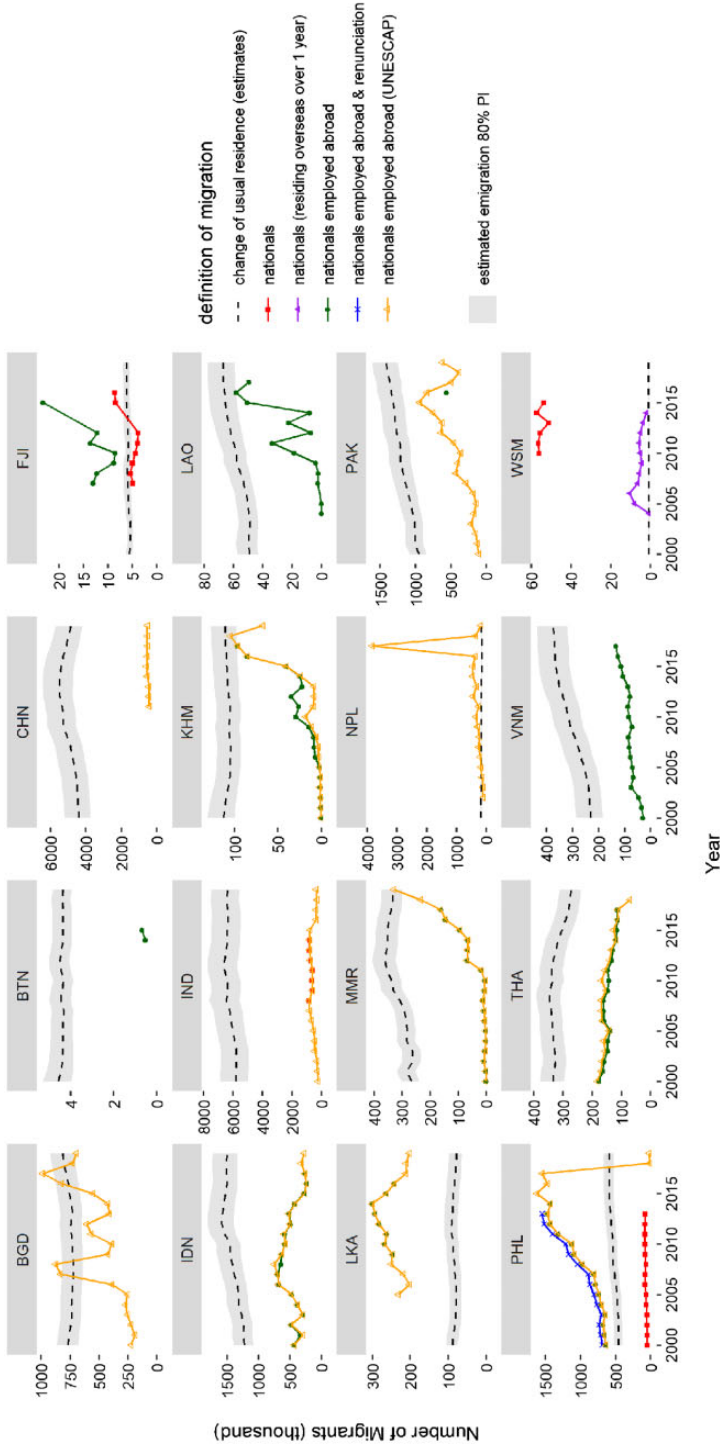


Figure 6. (a) Estimated emigration with data from ILMs and UNESCAP. (b) Estimated emigration with data from ILMs.



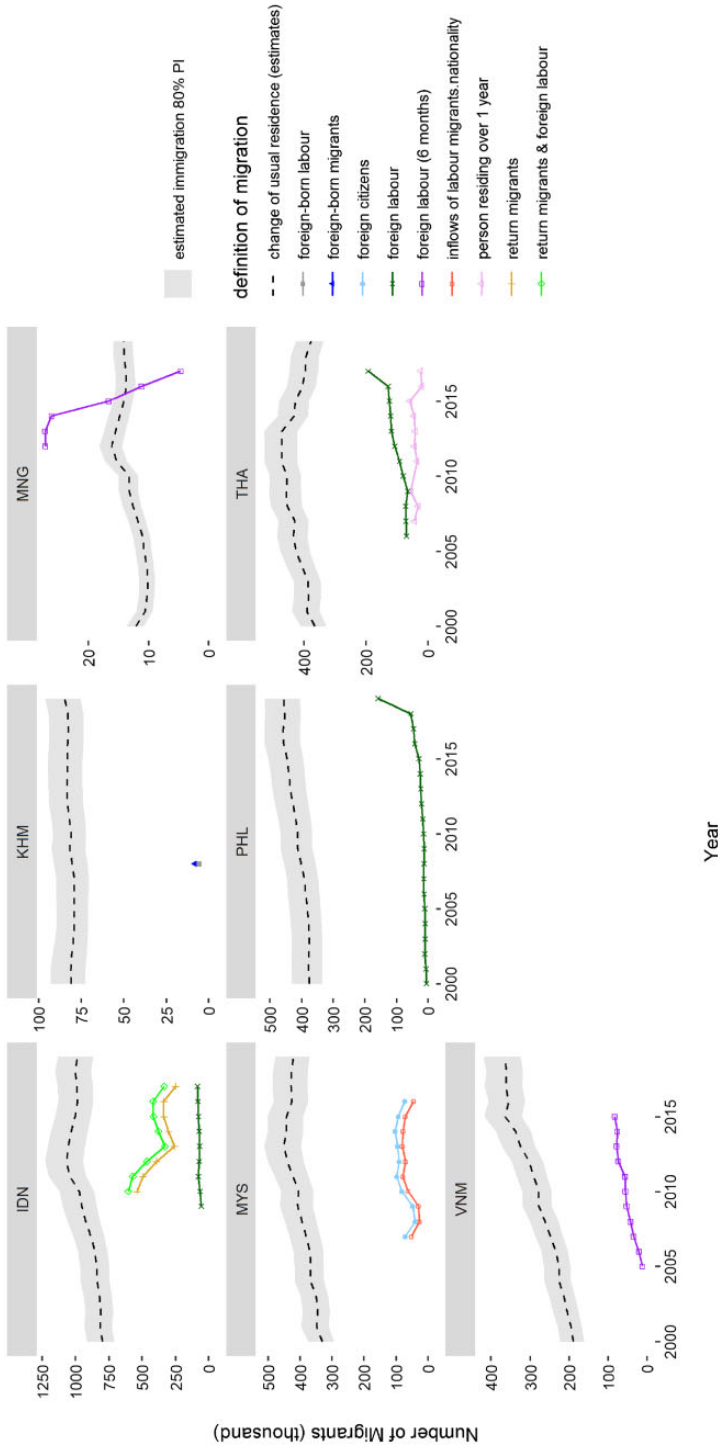


Figure 6. (Continued)

The levels of migration peaked at 31.3 million persons in 2012 with 29.7 million persons estimated to have migrated in 2019. This represents a 10.4 per cent increase in the levels of international migration over the 20-year period (see also [Online Appendix Fig. A.1](#)).

Grouping Asia-Pacific countries by sub-continent region, the median inter- and intra-regional flow estimates for 2000 and 2019 are presented in [Table 6](#). Consider first the total emigration (row margins) and total immigration (column margins) flows. Of the six Asia-Pacific regions and four world regions, Southern Asia was the largest sender and receiver of migrants. Over the 20-year period, total emigration from Southern Asia increased by 13.5 per cent, from 8.5 million persons (0.58 per cent of the Southern Asian population) to 9.6 million persons (0.50 per cent), whereas total immigration to Southern Asia increased by only 2.8 per cent, changing from 7.2 million in 2000 (0.49 per cent of the Southern Asian population) to 7.4 million in 2019 (0.39 per cent). The biggest sending country in Southern Asia was India. In 2000, this country contributed 68.8 per cent of total emigration from Southern Asia and 52.4 per cent of immigration into the same region. In 2019, the corresponding percentages were 66.0 per cent and 54.8 per cent, respectively (see also [Online Appendix Fig A.2](#)).

According to the estimates, Eastern Asia sent the second largest number of emigrants ([Table 6](#)), with around 5.5 million migrants (0.34–0.36 per cent of the Eastern Asian population) moving within or leaving the region every year. Between 2000 and 2019, total emigration increased by 3.8 per cent. As for immigration, countries in Eastern Asia received 4.4 million immigrants in 2000 (0.29 per cent of the Eastern Asian population) and 4.7 million in 2019 (0.28 per cent). Mainland China sent and received the most migrants in the region, contributing to 86.0 per cent of total emigration and 71.0 per cent of total immigration in 2019 (see also [Online Appendix Fig. A.2](#)).

The other regions in Asia Pacific also experienced substantial changes in migration levels over time ([Table 6](#)). For example, South-Eastern Asia sent 2.9 million emigrants in 2000 (0.55 per cent of the South-Eastern Asian population) and 3.6 million persons in 2019 (0.54 per cent), while immigration increased from 2.5 million persons (0.48 per cent of the South-Eastern Asian population) to 3.1 million persons (0.47 per cent), respectively. Emigration from Australia and New Zealand increased by 37.1 per cent and immigration increased by 69.4 per cent. The Other Oceania countries nearly doubled their emigration levels between 2000 and 2019—from 87.5 thousand persons (1.02 per cent of the Other Oceanian population) to 122.5 thousand persons (1.01 per cent). North America represented one of the largest destinations for Asia-Pacific migration. In 2000, 5.6 million Asia-Pacific migrants are estimated to have moved to the USA and Canada. Over time, however, immigration to these two countries declined by 5.4 per cent to 5.2 million. Emigration from the USA and Canada was fairly stable, with around 1.6 million persons leaving in 2000 and 2019 (0.51 per cent and 0.44 per cent of the North American population). Finally, the results show that Rest of Asia has become an increasingly important source of immigration to Asia-Pacific countries, while flows from Africa are still relatively small (albeit nearly doubling in Eastern Asia).

Consider next the inter- and intra-regional patterns presented in [Table 6](#). Values on the diagonal represent intra-regional migration. Between 3.2 and 2.8 million persons (0.22 per cent and 0.14 per cent of the Southern Asian population) are estimated to have changed usual residence within the Southern Asian region in 2000 and 2019, accounting

Table 6. Estimated regional migration flows in 2000 and 2019

| Destination Origin        | Eastern Asia | South-Eastern Asia | Southern Asia | Australia and New Zealand | Other Oceania | USA and Canada | Rest of Asia | Africa  | Europe    | South and Central America | Total      |
|---------------------------|--------------|--------------------|---------------|---------------------------|---------------|----------------|--------------|---------|-----------|---------------------------|------------|
| Eastern Asia              | 1,172,455    | 833,235            | 535,387       | 84,090                    | 11,495        | 1,009,406      | 237,462      | 86,361  | 1,226,633 | 251,841                   | 5,448,362  |
| South-Eastern Asia        | 925,277      | 924,155            | 635,362       | 187,943                   | 17,968        | 946,578        | 317,503      | 174,939 | 1,189,746 | 335,125                   | 5,654,594  |
| Southern Asia             | 868,353      | 669,064            | 190,630       | 42,888                    | 18,835        | 318,242        | 370,844      | 20,102  | 378,007   | 20,861                    | 2,897,824  |
| Australia and New Zealand | 1,040,794    | 800,900            | 362,448       | 64,075                    | 26,330        | 321,702        | 510,867      | 33,820  | 360,058   | 44,542                    | 3,565,533  |
| Other Oceania             | 913,608      | 336,961            | 3,162,152     | 39,720                    | 6,628         | 779,088        | 1,373,098    | 208,275 | 1,575,881 | 91,698                    | 8,487,106  |
| USA and Canada            | 877,993      | 494,353            | 2,767,099     | 114,586                   | 7,233         | 839,177        | 2,498,987    | 374,203 | 1,484,266 | 179,192                   | 9,637,087  |
| Rest of Asia              | 79,068       | 27,952             | 19,384        | 21,203                    | 13,338        | 12,470         | 13,661       | 7,451   | 81,047    | 4,497                     | 280,070    |
| Africa                    | 162,316      | 35,609             | 48,187        | 25,197                    | 11,825        | 10,079         | 15,117       | 11,062  | 59,888    | 4,791                     | 384,068    |
| Europe                    | 22,269       | 22,263             | 1,559         | 16,593                    | 6,196         | 3,636          | 465          | 465     | 13,776    | 243                       | 87,464     |
| South and Central America | 39,095       | 38,706             | 1,883         | 17,255                    | 6,750         | 3,384          | 3,648        | 443     | 11,093    | 290                       | 122,545    |
| Total                     | 307,472      | 117,728            | 117,018       | 9,838                     | 2,451         | 69,335         | 62,166       | 29,148  | 305,644   | 558,857                   | 1,579,656  |
|                           | 264,964      | 120,298            | 191,460       | 13,150                    | 2,391         | 100,905        | 76,332       | 47,572  | 259,558   | 540,600                   | 1,617,227  |
|                           | 292,232      | 269,124            | 1,262,149     | 15,136                    | 698           | 184,071        | 0            | 0       | 0         | 0                         | 2,023,409  |
|                           | 391,258      | 418,481            | 2,227,350     | 22,517                    | 624           | 188,409        | 0            | 0       | 0         | 0                         | 3,248,639  |
|                           | 56,187       | 13,789             | 347,730       | 9,904                     | 288           | 126,916        | 0            | 0       | 0         | 0                         | 554,814    |
|                           | 106,926      | 21,632             | 217,754       | 23,373                    | 352           | 173,605        | 0            | 0       | 0         | 0                         | 543,641    |
|                           | 516,867      | 189,259            | 1,440,049     | 135,550                   | 6,033         | 928,692        | 0            | 0       | 0         | 0                         | 3,216,450  |
|                           | 659,938      | 208,713            | 810,259       | 164,015                   | 8,333         | 826,732        | 0            | 0       | 0         | 0                         | 2,677,989  |
|                           | 153,107      | 10,384             | 117,976       | 5,209                     | 162           | 2,138,636      | 0            | 0       | 0         | 0                         | 2,425,473  |
|                           | 241,835      | 26,392             | 132,070       | 11,736                    | 192           | 1,860,584      | 0            | 0       | 0         | 0                         | 2,272,809  |
|                           | 4,381,616    | 2,489,759          | 7,194,033     | 380,130                   | 66,123        | 5,570,490      | 2,057,694    | 351,801 | 3,580,986 | 927,997                   | 27,000,627 |
|                           | 4,710,395    | 3,089,237          | 7,393,870     | 643,845                   | 81,996        | 5,271,152      | 3,422,452    | 642,037 | 3,364,607 | 1,104,539                 | 29,724,129 |

Note: First row for each destination origin represents the year 2000; the second row represents 2019.

for approximately a third of total emigration and 40 per cent of total immigration. The majority of these persons are estimated to migrate between large populations. For example, in 2019, 1.0 million persons are estimated to have changed residence between India and Pakistan, contributing to 35.1 per cent of the intra-regional flow in Southern Asia. Between India and Bangladesh, it is estimated that 773.6 thousand persons had changed residence in 2019, contributing to 28.0 per cent of the intra-regional flow. Eastern Asia also exhibited substantial intra-regional migration flows with the largest flow occurring between mainland China and Japan. In 2000 and 2019, 380.4 thousand migrants and 200.7 thousand migrants, respectively, are estimated to have moved in this direction.

The largest inter-regional flows are found between Southern Asia and the Rest of Asia, driven in large part by flows between India and the Gulf States. Substantial migration flows are also estimated from Eastern Asia to Europe, South-Eastern Asia to Eastern Asia, Southern Asia to Europe, Europe to Southern Asia, and South and Central America to the USA and Canada. These large inter-regional flows reflect the increasing importance of Eastern and South-Eastern Asian countries as new destinations for international migration, although a large portion would represent migrants returning.

To further examine country-level migration flows, we next turn to countries with the highest net gains and net losses in 2000 and 2019. These numbers are presented in [Tables 7 and 8](#), ranked by the size of net migration in 2000. [Table 7](#) presents countries with the largest net losses. Countries on this list are primarily large developing populations with India, China, and Indonesia exhibiting the negative net migration totals. With increasing migration levels, India and Indonesia are estimated to have experienced increased net migration losses: India from 2.1 million in 2000 to 2.3 million in 2019; Indonesia from 415.3 thousand in 2000 to 513.6 thousand in 2019. However, China was estimated to have experienced a decline in net emigration over the 20-year period as a result of increasing immigration.

Other Asia-Pacific countries with high net migration losses in both 2000 and 2019 are Iran, the Philippines, Myanmar, Vietnam, North Korea, Cambodia, Papua New Guinea, and Pakistan, many of which are considered traditional sending countries. The North Korea numbers, however, appear too high for a country with very strict border controls. We estimated 96 thousand immigrants and 132 thousand emigrants for North Korea in 2000. In 2019, we estimated 58 thousand immigrants and 92 thousand emigrants for this country. In the United Nations migration stock database ([United Nations 2019a](#)), the number of migrants living abroad (migrant stock) who originated from North Korea was estimated to be 131.8 thousand in 2000 and 92.4 thousand in 2019, while the number of migrants living in North Korea born outside the country was estimated to be 36.2 thousand in 2000 and 49.4 thousand in 2019. Therefore, we believe these estimates are likely to be too high, as the model did not consider border control policies. Another unexpected result was, in 2000, Pakistan received 1.2 million immigrants and sent 0.9 million emigrants. In 2019, the corresponding numbers were 1.2 million immigrants and 1.4 million emigrants. As a result, Pakistan's net migration changed from positive (301.7 thousand in 2000) to negative (−191.6 thousand in 2019). Annual estimates of Pakistan's total emigration and immigration between 2000 and 2019 are presented in [Online Appendix Fig. A.2](#).



Table 8. Major origins and destinations in 2000 and 2019—Countries of the largest net gain (in thousands)

| Region        | USA and Canada | JPN Eastern Asia | BGD Southern Asia | PAK Southern Asia | CAN USA and Canada | MYS South-Eastern Asia | AFG Southern Asia | AUS Australia and New Zealand | NPL Southern Asia | LKA Southern Asia | THA South-Eastern Asia | KOR Eastern Asia |
|---------------|----------------|------------------|-------------------|-------------------|--------------------|------------------------|-------------------|-------------------------------|-------------------|-------------------|------------------------|------------------|
| 2000          |                |                  |                   |                   |                    |                        |                   |                               |                   |                   |                        |                  |
| Ranking       | 1              | 2                | 3                 | 4                 | 5                  | 6                      | 7                 | 8                             | 9                 | 10                | 12                     | 13               |
| Net migration | 3,797          | 624              | 315               | 302               | 199                | 146                    | 114               | 111                           | 104               | 59                | 32                     | 26               |
| Immigration   | 5,301          | 1,019            | 1,087             | 1,254             | 273                | 331                    | 301               | 318                           | 272               | 148               | 366                    | 226              |
| Emigration    | 1,504          | 395              | 771               | 952               | 75                 | 185                    | 187               | 206                           | 168               | 89                | 334                    | 200              |
| 2019          |                |                  |                   |                   |                    |                        |                   |                               |                   |                   |                        |                  |
| Ranking       | 1              | 3                | 7                 | 50                | 2                  | 5                      | 8                 | 4                             | 10                | 11                | 9                      | 6                |
| Net migration | 3,171          | 423              | 148               | -192              | 488                | 167                    | 110               | 211                           | 76                | 64                | 105                    | 146              |
| Immigration   | 4,698          | 555              | 963               | 1,224             | 578                | 420                    | 390               | 534                           | 234               | 142               | 377                    | 382              |
| Emigration    | 1,527          | 132              | 815               | 1,415             | 90                 | 254                    | 280               | 323                           | 159               | 78                | 272                    | 236              |

Table 8 contains countries with the largest net gains from international migration in 2000. As one might expect, the list is dominated by highly developed countries: the USA, Hong Kong, Japan, Canada, Singapore, Australia, and South Korea. Apart from these economics, Bangladesh, Pakistan, Malaysia, and Thailand were estimated to have experienced high net gains. Malaysia and Thailand are developing countries known for high levels of immigration (De Haas et al. 2020: 181), whereas Bangladesh appears questionable. For the USA, 5.3 million persons were estimated to immigrated in 2000 with a slight decline of 4.7 million persons in 2019, while over 1.5 million persons are estimated to have left the country each year.

In Fig. 7a, we present the migration flows for India, China, North Korea, and Pakistan representing large senders of migrants. In Fig. 7b, we present the migration patterns for the USA, Australia, Malaysia, and Thailand, representing large immigrant-receiving countries. Our estimates support the general literature on migration from India with most of the migrants going to the Gulf States, the USA, and other developed countries. Manual labourers generally go to the Gulf States, whereas highly skilled migrants are expected to go to the USA and other developed countries (De Haas et al. 2020). Our model does not capture the type of migration but does predict a relatively high turnover rate for flows between India and the Rest of Asia.

For China, the most popular destinations predicted by the model are Europe, the USA, South and Central America, and Japan. These destinations are either advanced economies or large populations. For North Korea, emigrants are most likely to go to China, the Rest of Asia, and Europe. At the beginning of the 21st century, emigration from North Korea to South and Central America was estimated to be fairly large. This result is driven by the trade variable in our model: South and Central America was a major trading partner with North Korea and about 30 per cent of North Korea's export went to this region. South Korea does not show up in Fig. 7a as a primary destination for North Korea, because the bilateral trade data and flow from North Korea to South Korea, which we used to distribute emigration flows, are missing between the two populations. South Korea Ministry of Unification (2020) reports that around 1,000 to 3,000 North Korean defectors entered South Korea each year between 2002 and 2019. In our model, we estimated the annual flow from North Korea to South Korea to be 876 in 2000 and 722 in 2019.

India, Europe, and the Rest of Asia are leading migration destinations and origins for Pakistan. It is estimated that there are more migrants moving from these three countries or regions to Pakistan than the other way around. A reverse in the trend, however, appears after 2009. Over time, the number of migrants from Pakistan to Europe, the Rest of Asia, and China increased substantially. For the other major destination countries, our results show that more people moved from Pakistan to Afghanistan than the other way around. This could be explained by the repatriation of refugees and/or poor economic conditions in Pakistan (UNHCR 2018).

For the USA, the largest source of immigrants is South and Central America, followed by China, Europe, and India. The large flows from South and Central America reflect the geographic proximity and extensive migrant networks. For Australia, immigration from Europe, China and India represent the largest origins. Immigration from Europe is driven by the historical migration connections between Europe and Australia. Large numbers of migrants from China and India are a result of the more recent focus on skilled migration (Raymer et al. 2018). While the model results captured the large observed inflows from

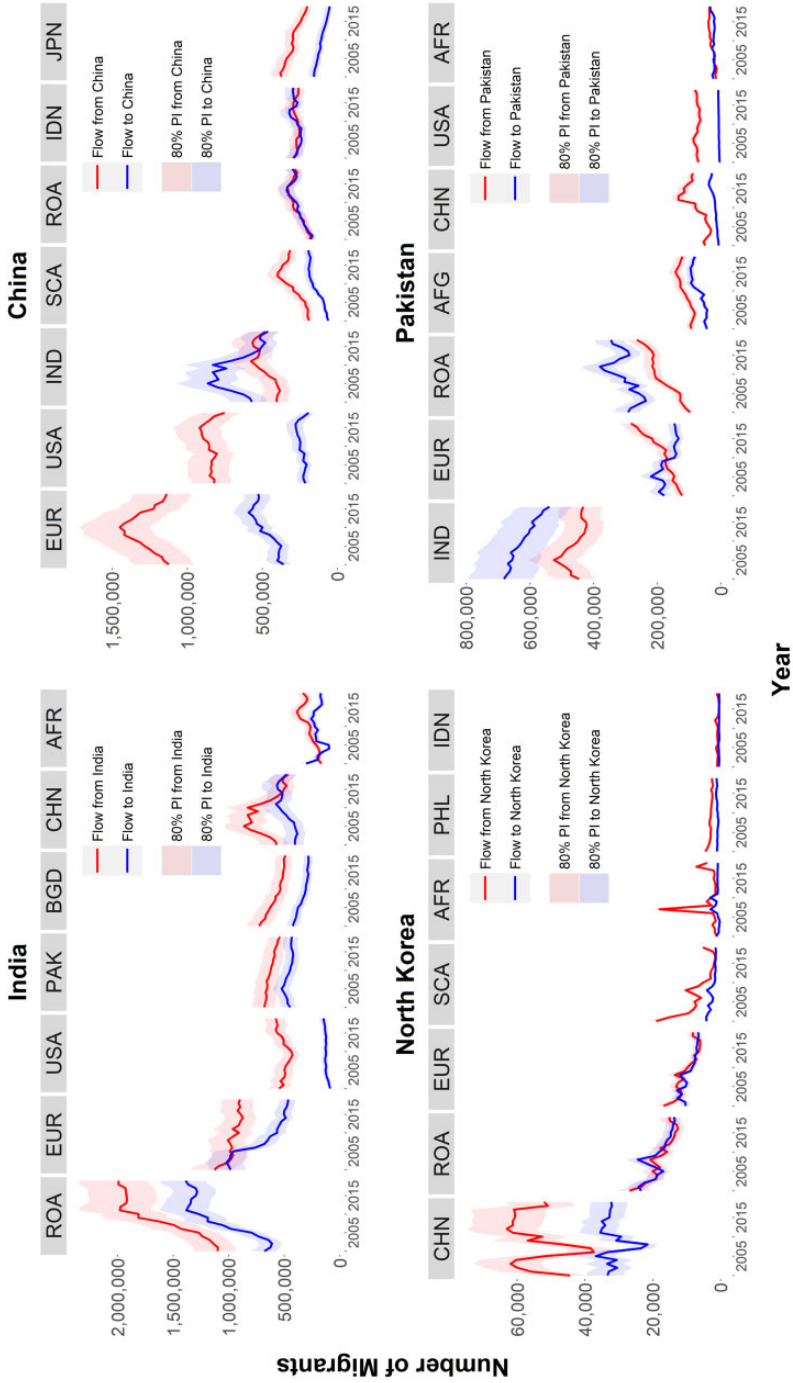


Figure 7. (a) Top seven destinations of four major emigration countries, 2000–19. (b) Top seven origins of four major immigration countries, 2000–19.



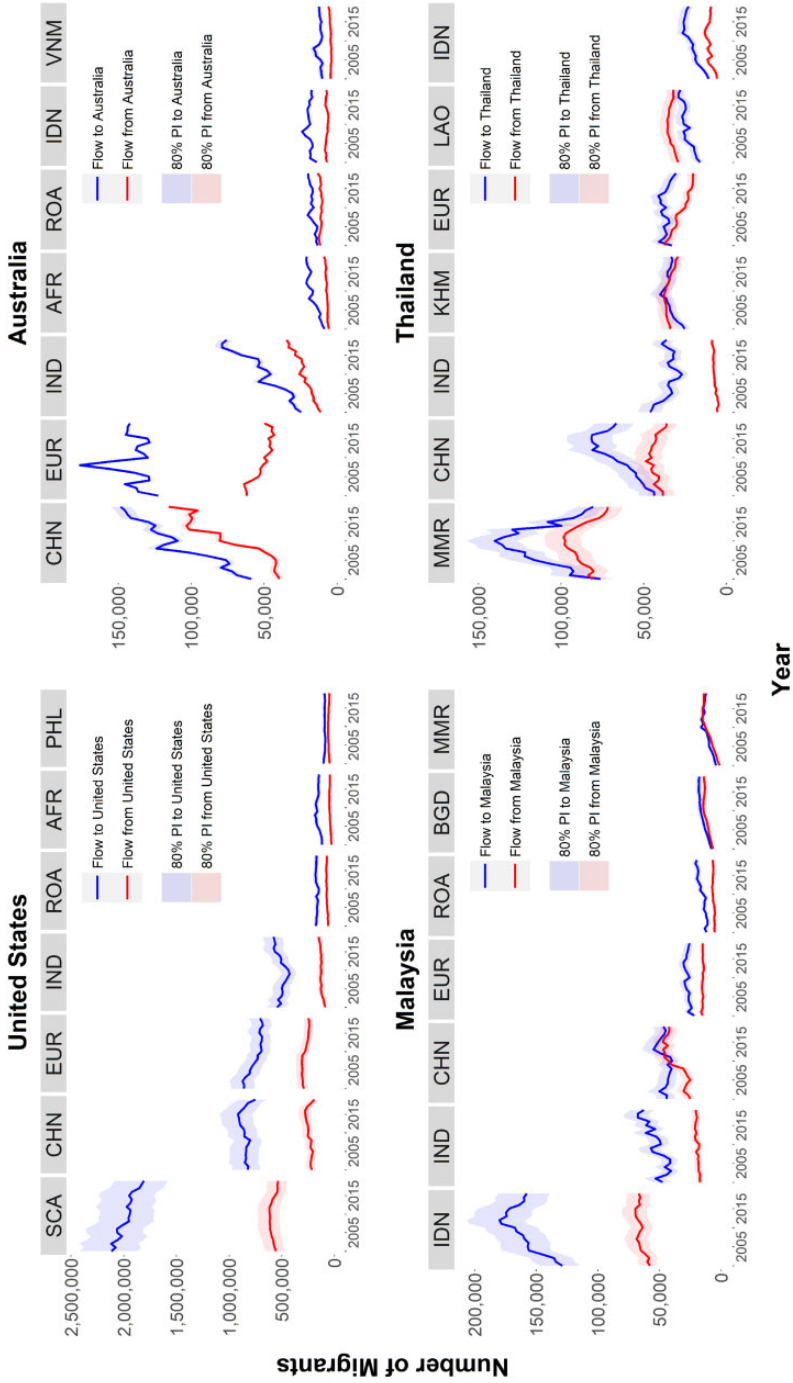


Figure 7. (Continued)

Europe, China, and India, it failed to capture the substantial number of migrants from New Zealand. This is due to the small population size of New Zealand and the exclusion of any bilateral migration agreements—in this case, the Trans-Tasman Travel Agreement between Australia and New Zealand.

Finally, large migration flows were estimated from Malaysia to Indonesia, India, China, Europe, and the Rest of Asia. For Thailand, large immigration flows were estimated from Myanmar, China, India, Europe, and many other Southeast Asia countries. By design, our model also estimates correspondingly high return migration from Thailand to Myanmar, Cambodia, Europe, and Laos.

## 5. Conclusion and discussion

In this paper, we have developed a generation–distribution methodology for estimating annual migration flows amongst countries in the Asia-Pacific region. These estimates are needed for understanding and quantifying the movements occurring in this region, which is undergoing rapid demographic and economic change. The sizes of flows are large. We estimated that migration increased from around 27 million persons in 2000 to 30 million persons in 2019. Over the 20 years, that translates into more than 500 million persons changing their country of residence.

The challenges to providing migration flow estimates in this region are immense. Hardly any countries provide data, and for those countries that do provide data, they are not comparable with other countries or often incomplete. Further, immigrant population stock data, which currently represent the best information available for studying migration in the region, do not translate well into flows. Stocks are based on birthplace or citizenship and, thus, fail to capture the large return (counter-flow) movements. They also represent a net accumulation of flows over time, and since migration evolves over time, they can misrepresent actual movements, especially for countries with ageing immigrant populations. Ideally, flows and stocks of migration would be aligned in terms of timing and measurement ([United Nations 2020c](#)).

In terms of future directions, the model framework presented in this paper is extendable in three obvious ways. First, the framework can be applied to estimate flows in other regions of the world where migration data are largely absent. Second, the framework can be extended to include more detail, such as sex or age. Other characteristics, such as education, skill levels, reason for migration could also be included provided we had information to draw from. Third, work should be carried out to improve the estimates of migration. This can be accomplished by working with national statistical offices or experts in the region to revise and refine the estimates or to incorporate additional data were available, including the possible consideration of digital trace data ([Fiorio et al. 2021](#)). The model framework is designed in a way that estimates can be revised with improvements in data or information. Of course, in the context of international migration estimates where reliable observations are sparse, validation is a major challenge (see, e.g. [Raymer et al. 2013](#); [Abel and Cohen 2019](#)). Finding ways to ensure the estimates are robust and meaningful, as well as convince policy makers of this, are needed for successful implementation. Finally, efforts are needed to improve the measures of uncertainty. The

uncertainty measures presented in this paper are likely to be underestimated, as they only reflect the variability of the data that underlie the relationships between total migration and predictor variables. Other important sources of uncertainty, such as the specification of the generation model and of the distribution of total emigration to bilateral flows, have not been taken into account.

In conclusion, there is a real need for better data on migration in the Asia-Pacific region and worldwide. The absence of good quality migration data is a longstanding ‘urgent’ problem—nearly 30 years ago, Frans Willekens wrote:

What is urgently needed is an international migration data base that is complete, consistent and contains reliable migration estimates. Completeness is striven for by bringing together information about all main aspects of the migration process. Consistency is reached through coordination of concepts and coverage and by an integration procedure which forces the migration data to fulfil the sets of definitions and accounting equations. (Willekens 1994: 4)

Over 10 years ago, Jeromey Huguet wrote:

Without a clear understanding of the many complexities associated with international migration, public perceptions can be inaccurate and can lead to distorted public policy. It would be useful to instill in government agencies the understanding that the statistics they compile and disseminate are not simply administrative data but are the basis for public discourse and policy making. (Huguet 2008: 252)

We believe the research presented in this paper works towards addressing these concerns. Moreover, it addresses three of Willekens’ (2019: 262–5; see also Willekens et al. 2016) recent recommendations for improved international migration estimates, namely the (1) documentation of available sources of international migration flows in the Asia-Pacific region, (2) utilisation of mathematical/statistical models to produce harmonised estimates, and (3) development of a ‘learning process’ platform for estimation.

The need for consistent and complete migration flow estimates is clearly evident in the Asia Pacific region where countries have been undergoing rapid demographic and economic developments. While by no means should our estimates be considered perfect, they do represent another major attempt at estimating flows alongside the work by Abel and colleagues that use immigrant stocks and demographic accounts to estimate flows (Abel, Raymer and Guan 2019). Although we incorporated the best available information we could gather, they too are likely to contain errors. That does not mean the estimates are not valuable. They provide a critical starting point for understanding the patterns and complexity of the movements. The alternative and current approach is to ignore the movements because there are no data. The estimates and methodology can assist national statistics offices and policy makers to overcome current data limitations. Moreover, the modelling framework can continue to be improved and revised until the day comes when they are no longer needed.

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## Supplementary data

[Supplementary data](#) is available at *Migration Studies* online.

*Conflict of interest statement.* None declared.

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