Disability in the kinship network: measuring lifetime exposure to kin with disability in 28 European countries

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Significance

The consequences of disability extend through kin networks, affecting kin across multiple dimensions of life. Our study highlights that disability is a widespread kin experience. This shift in perspective matters for understanding care demands, cumulative inequalities, and policies and environments needed to support people with disability and their kin. To quantify exposure to kin with disability in ways not possible with traditional surveys or conventional individual-level data, we use demographic kinship models for 28 European countries and show that such exposure is common across ages. Even when disability affects only a share of the population, kinship multiplies its reach: one case may affect several kin, and individuals themselves also become more likely to experience disability as they age.

Abstract

Although disability is not rare (as it directly affects 16% of the global population), its broader relational reach through kinship remains largely unmeasured. We use demographic kinship matrix models across European countries, combining fertility and mortality schedules with disability prevalence, to estimate exposure to kin with disability across ages in 2021. We quantify this exposure using three complementary measures: the probability of having at least one kin with disability, the (population-level) absolute number of individuals exposed, and the proportion of kin with disability. Our results show that, across the 28 European countries studied, exposure is widespread: in childhood and early adulthood, more than half to three-quarters of women have at least one grandparent with disability, and in midlife, about one-third to nearly one-half have at least one parent with disability. In population terms, this corresponds to about 1.5 million women exposed through grandparents and about 1.4 million through parents at those ages. Throughout much of a women's ages, between 20% and 40% of their close kin have disability. Although levels vary across countries, the life-course patterns are strikingly similar. These findings show that disability is not only an individual condition but also a relational exposure amplified by kinship, with implications for care demands, inequality, and the design of more inclusive social environments.

Acknowledgements

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Introduction

The medical model of disability has historically defined disability as a purely medical impairment. A lasting legacy of this approach is that disability continues to be viewed mainly as an individual condition, affecting only a limited segment of the population. However, the WHO has formally defined disability also as a social condition, stressing that the environment in which a person with an impairment is situated is crucial (1). Following this perspective, disability needs to be studied not as an isolated phenomenon. In general, since birth, individuals are embedded in kinship networks (2, 3) that connect them to other individuals across the life course, such as parents, grandparents, siblings, children, and grandchildren. Kin networks constitute a crucial social structure that shapes individuals' opportunities, resources, and constraints (3, 4). Kin provide companionship, practical assistance, and long-term support, often reducing social barriers, constituting a latent web of support and a relational reserve that is activated in times of need to safeguard its members throughout their life courses, thus becoming the most important resource when disability arises (5–8). Through these networks, the consequences of disability extend well beyond the individuals who directly experience it. Disability may, in fact, generate needs for care, support, and adaptation that may affect multiple kin simultaneously. Understanding this broader reach is increasingly important in ageing societies, where disability shapes not only individual well-being but also family care demands, intergenerational obligations, and the accumulation of social and economic disadvantage. However, these patterns remain poorly understood because most available data sources usually capture kin links and health only within households, for selected relationships, or in specific national contexts, leaving exposure to disability across the broader kin network (also including non-coresident kin) largely unmeasured. Disability itself is far from rare: worldwide, the World Health Organization estimates that more than 1 billion people have a disability, reaching around 16% of the world population (9). Despite this, its broader relational reach remains largely unmeasured. In fact, we still lack population-level evidence on how many people are exposed to disability of a kin and how such exposure is distributed across ages, kin types, and countries.

This gap is particularly striking because kin are central to how care and support are organised in most societies. Close family members are often the primary providers of long-term assistance (6), representing not only a source of social capital and reserves but also the potential pool of informal caregivers on which individuals and welfare systems rely. Having a kin member with disability can therefore shape individuals' lives in important ways, including: adverse health outcomes such as increased psychological distress, physical strain, and even elevated mortality risks (10, 11); changes in family trajectories and household organisation, influencing fertility expectations, partnership dynamics, and the timing of family formation when people anticipate or assume caregiving roles (12, 13); reduce labour market participation through lower working hours, transitions to part-time work, or labour-force exit, with long-term implications for income, pension accumulation, and economic security, as indirect costs (14–18); direct costs related to treatment, rehabilitation, assistive technologies, transport, or the purchase of formal support when public provision is limited (15, 19). These consequences often accumulate over the life course and intersect with broader axes of stratification, and especially with gender inequality, as women continue to assume a disproportionate share of care-related family responsibilities (20, 21). At the same time, exposure to disability within families should not be understood only through a burden lens: having a kin with disability may also foster solidarity, empathy, and prosocial orientations within kin relationships (22–25). Although much has been learned about the consequences of disability for kin members and its associations with individual-level outcomes, a basic first step is to establish how many people are exposed to disability through kin, and how this exposure varies by age, sex, kin type, and country. This makes measuring exposure to disability in kin networks crucial, not only because for identifying potential caregiving demands, but for revealing how widely disability shapes the lives and outcomes of people beyond those directly experiencing it.

In line with the ICF framework developed by the WHO (1), we rely on a definition of disability as a multidimensional outcome arising from the interaction between health conditions, functional limitations, and the social and physical environments in which people live, affecting individuals' ability to carry out everyday activities and to participate fully in social life, rather than as a fixed attribute of the individual alone.

Despite disability being usually framed only at the level of the individual, its implications are inherently relational. Kinship creates, in fact, a multiplier effect: when one person experiences disability, multiple kin may be affected at the same time through care responsibilities, financial consequences, altered family roles, and the need to navigate institutions and environments that are more or less inclusive. The presence of disability in one generation may also reverberate across others simultaneously: middle-aged adults may provide support to ageing parents while still caring for children (26), and the health status of grandparents may shape their ability to remain involved in intergenerational support.

Moreover, over the life course, individuals are themselves increasingly likely to experience disability, as reflected in age-specific prevalence and risks. Disability is therefore not confined to a small subgroup of the population. Rather, in different ways, it is encountered by many (and likely most) individuals either directly, indirectly through their kin, or both. This perspective shifts attention from disability as an isolated or marginal condition to disability as a widespread and interconnected feature of social life. For this reason, it also reinforces the urgency of creating more inclusive societies and environments. If disability is a widespread and interconnected feature of social life, then non-inclusive institutions, inaccessible spaces, discriminatory norms, and the treatment of disability as something isolated, different, or external have consequences that extend beyond those directly affected: they also shape the lives of kin, amplifying disadvantage across family networks and across generations.

This perspective is especially important in the context of demographic change. Across Europe, long-term declines in fertility and mortality have profoundly reshaped kinship structures (27, 28). Historically, higher fertility and lower survival produced kinship systems with broad horizontal ties and relatively short vertical overlap. As fertility declined and longevity increased, kinship networks shifted toward more “beanpole” structures: fewer members within each generation, but longer vertical extension across generations (27). In these thinner yet longer families, horizontal kin such as siblings become less numerous, while vertical ties such as parents, grandparents, children, and grandchildren are more likely to coexist for longer periods. At the same time, postponement of childbearing has widened age gaps between generations and shifted overlap toward older ages. Together, these changes mean that kin networks are ageing. Individuals may now spend more years coexisting with older parents and grandparents at ages when disability becomes more prevalent, while the pool of kin available to share responsibilities may shrink. This points to a more complex picture. On the one hand, smaller families may reduce some forms of multiplication of disability exposure simply because there are fewer kin. On the other hand, older kin networks imply more older relatives, for more years, at ages when disability risks are higher. Future disability exposure may therefore become concentrated within older and numerically thinner kinship networks, potentially intensifying pressures on fewer individuals.

These dynamics are unlikely to be uniform across countries. European populations have undergone fertility decline, mortality improvement, and epidemiological change at different times and with different intensity, producing substantial variation in kin availability, kin composition, and the age structure of kin networks (27–29). Southern European countries, characterised by very low fertility and rapid population ageing, tend to exhibit vertically extended but numerically smaller kin networks, while Northern and some Western European countries often retain somewhat larger kin pools because of higher fertility combined with similar low mortality. Central and Eastern Europe followed yet other demographic trajectories, resulting in more heterogeneous patterns, marked in many cases by persistently lower life expectancy and high avoidable mortality (30), yielding more heterogeneous

patterns of kin availability and characteristics. European countries also differ in the extent of investment in prevention and healthy ageing (31), which may contribute to cross-national variation in the timing and pace of epidemiological transition, and thus in the resulting health and disability profiles.

In addition, countries differ in how care responsibilities are organised between families, the state, and the market (32–36). In more familistic contexts, kin remain the primary providers of care because public alternatives are scarce or limited; in more de-familialised contexts, state and market actors reduce dependence on families through formal childcare, long-term care services, and income support. The same level of exposure may therefore generate different pressures on individuals and households depending on whether care is assumed mainly within families, supported by public policies, or partially substituted by formal services: where welfare services are less generous, disability is more likely to translate into substantial burdens for kin, whereas in contexts with stronger public support, these consequences may be partly mitigated. Europe offers a valuable comparative setting for examining how disability exposure through kinship is shaped jointly by demographic history, health profiles, and to reflect on how its implications may vary across care contexts.

Understanding patterns of exposure to kin with disability is usually difficult because data rarely capture whole kinship networks directly, together with their health status. In most surveys, administrative sources, and population registers, detailed kin links are observed only within households, for selected relationships, or for specific national contexts, leaving the broader family network and its health status largely untracked. Formal demographic kinship models have become a crucial tool for estimating kin availability and kin structure from fertility and mortality schedules. A growing literature has used these models to show how demographic regimes shape the number and composition of kin over the ages and populations (2, 28, 37–43). Some recent work has also started to incorporate health conditions into kinship analyses. In particular, Feng and colleagues examined kin-based dementia exposure in the United States and projected the future dementia burden in China, showing how population ageing and family change redistribute potential care demands across generations (44, 45). These studies demonstrate the value of integrating the health component into the study of kinship, but evidence on disability exposure and comparisons across countries remains lacking. This leaves an important gap. Compared with specific late-life conditions, overall disability is broader and more prevalent, spans a wider part of the life course, and is likely to affect kinship networks in ways that are both quantitatively substantial and socially consequential. Yet we still don’t know how many people are exposed to disability within kin networks, how this exposure changes with age, and how it varies across countries.

Addressing this gap is important for at least three reasons. First, exposure to disability through kinship is likely to be widespread. Even when disability affects a minority at particular ages, most individuals are connected to several kin, so that one case may affect multiple lives simultaneously. Second, this exposure shapes individual outcomes, such as health, labour supply,

family trajectories, and economic security, and those effects may accumulate across the life course and reinforce existing inequalities. Third, a kinship perspective adds to existing arguments for inclusive environments by showing that the disadvantages associated with disability are not confined to individuals with disability, but also affect the many relatives whose lives are organised around support, care, and adaptation. Viewing disability only at the level of the individual, therefore risks understating both its prevalence in everyday social life and its broader implications for inequality, intergenerational dependency, and welfare-state sustainability.

In this study, we quantify exposure to disability within kinship networks across European countries using demographic kinship models. We combine age- and sex-specific fertility and mortality rates with disability prevalence to reconstruct kinship networks and characterise their disability composition across individuals' ages. We focus on a restricted pool of close kin, namely grandparents, parents, siblings, children, and grandchildren, because these relationships are especially relevant for support and care (7, 46, 47). This pool includes the close kin of first-degree (parents and children) and second-degree (grandparents, grandchildren, and siblings), while excluding more distant kin. It allows us to follow four family generations, which have become increasingly important as vertical kinship relations lengthen. We assess exposure to disability in the kinship network through three complementary metrics: the probability of having at least one kin with disability, the absolute number of individuals affected, and the proportion of kin with disability. Together, these measures capture how likely exposure is, how many people it reaches, and how large a share of kin networks it represents. By combining these perspectives, we conceptualise exposure to kin disability as a structural characteristic of kinship systems.

To do so, our analytical approach proceeds in four steps: (i) we draw on age-, sex-, and country-specific fertility and mortality schedules from 1950 to 2021 from the United Nations World Population Prospects (UNWPP), to reconstruct kinship networks for 28 European countries and an EU aggregate, and to estimate the expected number of kin by kin type, sex, and age of a focal individual; (ii) we combine these kinship estimates with age- and sex-specific disability prevalence from EU-SILC survey to specifiy kin disability status (with or without disability); (iii) from these quantities, we derive the two complementary measures of exposure to disability through kin, namely the probability of having at least one kin with disability and the proportion of kin with disability; and (iv) we use age- and sex-specific population counts from the UNWPP to translate the probabilities into population-level figures.

Figure 1 illustrates the logic of the three measures used in the study with a schematic example population of four (focal) women at same age, e.g. aged 35, and each has five living kin, but their kin networks differ: A has two parents, one sibling, and two children, with one parent having disability; B has two parents, one sibling, one grandparent, and one child, with no kin having disability; C has one parent, one sibling, one grandparent, and two children, with one sibling and one child having disability; and D has two parents, one sibling, and two children, with one parent having

disability. The figure illustrates the logic of the three measures used in the study using this toy population of four focal women. First, the probability represents the share of individuals who have at least one kin with disability at age 35; in the example, 3 of 4 women age 35 have at least one kin with disability, yielding a probability of 0.75. Second, this probability can be translated into an absolute population estimate by multiplying it by the number of women at that age in the overall population of women aged 35 in the specific country. Third, the proportion of kin with disability when women are 35 years old measures, in relative terms, how many of their kin have a disability: for the focal individual C in the example, 2 of 5 alive kin have disability, corresponding to the 40%. For the same individual, this 40% can be broken down into a 20% that is the share of kin that are siblings and are with disability, and 20% that are children and are with disability, summing to a total of 40% share of overall kin with disability. This figure is purely schematic and is intended only to illustrate the logic of the measures. The circles, in fact, represent simplified examples of kinship networks in which some kin have disability and others do not, but the empirical estimates in our analysis are not obtained by directly counting observed individuals in observed kinship networks. Instead, for each focal age, sex, country, and kin type, the kinship model uses fertility and mortality schedules to estimate an average kinship network with the expected number of living kin, and then combines these estimates with age- and sex-specific disability prevalence to derive the expected number of kin with disability. The measures of interest are then derived from these expected values.

Full details are provided in Data and Methods section.

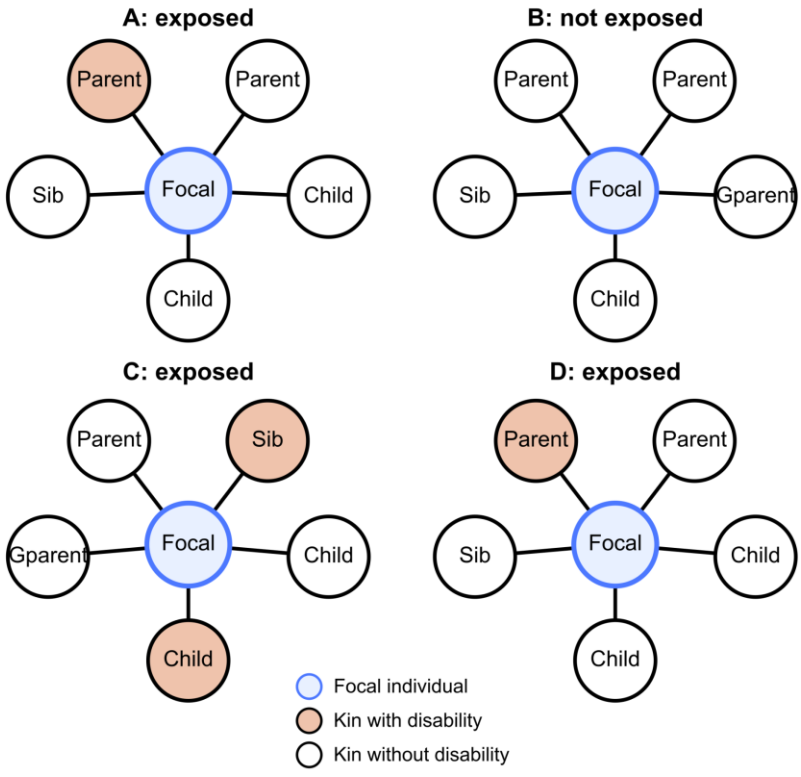

Figure 1: Illustrative example of some kinship networks, where kin are specified by type and disability status.

Results

Probability of having at least one kin with disability

To understand how widespread exposure to disability through kin is across individuals, Figure 2 shows the probability that women, at each age in 2021, have at least one kin member with disability, for each kin and across all study countries, with Italy and Portugal highlighted as examples of contexts with high and low probability respectively, along with the EU-27 aggregate.

Across contexts, the overall age pattern is strikingly similar. The probability of having at least one grandparent with disability is high in early life and rises sharply through childhood and adolescence, reaching its maximum in young adulthood. At these ages, individuals have a high probability of having at least one grandparent with disability, making grandparental disability a common form of exposure early in life. This peak ranges roughly between 50% and 75%, meaning that more than half to nearly two-thirds of individuals have at least one grandparent with disability at these ages. Thereafter, this probability declines relatively quickly across adulthood, approaching zero at older ages, as grandparent extinct from the kin network. The probability of having at least one parent with disability is already non-negligible in childhood and early adulthood and typically increases steadily later in life, as parents age. It peaks around age 50 (or shortly earlier), when individuals' probability of having at least one parent with disability reaches approximately 30 to 50% (meaning that roughly one third to half of individuals in midlife have a parent with disability), and then declines at women's older ages.

For both older and younger siblings of the focal individual, the probability increases gradually through adulthood as siblings age and disability becomes more prevalent, and the probability reaches the highest levels in later life (with the probability of having at least one older sibling with disability rising earlier than that for younger siblings, reflecting age ordering within sibships). At very older ages, the probability of having at least one sibling with disability is around or exceeds the 25%, indicating that exposure to sibling disability becomes more common in later life, affecting many older individuals who have siblings alive at older ages. In terms of exposure to disability among descendant kin, the probability of having at least one child with disability begins to rise in young adulthood as children are born and age, and continues increasing into mid and later life. By very old ages (85+), often more than 30% of individuals reaching those ages have at least one child with disability. The probability of having at least one grandchild with disability emerges later (as also grandchildren are born, from midlife onwards), and rises progressively at older ages of the focal individual as grandchildren accumulate and grow older. Importantly, the probability of having children and especially grandchildren with disability at very old ages remains relatively high as a result of

both the selective survival of the focal individual (the focal individual being alive at very advanced ages) and the fact that the surviving descendants have themselves reached older ages, when disability becomes more prevalent.

Countries slightly differ in the overall level, shape, and timing of these probability profiles by age. In some contexts, probabilities are generally higher across kin types (e.g. Portugal), whereas in others they remain lower (e.g. Italy). In general, cross country differences generally shrink at older ages in the case of ascendant kin and siblings (as they generally extinct from the kin networks), while they narrow for descendants (likely because of heterogeneity in fertility levels and thus the number of descendant kin overall). The curves also vary in how strongly exposure is concentrated at particular ages, as some are more clearly peaked, while others are flatter and more gradual, with smoother shifts across kin types and ages.

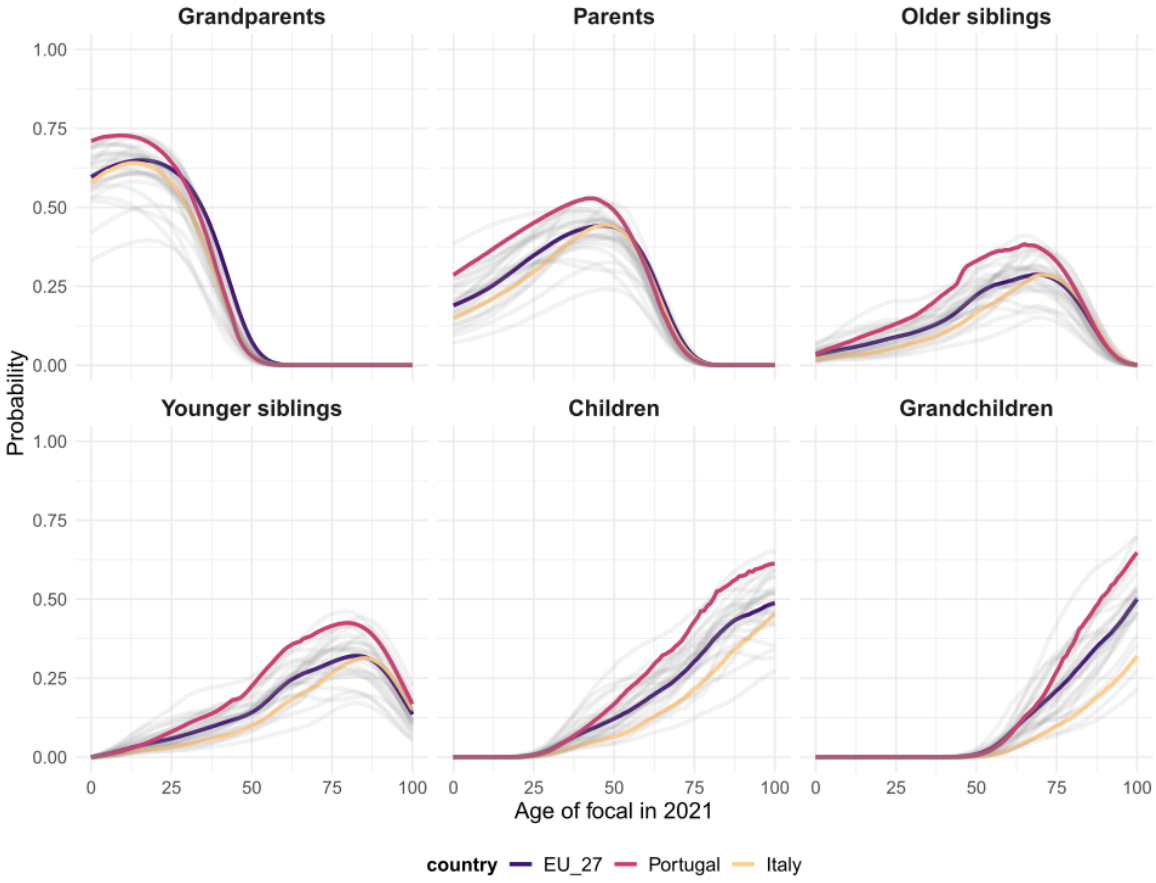

Figure 2: Probability of having at least a kin with disability, by kin type (e.g. probability of having at least one grandparent with disability, etc.) and age of a focal woman in 2021

Absolute number of kin with disability

Figure 3 translates the probability estimates into the absolute number of women who have at least one kin with disability by focal age and kin type in 2021, for the aggregate Europe (EU-27) in panel A and all considered countries in panel B. Expressing the results in absolute numbers highlights the population-level magnitude of this exposure and shows how many individuals are likely to experience disability within their kinship networks at different stages of life.

In overall Europe (Figure 3 panel A), exposure reaches very large numbers across women's ages: grandparent disability affects up to around 1.5 million women in childhood and early adulthood, parental disability peaks at around 1.4 million women in midlife, exposure through older and younger siblings reaches roughly 0.8 and 0.75 million women later in life, and exposure through children and grandchildren rises at very old ages to around 0.7 and 0.5 million women, respectively. As a country example, in Italy (Figure 3 panel B), exposure to grandparent disability involves up to around 175,000 women during childhood and early adulthood. Exposure to parental disability becomes most prominent in midlife, reaching more than 200,000 women between ages 40 and 55, and representing the largest group of exposed women across ages. Exposure to older siblings with disability generally involves up to around 100,000 women, peaking in later adulthood and early older age. At older ages, exposure to younger siblings can affect up to around 80,000 women, while exposure through children and grandchildren can involve up to about 75,000 and 35,000 women, respectively.

The overall age profile and sequencing of kin types are similar across different contexts (Figure 3 panel B). Exposure in absolute numbers is high early in life because of grandparent disability, followed in midlife by parental disability, and later by disability among siblings, children, and eventually grandchildren. These age profiles mirror the dynamics described for the probability measure and reflect the changing composition of kinship networks over the life course. In fact, different generations overlap at different stages of the life course, and the likelihood that each type of kin experiences disability changes with age, so that the ageing and disappearance of older generations and the progressive emergence and ageing of descendants shape which kin types contribute most to exposure at different ages. Although this common sequencing holds across all countries, the curves still slightly differ in overall levels, in how strongly exposure is concentrated at particular ages, and in the precise timing at which different kin types become most important. In some countries (e.g. Italy), the profiles are generally higher and more sharply peaked, with exposure more strongly concentrated in early life and midlife. In others (e.g. Sweden), the curves are lower overall and flatter, indicating a more gradual age pattern and less pronounced concentration at specific ages. Countries also differ in how clearly one kin type gives way to another as the main source of exposure. In some contexts (e.g. Poland), the life-course shift from grandparent-driven exposure in early life to parent-driven exposure in midlife, and later to sibling- and descendant-driven exposure, is more clearly marked. In others (e.g. Germany), these phases overlap more, so that the decline of one kin type and the rise of another occur more gradually and less suddenly. Differences across countries in the absolute number of women exposed reflect not only differences in the

probability of exposure, but also the size and age profile of the underlying female population. In other words, the number exposed at each age depends both on the likelihood of having at least one kin with disability and on how many women are alive at that age group in a given country (see Appendix Figure A8, showing these numbers alongside population counts at each age). Variation in the magnitude, shape, and location of these curves thus reflects also differences in cohort size across ages, shaped by each country's demographic history, including the timing and intensity of baby booms, subsequent fertility decline, and broader processes of population ageing.

This exposure may also be cumulative, as individuals can encounter disability among different kin at different ages.

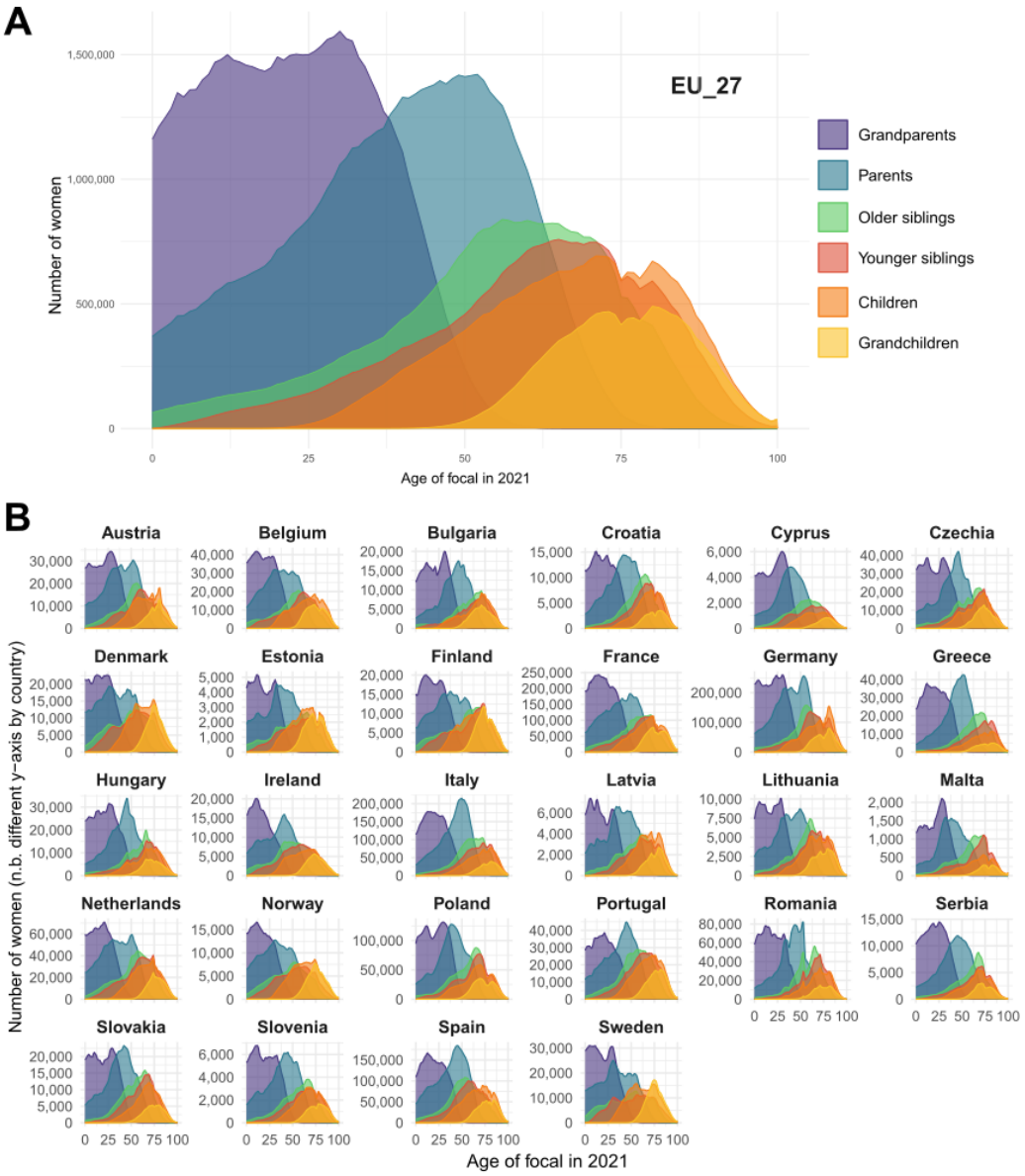

Figure 3: Absolute number of women having at least one kin with disability, by kin type and age of the focal woman in 2021

Proportion of kin with disability

A complementary perspective is provided by the proportion of the total kin of a woman who are with disability, providing a measure of the magnitude of such exposure, meaning, over total available kin, how many are with disability. Figure 4 panel B shows the proportion of kin with disability for a woman at age 25 in 2021. Across European countries, this proportion typically ranges from around 15% to around 35%. Some geographical patterns can be observed: countries in Northern and Western Europe often have lower proportions (Norway among the lowest overall), while countries in Southern and parts of Eastern Europe show higher proportions. Portugal has the highest proportion in Europe, while Italy has close to average levels, and lower than the other Southern European countries. France and Ireland show relatively low proportions (likely reflecting the overall larger number of kin in these countries due to higher fertility). Within Northern Europe, Finland and Denmark are exceptions, showing levels that are closer to the Baltic states (Estonia, Latvia, Lithuania) than to their Nordic neighbouring countries. Eastern Europe and the Balkanic area are quite heterogeneous, with both low (Serbia and Bulgaria) and high (Croatia) values depending on the country. Maps for the proportion at other ages are provided in the Appendix, Figures A6.1 to A6.4.

Figure 4, panel A shows the proportion of kin with disability across ages of a woman across European countries, with Portugal, Italy, and Norway highlighted as examples of countries with high, mid, and low values of this proportion, respectively. Also in the case of the proportion, across contexts a broadly similar age pattern can be observed, although in some countries the variations over age are less pronounced (such as in Norway). The proportion of kin with disability increases during women's early life (childhood and youth), reaching its overall maximum around age 25, then declines until around age 40. A second, smaller peak appears in late adulthood (around ages 50–55), followed by another decline up to around age 60. After this point, the proportion tends to rise again (reflecting the ageing and accumulation of disability at older ages among kin). While the overall level (and variation over age) differs between countries, the general age trend of the proportion of kin with disability is relatively consistent across Europe. These dynamics can be further understood if this overall proportion is broken down by kin type, as in Figure 4 panel C. The total proportion of kin with disability is first computed across all kin (as shown in Figure 4 panel A) and then subdivided by kin type, so that the stacked areas sum to the overall proportion, and each component represents the share of all kin that are of a given type and have a disability.

In the first part of life (up to around ages 40–50), the proportion is mainly driven by the disability of ascendant kin. The first peak around age 25 largely reflects the ageing of grandparents, who increasingly experience disability before gradually disappearing (by death) from the kin network. The second peak around late adulthood is mainly due to the ageing of parents, whose contribution then declines as they also begin to disappear. Then, and especially at older ages, the increase of the proportion of kin with disability is increasingly driven by siblings (first the older, then younger

ones) as well as by descendant kin, with children and eventually grandchildren contributing to the rising share of kin with disability at their older ages, in the oldest age of the focal individuals. Generally, these distributions also reflect the changing kinship composition across the ages of individuals. In early life, kin are mainly composed of grandparents, parents, and siblings (first the older, then the younger ones). During young and mid-adulthood (around ages 20–40), children start appearing and accounting for an increasing share of the kinship network. In later adulthood and at older ages (50+), grandchildren gradually appear, while older relatives begin to disappear, so that family composition shifts from being dominated by ascendants to being increasingly dominated by descendants. In terms of country differences, in Portugal, compared to the other two countries, grandparents have the largest share of the total proportion of kin with disability at younger ages, and children and grandchildren at older ages. In Italy, the contribution of parents is relatively higher around midlife, while at older ages, descendants play a smaller role than in Portugal. In Norway, the distribution is flatter overall, with the proportion of kin with disability remaining at less than 20% across all ages.

Full kin counts (denominator) underlying the proportion estimates in selected countries are shown in Appendix Figure A4, and the corresponding total counts of kin by disability status (numerator) are reported in Appendix Figure A5.

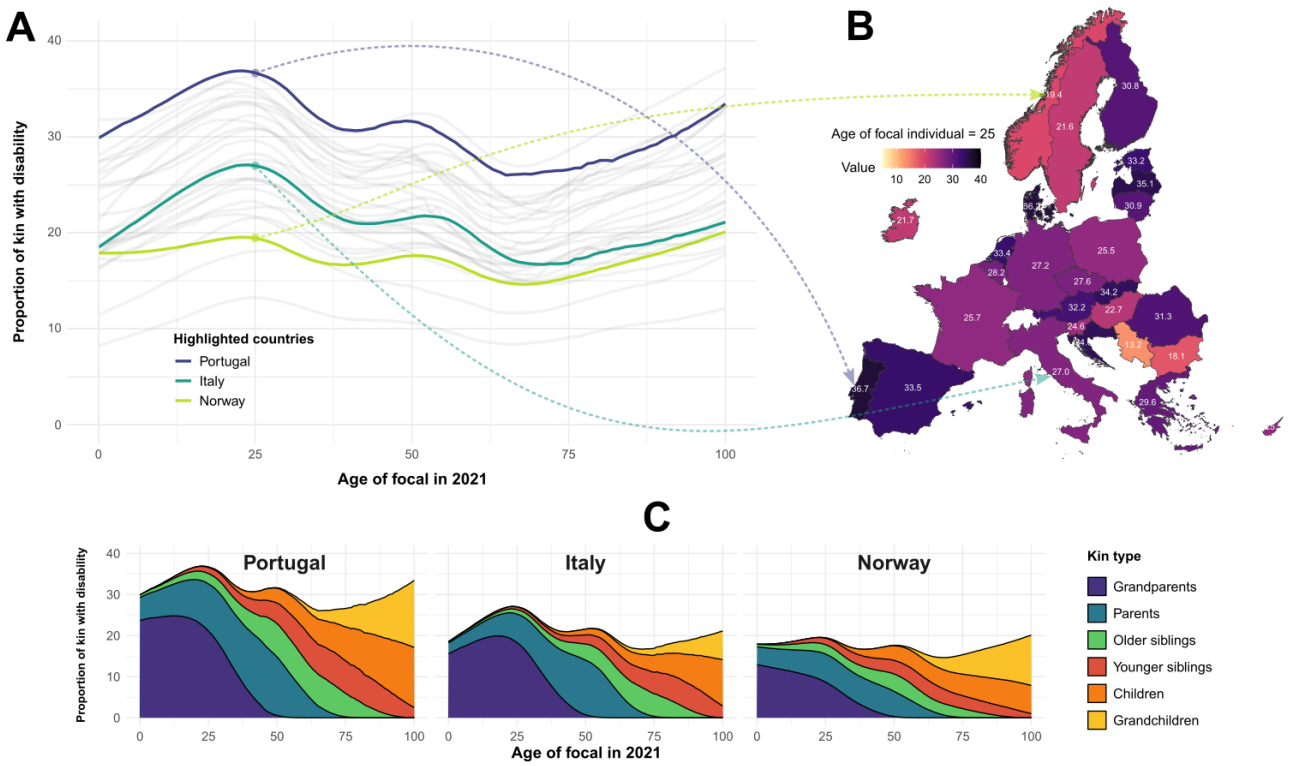

Figure 4: Magnitude of the exposure measured using the proportion of kin with disability. Panel A: Proportion of kin with disability over the life of a woman in 2021, highlighted for selected countries (Portugal, Italy, Norway); Panel B: Map of the proportion of kin with disability for a 25-year-old woman

in 2021 in European Countries. Panel C: Specification of the proportion by kin type, over the life of a woman in 2021 in selected countries.

Robustness analysis

We conducted two sets of robustness checks to assess whether the main findings depend on modelling assumptions and to compare selected estimates with directly observed survey data.

First, because the probability of having at least one kin with disability is derived from expected kin counts, we examined whether the results are sensitive to alternative assumptions about the extent to which disability may be concentrated within families (see methods section). Allowing for less or more clustering slightly changes the absolute level of the estimated probabilities only modestly, shifting them upward or downward, while leaving the age profiles and cross-national differences essentially unchanged (Appendix Fig. A7). The total range between the lower and upper probability bounds is generally around the 5% (about ± 2.5% around the main estimate). The same holds for the corresponding population-level estimates, which vary only within a limited range across alternative specifications (the lower-to-upper bound spans 5% of the main estimate, about ±2.5%), without altering the overall patterns or substantive conclusions (Appendix Fig. A9).

Second, we compared selected model-based estimates with corresponding indicators computed directly from individual-level EU-SILC data, where kin links can be tracked only for co-living individuals. This comparison focuses thus on mothers, fathers, and children who live in the same household as the focal individual (because these are the kin ties that can be identified consistently in SILC data). Other kin types (such as grandparents) are less likely to be observed in the same household and therefore their estimates cannot be compared. Despite this more restrictive comparison, the model-based estimates are found to be broadly consistent with the household-based SILC ones, indicating that the model captures similar levels of exposure where direct validation is possible (Appendix Fig. A10-13). We found some small differences, particularly for the probabilities at advanced age for parents and children, which tend to be slightly higher in the model-based estimates. This pattern is expected, because the kinship model captures exposure to all kin, whereas the empirical SILC measures are restricted to co-resident kin and therefore reflect a narrower subset of potential exposure, especially at later ages when kin are less likely to live together. Previous research has shown that demographic kinship models closely reproduce observed kinship structures when compared with survey and population register data, supporting their validity in capturing overall kin availability (48, 49). Here we extend that validation to the health dimension of kinship networks by comparing model-based estimates of disability exposure with empirical measures derived from SILC data for coresident kin.

Overall, these checks show not only that the main findings are robust to alternative assumptions and broadly consistent with the survey evidence when direct comparison is possible, but also that the study contributes methodologically by validating the modelling approach in this setting.

Discussion

Mapping the exposure to kin with disability is of crucial importance, yet no previous studies have estimated such exposure and explored how it develops across the ages of individuals, from which kin relation, and across countries. This is striking given that disability is far from rare, and even less rare are the many kin members whose lives are connected to it. To our knowledge, this study provides the first population-level estimates of exposure to disability through kinship, across European countries. Using demographic kinship models augmented with age- and sex-specific disability prevalence, we show that, across European countries, this exposure follows a strikingly consistent age pattern: exposure is concentrated from grandparents in childhood and young adulthood, shifts to parents in midlife, and increasingly involves siblings and descendants at older ages in young adulthood. Around one-half to three-quarters of women have at least one grandparent with disability; in midlife, roughly one-third to one-half have at least one parent with disability; and at older ages, exposure through siblings and descendants becomes increasingly common. When translated into population counts, very large numbers of women are exposed, reaching up to about 1.5 million women through grandparents in early life and 1.4 million through parents in midlife in Europe. The proportion of kin who are with disability can even reach the 20% to 40% of the total available kin when this exposure is highest. Taken together, these findings show that disability is not confined to a subgroup of individuals, but is high and a widespread relational exposure not confined to specific ages or kin types, but instead structured by demographic, health, and kinship regimes across Europe.

Interpretation and future trends

The similarity of the age profiles of exposure across countries suggests a common logic. Exposure to kin with disability depends on two linked processes: the age composition of kin networks (how many and which kin are alive at each age in a country) and the age gradient of disability (how likely individuals are to experience disability at each age in a country). The differences observed across countries are likely the result of distinct demographic and health trajectories that European populations have undergone. Fertility and mortality transitions unfolded at different times, with varying pace, intensity, and duration, generating diverse populations, with diverse age structures and kinship configurations across countries (27, 28). Age-specific fertility and survival schedules differ across contexts (see Appendix Figures A1 and A2), resulting in different pools of kin alive at

each age of the focal individual (Appendix Figure A4). For example, countries where low exposure is found, such as Norway, that are characterised by comparatively higher and earlier fertility levels in recent decades, tend to exhibit slightly larger and younger numbers of siblings, children, and grandchildren at most ages compared to high and mid exposure countries, such as Portugal and Italy. These structural differences in kin availability directly shape the size and composition by age and kin type of kinship networks. At the same time, cross-national variation in health and epidemiological trajectories (29) also plays an important role in determining the exposure to kin disbaility. Age-specific disability prevalence profiles differ across countries (see Appendix, Figure A3). For instance, Portugal has consistently higher disability prevalence at most ages, if compared to countries with low or medium exposure. This implies that even if two countries had identical kinship structures, the one having higher disability prevalence would exhibit higher proportions of kin with disability and a greater probability of having at least one kin with disability than a lower exposure one (see the differences in the overall number of kin with disability for selected countries in Appendix Figure A5). These dynamics can be better captured in future studies aimed at exploring drivers of changes in exposure to kin disability, disentangling how much is driven by each factor.

Mapping exposure to kin with disability helps capture how many individuals are likely to face caregiving responsibilities, which is crucial since such exposure can translate into an often overlooked source of inequalities in individuals' (social and health) outcomes, that can also intersect and accumulate with the other axes of stratification, such as gender and socioeconomic status. In fact, the exposure to kin disability can also be understood as a hidden structural inequality. Demographic and health trajectories shape the likelihood that individuals will face disability caregiving demands across their lives, so that exposure to kin disability is not merely an individual circumstance but a demographic driver of caregiving pressure.

Our results also speak to future demographic change. Because kinship networks and their health characteristics are structured by fertility, mortality and health regimes, demographic changes systematically redistribute potential care demands across generations and ages. Ongoing trends suggest that exposure to kin with disability is likely to intensify in important ways in the future across Europe. Sustained increase in life expectancy and population longevity act to extend the intergenerational overlaps, so that individuals are increasingly likely to coexist for longer periods with ageing parents and grandparents at ages when disability risk is highest. At the same time, sustained fertility postponement shifts this overlap to even older ages, while persistently low fertility reduces the number of siblings and descendants within families, shrinking the pool of potential caregivers with whom responsibilities can be shared. Future kinship networks are therefore likely to be even more vertically extended but numerically thinner, concentrating disability caregiving demands on fewer individuals and potentially intensifying pressures over the life course. These demographic pressures may be partly counterbalanced if countries succeed in reducing disability risks and postponing disability onset to later ages. Investments in prevention, healthier behaviours, medical

research, technological change, and more accessible environments could reduce the prevalence of disability at given ages or shift its onset further into later life, thereby lowering exposure to kin with disability over parts of the life course. Future exposure will therefore depend not only on changes in kinship structure, but also on the extent to which improvements in population health are able to delay or reduce disability at older ages.

The measures proposed in this study complement existing ones on kin availability by incorporating the health dimension of kin, thereby offering a more comprehensive assessment of intergenerational dependency structures and may also be interpreted as indicators of kinship vulnerability. By quantifying both how widespread this exposure is and its intensity, we provide a demographic metric of how "care-demanding" kinship networks are likely to be, for whom, and for how many people.

Limitations

This work has some limitations. First, we restrict attention to grandparents, parents, siblings, children, and grandchildren, thereby excluding extended kin and partners, even though they may also be important sources of support. Their exposure is therefore relevant to consider, especially for partners at older ages, when disability risk is highest. We do not include the latter here because partners' relationships can not (yet) be generated by standard demographic kinship models in the same way as biological kin. Incorporating partnership histories, union formation and dissolution, and partners' characteristics (such as age, determining their survival) would require a distinct modelling framework. For this reason, the omission of partners should not be interpreted as indicating lesser substantive importance, but rather as a limitation of the current modelling design. Extending the analysis to partners is therefore an important priority for future work.

Second, kin are only part of individuals' broader social networks, and our estimates only reflect *potential exposure* to kin disability rather than the actual quality or intensity of these relationships. Moreover, the consequences of having a kin member with disability may depend not only on the presence of disability itself, but also on how many other kin are available within the network. The effect of exposure may differ in smaller versus larger kinship networks, as caregiving responsibilities can be shared or concentrated depending on the number and type of available relatives. While our proportion measure partly captures this relational dimension by expressing kin with disability relative to overall kin availability, the heterogeneous implications of exposure depending on the kin composition, kin characteristics, and the presence of a broader social network remain beyond the scope of our analysis.

Third, our estimates implicitly assume that the disability prevalence observed among individuals of a given age also applies to those who are kin of the focal individual and have that age, so that the age profile of disability is applied to the age profile of the focal individual's kin. This assumption may not always hold. For instance, individuals with disability at birth or originating in

early life are less likely to have children, and thus disability prevalence among parents and grandparents may be lower than in the general population of the same age. However, disabilities that are present from birth or early life constitute only a (relatively small) share of all disability cases, whereas the vast majority of disabilities arise at older ages as a consequence of age-related health deterioration. Since the onset of most disabilities occurs after the reproductive period, the potential downward bias in disability prevalence among older kin is likely to be limited.

Fourth, the measurement of disability based on GALI indicator, which is a self-reported measure of activity limitations. Although GALI is widely used and harmonised across European countries (50–53), cross-national differences in disability prevalence may partly reflect variation in subjective perceptions of limitations, influenced by contextual factors such as infrastructure, accessibility, social norms, and expectations regarding functioning. As a result, individuals with similar objective health conditions may report different levels of limitation depending on the environments in which they live. At the same time, within the ICF framework (1), disability is exactly defined as the interaction between individual characteristics and contextual factors. Such variation in perception is thus not merely a source of measurement bias but may capture the ICF-defined disability, which reflects how inclusive or constraining different contexts are. Therefore, our estimates may incorporate both differences in underlying objective health conditions and differences in how environments shape the experience of activity limitations, which can be considered an integral part of the exposure we aim to capture

Finally, the meaning and implications of such exposure are likely to vary across contexts (as anticipated in the introduction): in more “familistic” societies, for example, having a close kin with disability may translate into stronger caregiving responsibilities than in countries where care is more institutionalised or shared outside the family (32–36). This contextual variability reflects the broader demographic and institutional differences across European countries, as fertility histories, longevity patterns, and care regimes jointly shape both the availability of kin and the extent to which disability within kinship networks translates into concrete caregiving pressures and social inequalities.

Implication for policy

These results carry substantial policy implications. The societal implications of disability extend far beyond those directly experiencing it, with the kinship network producing a multiplicative effect. Exposure to kin disability is thus a demographic pathway through which inequality can accumulate. Policies should therefore adopt a more relational perspective on disability, recognising its indirect effects across generations and kinship networks. Strengthening integrated support systems that address not only persons with disabilities but also their kin members is essential to reducing cumulative social and economic disadvantages associated with long-term care responsibilities. At the same time, the future burden of kin disability will also depend on whether disability can be delayed or reduced at older ages. Investments in health systems, prevention,

healthier behaviours, medical research, technological innovation, and more accessible environments may compress disability into later life, thereby reducing exposure to kin with disability over part of the life course. Finally, the negative effects of exposure to kin with disability are likely to fall disproportionately on women, given persistent gender norms in care provision and existing inequalities in the labour market in many countries. Exposure to kin disability can contribute to reduced labour force participation, interrupted career trajectories, lower lifetime earnings, and pension gaps, thereby reinforcing cumulative gender inequality over the life course. Addressing these dynamics requires policies aimed at expanding accessible and affordable long-term care services, strengthening caregiver allowances, and ensuring pension credits for caregiving periods, to help mitigate the long-term socioeconomic consequences of extended family-based care. Such measures are particularly relevant in more familistic regimes (such as Italy and other Southern European countries), where care is more concentrated within households and where women's outcomes, opportunities and decisions (such as labour market participation) remain closely intertwined with unpaid caregiving responsibilities.

Finally, beyond these substantive implications, the estimates generated in this study provide a new empirical basis for policy and future research. By quantifying the distribution of exposure to kin disability by age, sex, kin type, and country, the study makes visible the size and composition of the populations exposed to disability through kin networks, information that has so far been largely unavailable, also in a comparable form across contexts. These estimates, available in downloadable tables (in the public reproducibility repository - to be added), can serve to inform the design and targeting of care systems, caregiver support, and healthy ageing policies, while also providing a baseline for future work on the social and economic consequences of kin disability.

More broadly, the study makes three main contributions. First, it advances a conceptual shift by showing that disability should be understood not only as an individual condition, but also as a relational exposure that extends through kinship networks. Second, it provides comparable demographic estimates of exposure to kin disability by age, sex, kin type, and country across Europe, thereby making available the information on the size and composition of populations indirectly affected through kin ties and creating a basis for data resources that can inform policy and future research. Third, it contributes methodologically by showing that model-based estimates of kin disability exposure remain stable across alternative specifications and align closely with observable survey evidence where direct comparison is possible.

Future studies

Future studies are called to explore the drivers of changes in exposure to kin with disability. For example, how and how much changes in mortality and fertility rates and disability prevalence influence differences across countries? How much does their evolution affect changes in exposure to kin with disability over time?

Data and methods

Data

The analytical approach is based on kinship matrix models, where the input data to construct kinship networks are fertility and mortality rates and, in this case, disability prevalence.

Age and gender specific mortality and fertility rates, and the sex ratio at birth, come from the United Nations World Population Prospects (UNWPP) (54) with data from 1950 to 2023. While female age-specific fertility rates are routinely available in international demographic databases, male fertility schedules are considerably less consistently reported. Rather than relying on the androgynous approximation (i.e., assuming identical fertility schedules for men and women (39)) as in similar works, we constructed male fertility rates drawing on different sources. Whenever available, we used observed male age-specific fertility rates from the Human Fertility Collection (55); for countries and years not covered by the HFC, we derived male fertility schedules by shifting the female age pattern according to the country-specific difference between the mean age at fatherhood and the mean age at childbearing, following Schoumaker (56). Appendix, Table A1 summarises, for each country, the periods covered by each fertility data source. Fertility and mortality rates by gender and age from 1950 to 2023 in selected countries are shown in the Appendix, Figures A1 and A2.

In order to compute the (population level) absolute number of individuals exposed to disability, we draw, for each selected country, on the total population count, by gender and age, of 2021 from the UNWPP.

Age and sex specific disability prevalence are derived from the EU Statistics on Income and Living Conditions (EU-SILC), including the 2021 ad hoc module, which collects information on activity limitations through the Global Activity Limitation Indicator (GALI) for individuals of all ages (with children covered in the ad hoc module). The GALI question asks respondents whether, for at least the past six months, they have been limited in activities people usually do because of health problems. Response categories include “severely limited,” “limited but not severely,” and “not limited”, and we classify individuals reporting either severe or moderate limitations as having a disability, while those reporting no limitations as disability-free. The GALI constitutes the official measure used by Eurostat to compute the Healthy Life Years (HLY) indicator (one of the core indicators of the European Structural Indicators and the European Pillar of Social Rights), and it has been validated for its goodness in terms of harmonization and comparability of health measurement across age groups, periods, and European countries (50–53). Disability prevalence from the SILC survey is available for most European countries, and it is also publicly available from Eurostat websites, detailed by age classes (https://doi.org/10.2908/HLTH_SILC_12 and https://doi.org/10.2908/ILC_HCH13). This public data is available by gender for ages above 16. For

younger ages, gender-specific data are not available, and therefore, males and females aged 0–16 are assigned to have the same disability prevalence (i.e., equal prevalence across genders). The 28 specific countries for which this information is available are: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, and Sweden. Age and gender specific prevalence used are shown in Appendix, Figure A3.

In addition to country-specific estimates, we also draw on aggregate EU-27 estimates based on the standard 27-country European Union definition. This aggregate is available consistently across all data sources used in the analysis, including fertility, mortality, and population counts from the UNWPP and disability prevalence from Eurostat website. For fertility rates, which are not available separately by gender for the EU-27 aggregate, we use the androgynous approximation, assigning female fertility rates to both genders. Compared with the set of study countries (see above), the EU-27 coverage is nearly identical, differing only by the inclusion of Luxembourg and the exclusion of Norway. This EU aggregate is used to present overall European estimates alongside the country-specific results.

Methods

Our analysis relies on formal demographic kinship models that reconstruct the expected number and composition of living kin for individuals at each age using observed fertility and mortality schedules (from 1950 to 2021). This approach follows the demographic principle that a population's age-specific vital rates implicitly determine its kinship structure (Goodman et al., 1974), as kinship networks are endogenous products of demographic regimes. By combining age and sex specific fertility and mortality rates over time, it is therefore possible to derive the expected number of each type of kin at each age of a focal individual (ego).

We employ the two-sex, time-varying matrix kinship framework developed by Caswell and colleagues (39, 40). This method allows for modelling both male and female populations of kin (*two-sex*), and accounts for historical changes in timing and trends of fertility and mortality (*time-varying*), so that kin availability reflects past demographic regimes. All estimates are computed separately for female and male focal individuals, and are here shown only for women. We implement the kinship matrix computations using the DemoKin package in R (58).

To incorporate disability into the kinship framework, we extend the kinship model (similarly to Feng et al. (2024)), by applying the age and sex specific prevalence of disability. The kinship matrix method, for each age of the focal, produces the expected number of living kin of each type, age, and sex; applying the age and sex specific disability prevalence to these modelled age distributions of kin allows to specify the expected number of kin by disability state, yielding the

expected number of kin with disability and the expected number of kin without disability. This assumes that disability prevalence among kin by age and sex corresponds to population-level prevalence for that group.

From these quantities, we compute three complementary measures of exposure to disability within the kin network:

1. *Probability of having at least one kin with disability*: For each kin type, this measure represents the probability that an individual of a specific age has at least one living kin of that type with disability. For example, the probability of having at least one grandparent with disability corresponds to the likelihood that a focal individual, at a specific age, has one or more grandparents with disability. This measure captures how widespread exposure is across individuals in the population, that is, the share of individuals at a given age who are likely to experience the exposure to disability within a specific kin relationship during their life course.
2. *The absolute (population-level) number of women having at least one kin with disability*: For each kin type and at each specific age, we compute the absolute number of women, at the population level in each country, who have at least one kin with disability.
3. *Proportion of kin with disability*: This measure is computed as the expected number of kin with disability divided by the total expected number of (alive) kin at each age of the focal individual. It is calculated for the overall kinship network and also separately by kin type. This indicator reflects the intensity of exposure to disability within the kinship network and can be interpreted as a measure of the weight of potential caregiving demand faced by individuals in their kinship network.

The probability of having at least one kin with disability, by kin type, is derived from the expected number of kin with disability. As in Song & Mare (59), we assume that the number of kin follows a Poisson distribution with mean $\lambda = \mu(x)$, so that $\mu(x)$ denotes the expected number of kin at the age x of the focal. If N is the random variable representing the number of kin, then:

$$N \sim Poisson(\lambda = \mu(x))$$

so that:

$$P(N = n) = \frac{\mu(x)^n}{n!} e^{-\mu(x)}, n = 0,1,2,\ldots$$

The probability of having no kin is defined as:

$$P(N = 0) = e^{-\mu(x)}$$

and the probability of having at least one kin is defined as:

$$P(N \geq 1) = 1 - e^{-\mu(x)}$$

Feng et al. (44) extended this logic to specify kin's health condition. Let $\pi(x)$ denote the age-specific prevalence of disability, so that the expected number of kin with disability, for each kin type, is defined as:

$$y(x) = \pi(x)\,\mu(x)$$

Under the Poisson assumption, and if M is the random variable representing the number of kin with disability, the probability of having at least one kin with disability is defined as:

$$P(M \geq 1) = 1 - e^{-y(x)}$$

This approach assumes that events have a fixed mean $y(x)$ equal to the variance. In real kinship, however, disability risk may cluster within families because of shared genetic, socioeconomic, or environmental factors, and some focal individuals may belong to systematically higher-risk kin networks than others. Such mechanisms may induce overdispersion, thereby violating the assumption of the variance being equal to the mean, as the variance of the count of kin with disability is inflated beyond the Poisson one.

To account for potential overdispersion, we extend the previous formulation and assume instead that the number of kin with disability follows a Negative Binomial distribution (Poisson-Gamma mixture), relaxing the constraint of the Poisson model.

Conditional on a latent rate Λ,

$$M \mid \Lambda \sim Poisson(\Lambda)$$

and the rate varies across focal individuals:

$$\Lambda \sim Gamma(r, \theta)$$

The number of kin with disability M follows a Negative Binomial with mean $y(x)$ and variance:

$$Var(M) = y(x) + ky(x)^2, \text{ where } k = \frac{1}{r}$$

The probability of having no kin with disability, for each kin type, is thus defined as:

$$P(M = 0) = (1 + ky(x))^{-\frac{1}{k}}$$

and therefore the probability of having at least one kin with disability, for each kin type, is:

$$P(M \geq 1) = 1 - (1 + ky(x))^{-\frac{1}{k}}$$

As $k \to 0$, i.e. in the case of no overdispersion, this expression converges back to the Poisson definition of variance equal to the mean, and $P(M \geq 1) = 1 - e^{-y(x)}$, while a larger k value indicates stronger overdispersion. In an overdispersed process, the variance of counts is higher; that is, some focal individuals have many kin with disability, but more focal individuals have no kin with disability, and the fraction of those having at least one kin with disability is therefore smaller than from the Poisson assumption. We adopt a conservative baseline level of $k = 0.3$, which represents moderate overdispersion and captures possible clustering within families. As robustness, we report sensitivity checks with $k \in \{0 \; to \; 0.6\}$, in the Appendix Figures A7. Other methodological considerations in the computation of the probability are discussed in the Appendix (section "Methodological note for the probability computation").

To compute the absolute number of individuals having at least one kin with disability, we multiplied the computed probability estimates by the total population count in 2021 at each (focal) age for each country.

These computations require as input: age and sex-specific mortality and fertility rates over time; sex ratios at birth; sex of the focal individual (male or female kinship networks); the age and sex-specific total population (of 2021) for each country; the sex-specific prevalence of disability for a given time point of interest (2021). Since the information on the prevalence is not publicly available for all single ages (rather, they are available by age classes), generalised additive models (60) and penalised regression splines (61) are used to model the trend of the prevalence by single age (with the number of knots selected to balance flexibility and avoid overfitting, and with smoothness estimated using restricted maximum likelihood). Smoothed prevalence over ages for selected countries are presented in the Appendix, Figure A3.

All data analysis is performed in the R software (62) and is documented in an open-access and reproducible repository (for which the link will be added here shortly).

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Appendix

Table A1: Sources of male age-specific fertility rates by country and period

Country	Fertility data source and period of coverage
Austria	Schoumaker shift: 1950–2023
Belgium	Schoumaker shift: 1950–2023
Bulgaria	Schoumaker shift: 1950–2023
Croatia	Schoumaker shift: 1950–2023
Cyprus	Schoumaker shift: 1950–2023
Czechia	Schoumaker shift: 1950–2023
Denmark	Schoumaker shift: 1950–1985; HFC: 1986–2015; Schoumaker shift: 2016–2023
Estonia	Schoumaker shift: 1950–1988; HFC: 1989–2014; Schoumaker shift: 2015–2023
Finland	Schoumaker shift: 1950–1986; HFC: 1987–2015; Schoumaker shift: 2016–2023
France	Schoumaker shift: 1950–1997; HFC: 1998–2013; Schoumaker shift: 2014–2023
Germany	Schoumaker shift: 1950–1990; HFC: 1991–2013; Schoumaker shift: 2014–2023
Greece	Schoumaker shift: 1950–2023
Hungary	Schoumaker shift: 1950–1969; HFC: 1970–2014; Schoumaker shift: 2015–2023
Ireland	Schoumaker shift: 1950–2023
Italy	Schoumaker shift: 1950–1998; HFC: 1999–2014; Schoumaker shift: 2015–2023
Latvia	Schoumaker shift: 1950–2023
Lithuania	Schoumaker shift: 1950–2023
Malta	Schoumaker shift: 1950–2023
Netherlands	Schoumaker shift: 1950–2023
Norway	Schoumaker shift: 1950–2023

Poland	Schoumaker shift: 1950–1985; HFC: 1986–2014; Schoumaker shift: 2015–2023
Portugal	Schoumaker shift: 1950–1979; HFC: 1980–2015; Schoumaker shift: 2016–2023
Romania	Schoumaker shift: 1950–2023
Serbia	Schoumaker shift: 1950–2023
Slovakia	Schoumaker shift: 1950–2023
Slovenia	Schoumaker shift: 1950–2023
Spain	Schoumaker shift: 1950–1974; HFC: 1975–2014; Schoumaker shift: 2015–2023
Sweden	Schoumaker shift: 1950–1967; HFC: 1968–2015; Schoumaker shift: 2016–2023

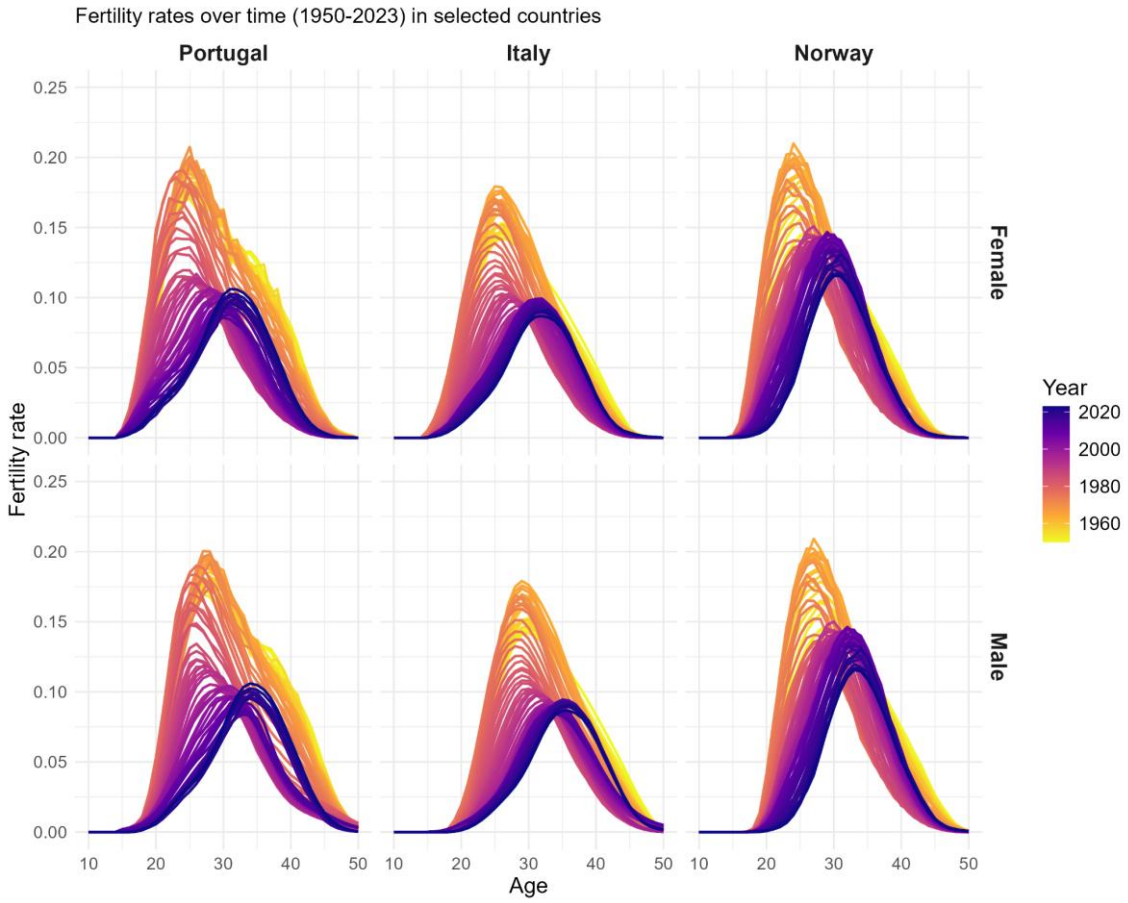
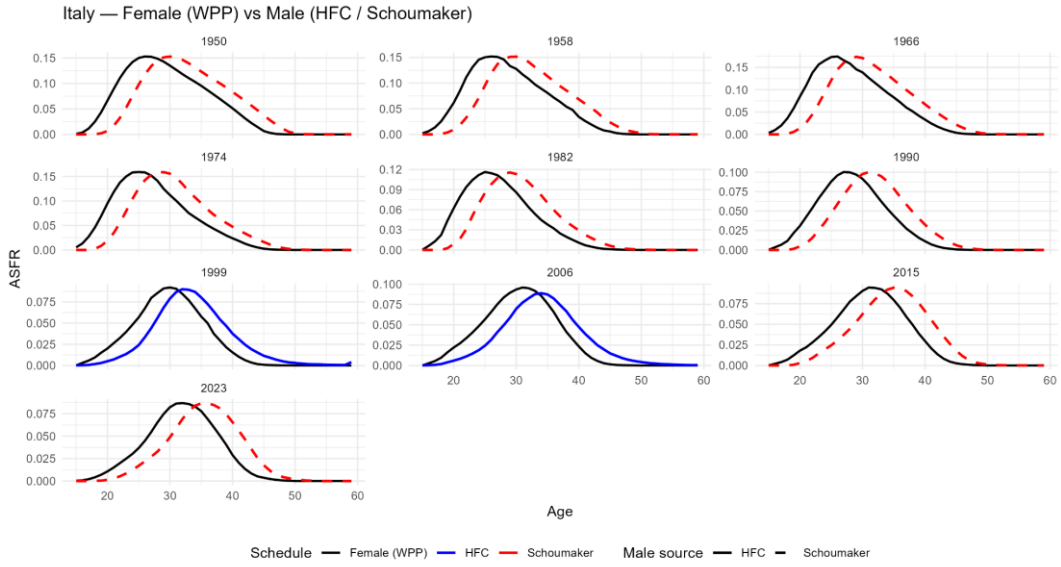
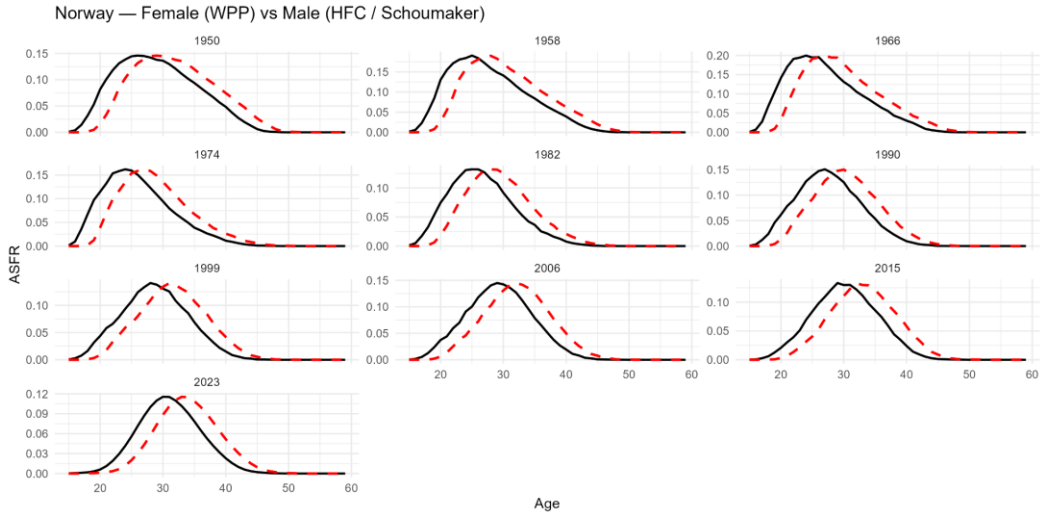


Figure A1: Fertility rates by age over time (1950-2023) shown for selected countries. Source: World Population Prospects (54)), HFC, Schoumaker (2019).


Italy — Female (WPP) vs Male (HFC / Schoumaker)
1950
1958
1966
1974
1982
1990
1999
2006
2015
2023
ASFR
Age
Schedule Female (WPP) HFC Schoumaker
Male source HFC Schoumaker


Norway — Female (WPP) vs Male (HFC / Schoumaker)
1950
1958
1966
1974
1982
1990
1999
2006
2015
2023
ASFR
Age
Schedule Female (WPP) Schoumaker
Male source Schoumaker

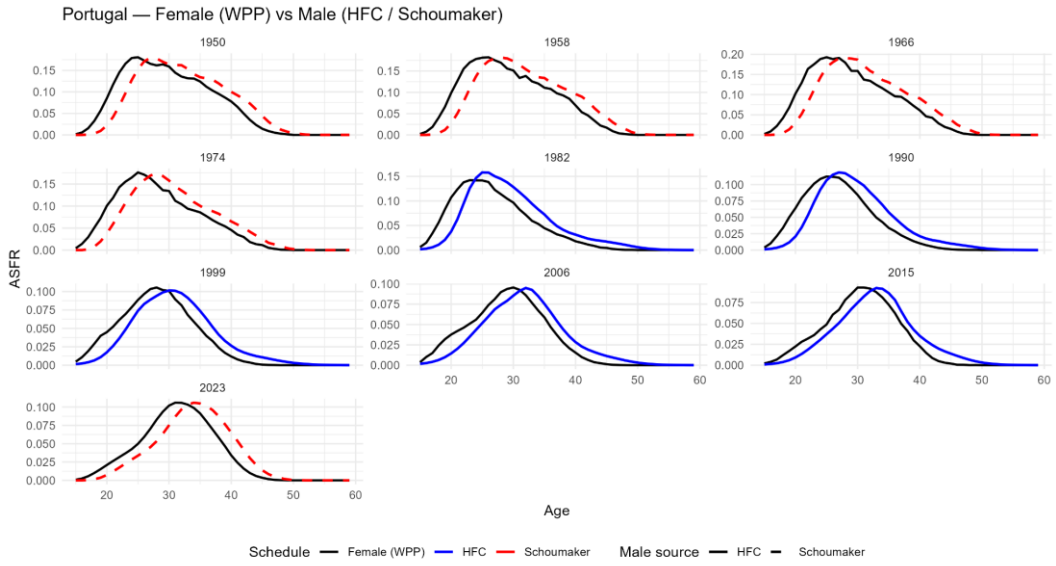

Portugal — Female (WPP) vs Male (HFC / Schoumaker)
1950
1958
1966
1974
1982
1990
1999
2006
2015
2023
ASFR
Age
Schedule Female (WPP) HFC Schoumaker
Male source HFC Schoumaker

Figure A1.1: Male fertility rate comparison, for selected countries, from the different sources used: male fertility = female fertility from World Population Prospects (54), male fertility from HFC (when available), male fertility = female fertility but shifted based on (56) (see methods section)

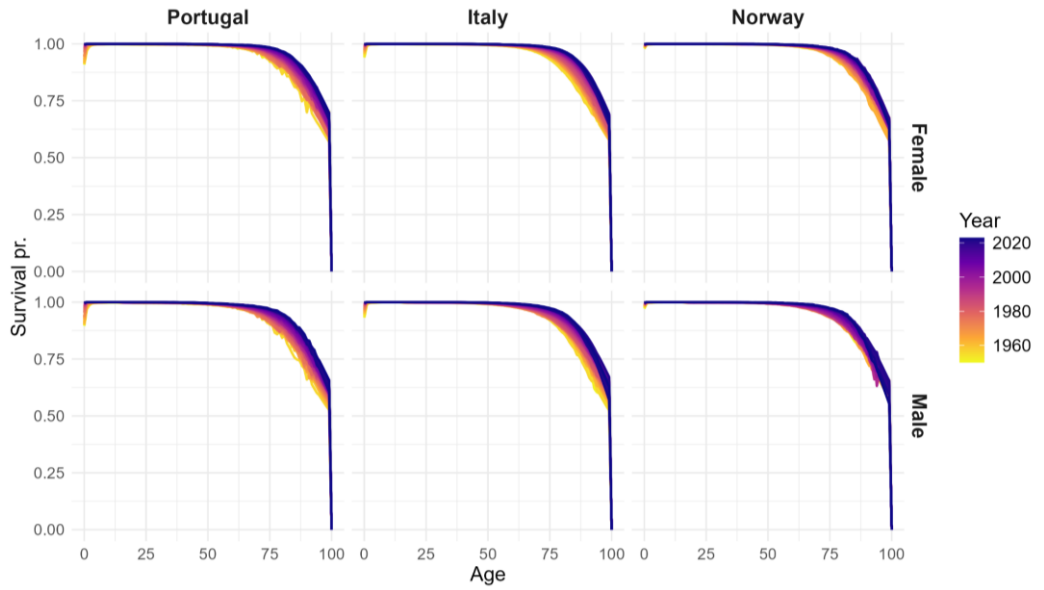


Figure A2 Survival probability by age over time (1950-2023) shown for selected countries. Survival probability is set at 0 from age 100. Source: World Population Prospects (54).

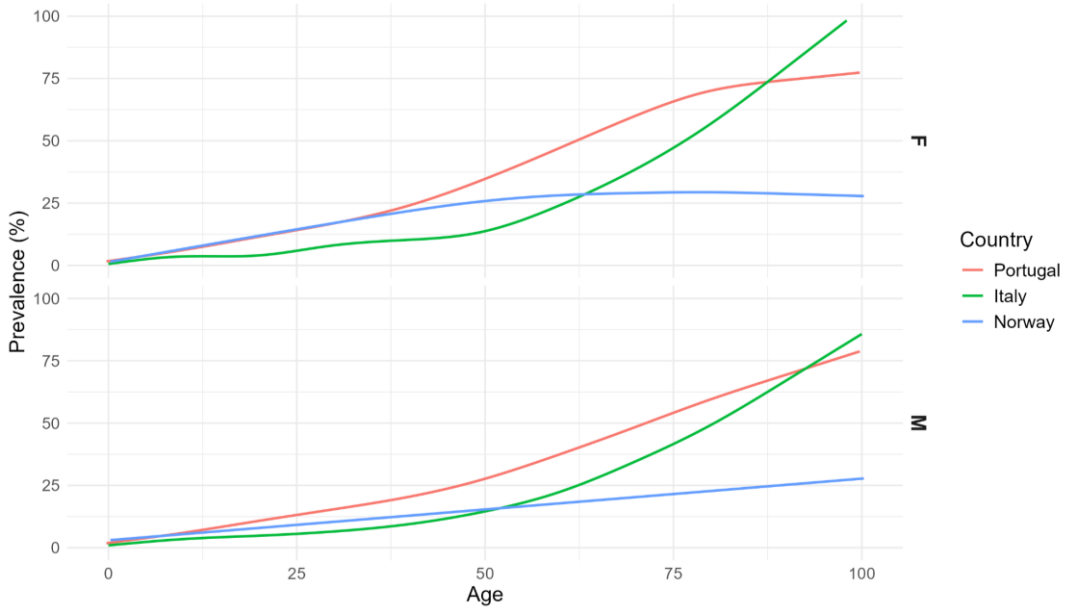


Figure A3 Smoothed disability prevalence by age in 2021, shown for selected countries. Source: EU-SILC; non-smoothed prevalence by age classes is available at: https://doi.org/10.2908/HLTH_SILC_12; https://doi.org/10.2908/ILC_HCH13

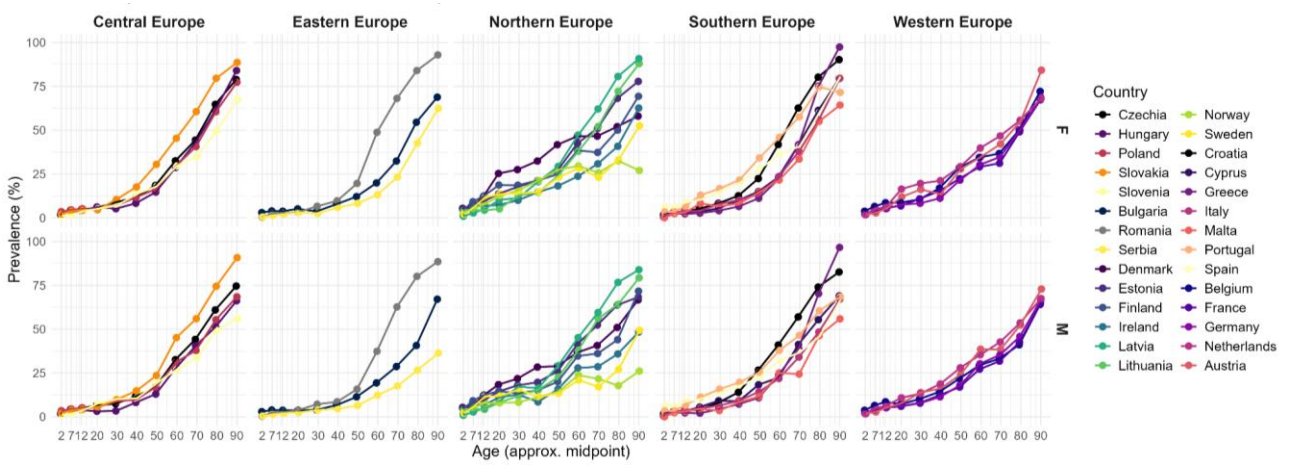


Figure A3.1 Smoothed disability prevalence by age in 2021. Source: EU-SILC; non-smoothed prevalence by age classes is available at: https://doi.org/10.2908/HLTH_SILC_12; https://doi.org/10.2908/ILC_HCH13

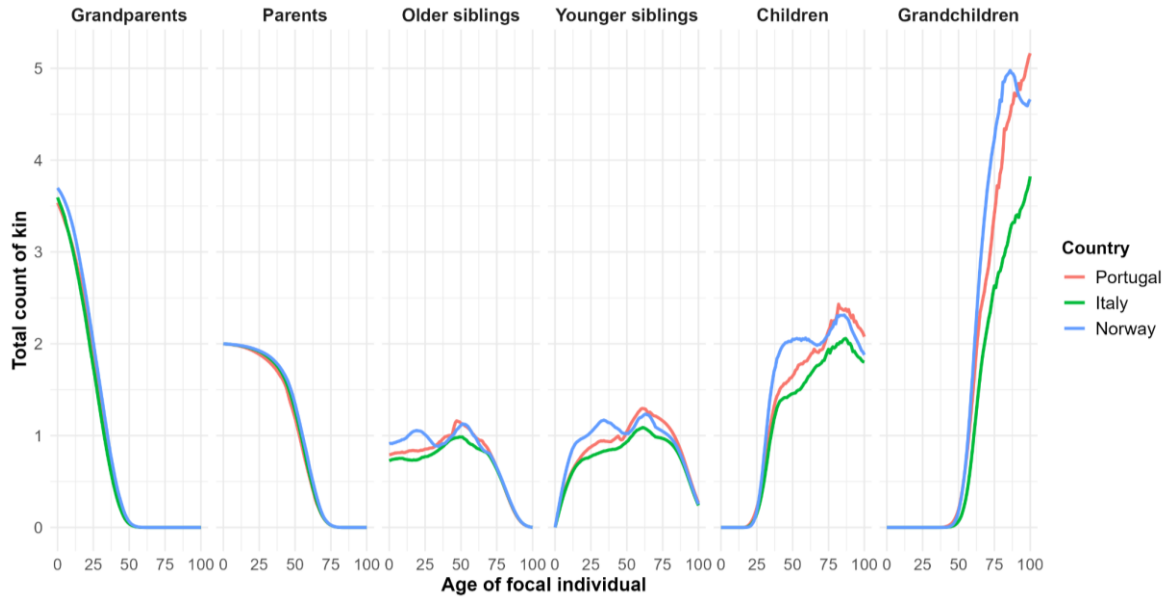


Figure A4: Total number of kin by kin type and focal age, in selected countries for women in 2021

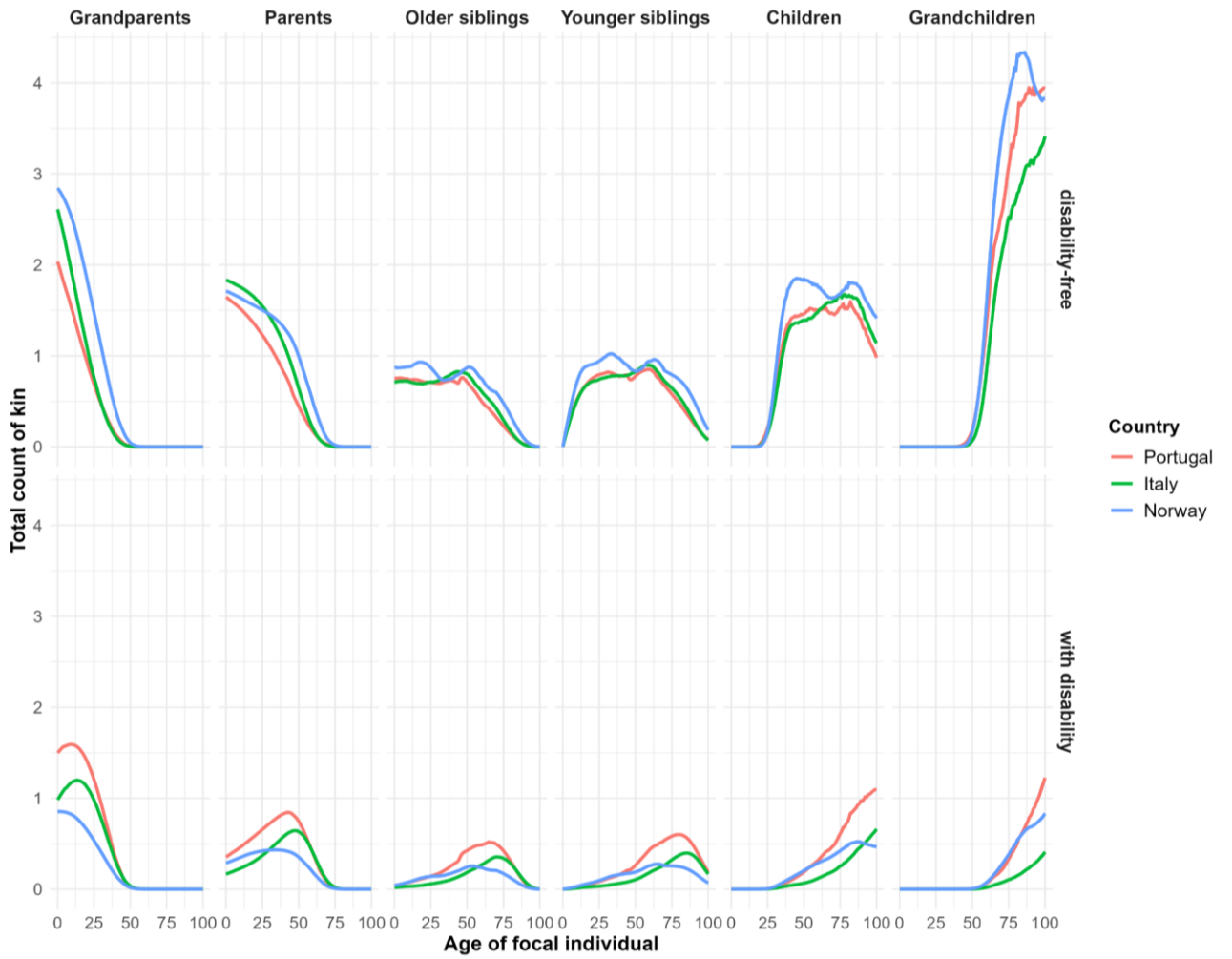
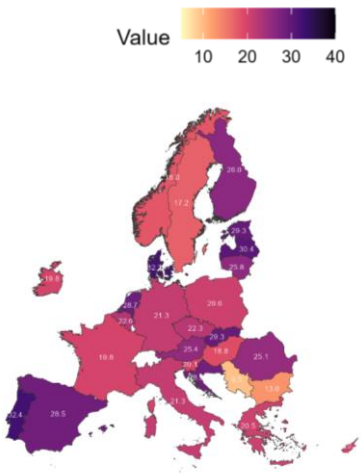
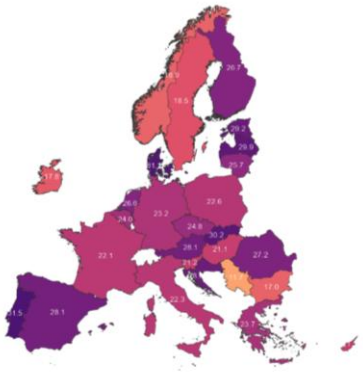


Figure A5: Total number of kin by kin type, focal age and kin disability state, in selected countries for women in 2021



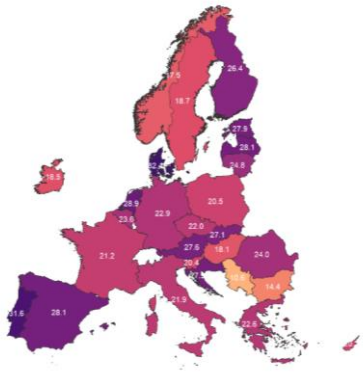
AGE 10

Figure A6.1: Proportion of kin with disability for women in 2021; focal age 10.



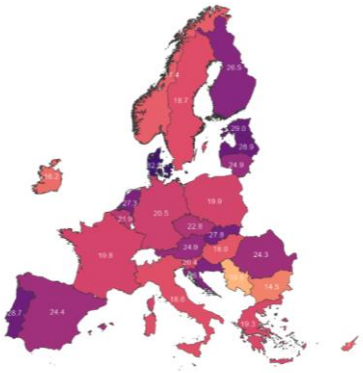
AGE 40

Figure A6.2: Proportion of kin with disability for women in 2021; focal age 40.



AGE 50

Figure A6.3: Proportion of kin with disability for women in 2021; focal age 50.



AGE 85

Figure A6.4: Proportion of kin with disability for women in 2021; focal age 85.

Robustness checks

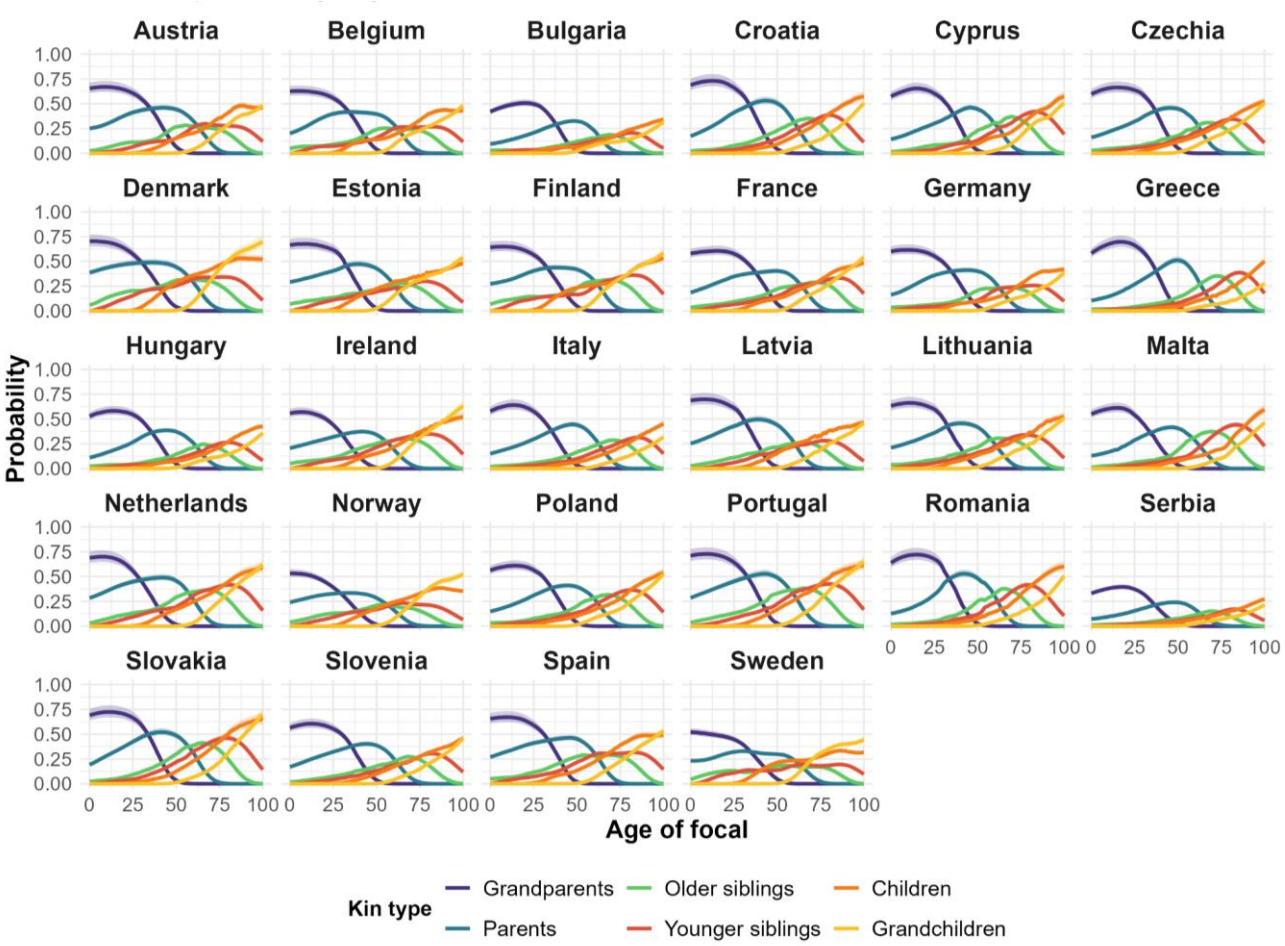


Figure A7: Probability of having at least a kin with disability, by kin type and age of a focal woman in 2021, using a range of k values: from k = 0 (i.e. using the Poisson approximation, meaning no overdispersion) to k = 0.6 (high overdispersion); central estimate corresponding to k=0.3

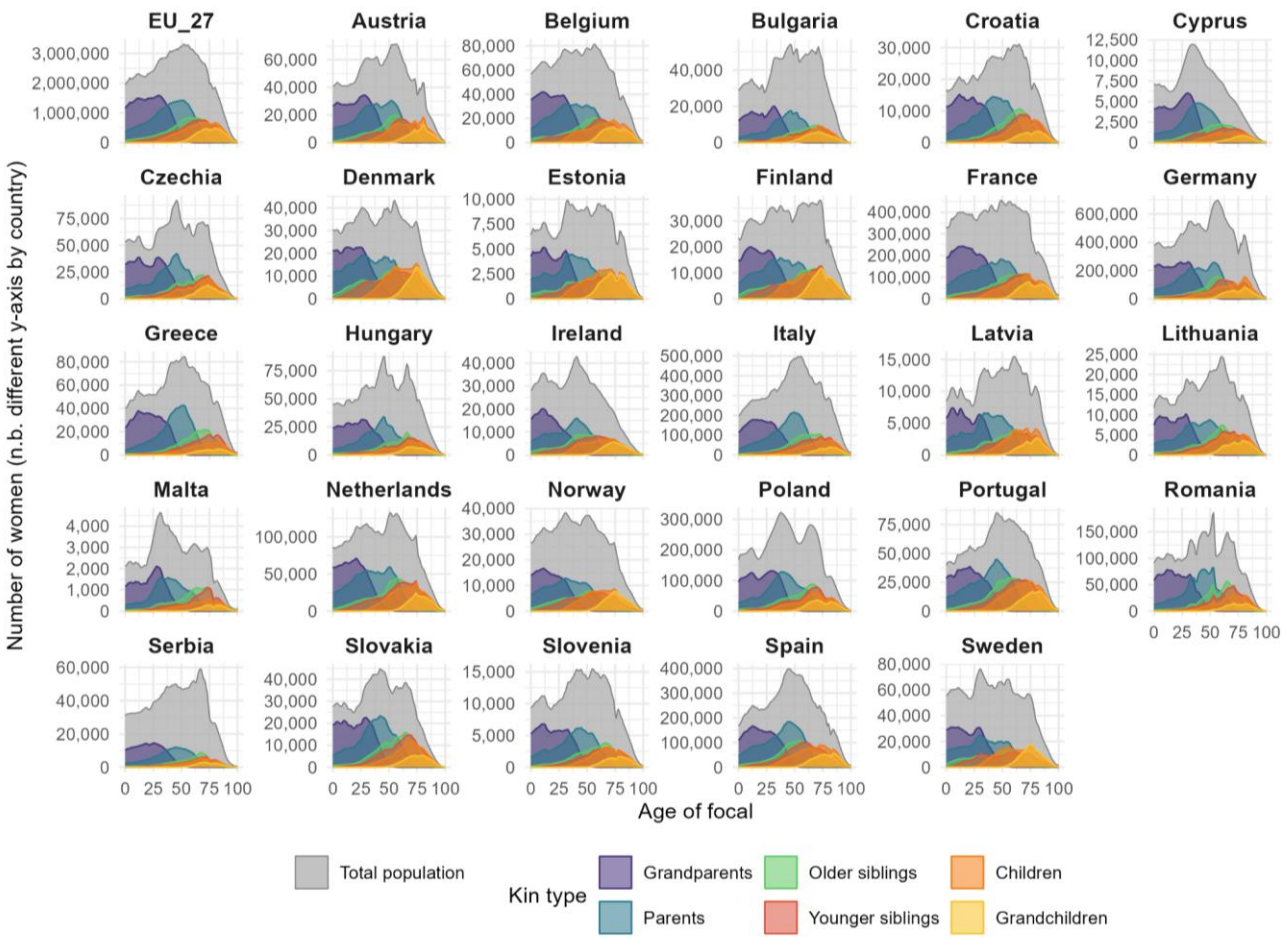


Figure A8: Absolute number of women having at least one kin with disability, by type of kin and age of the focal woman, compared to the total population of women at each age (grey areas)

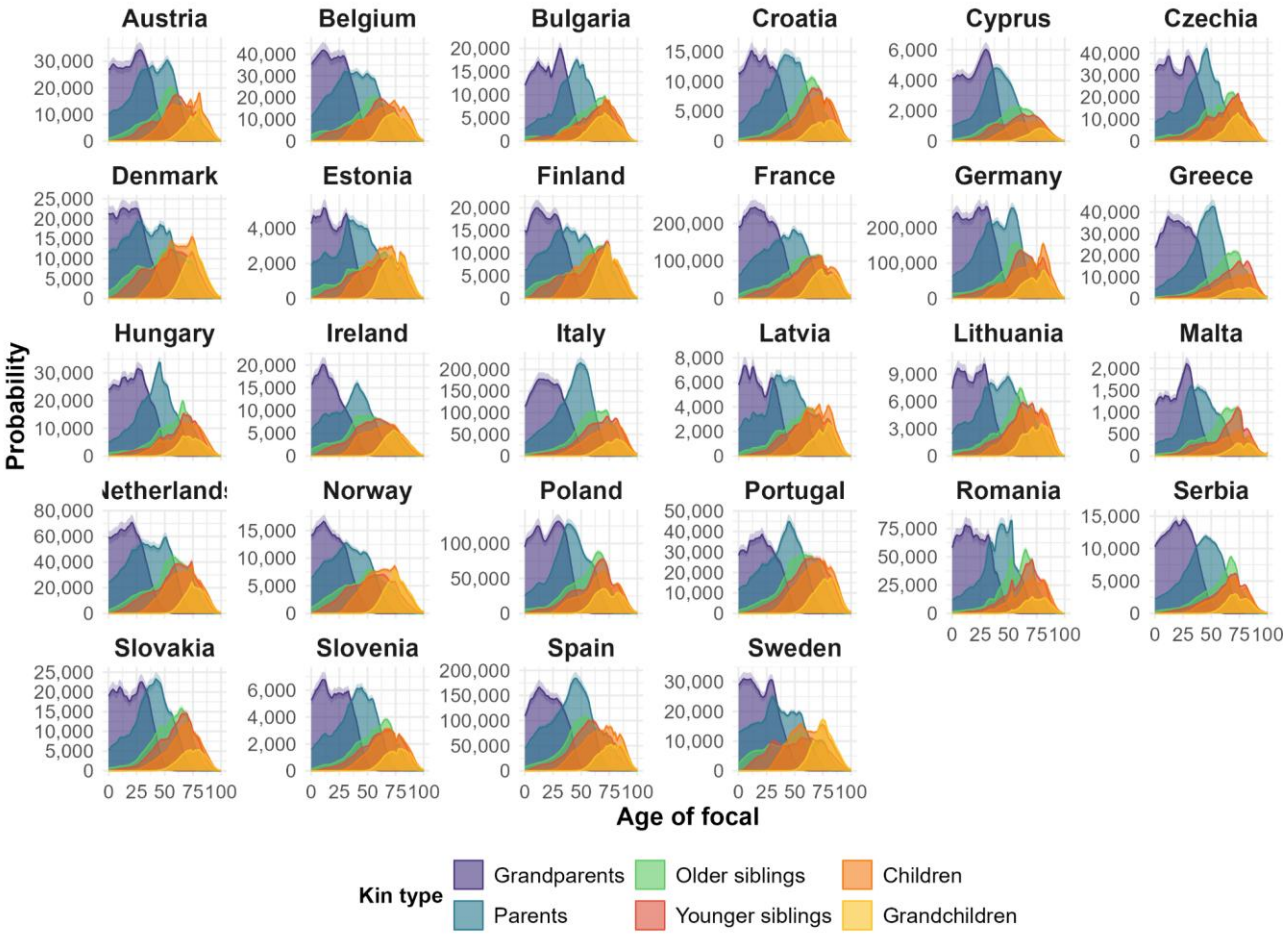


Figure A9: Absolute number of women having at least one kin with disability, by type of kin and age of the focal woman, bounded using the same range of k values used in the computation of the probabilities

Comparison of some of our estimates with SILC data

Here we compare selected estimates derived from our model with corresponding indicators computed from raw SILC data, focusing in particular on the presence of mothers, fathers and children with a disability living in the same household as the focal individual. We selected only this kin for the comparison because other kin types (such as grandparents) are less likely to live in the same household, and would not thus be captured in SILC data where kin linkage are possible only for individuals living in the same household (e.g. it is not possibile to identify the grandparent of an individual if they are not living in the same household), as the kinship structure linkage is not extended outside the household.

Methodological note for the probability computation: For mother and father the total count of this kin for a focal individual is structurally bounded between 0 and 1. There may be cases for individuals

having more than one mother or father, e.g. famale/male same-sex families, but their prevalence is still quite low, and the SILC data still captures just one mother/father ID, so individuals in this data can only have a maximum of one mother and one father. Although this count is thus binary (0 or 1), we estimate it using the same Negative Binomial distribution used for other kin counts in order to maintain consistency across kin types. Importantly, this specification is unlikely to induce important distortion, because the mean parameter of this distribution (here being the mean of mother/father with disability) is relatively low. When the mean is small, the Negative Binomial distribution concentrates almost all its probability mass between 0 and 1, so that the distribution closely approximates a Bernoulli process.

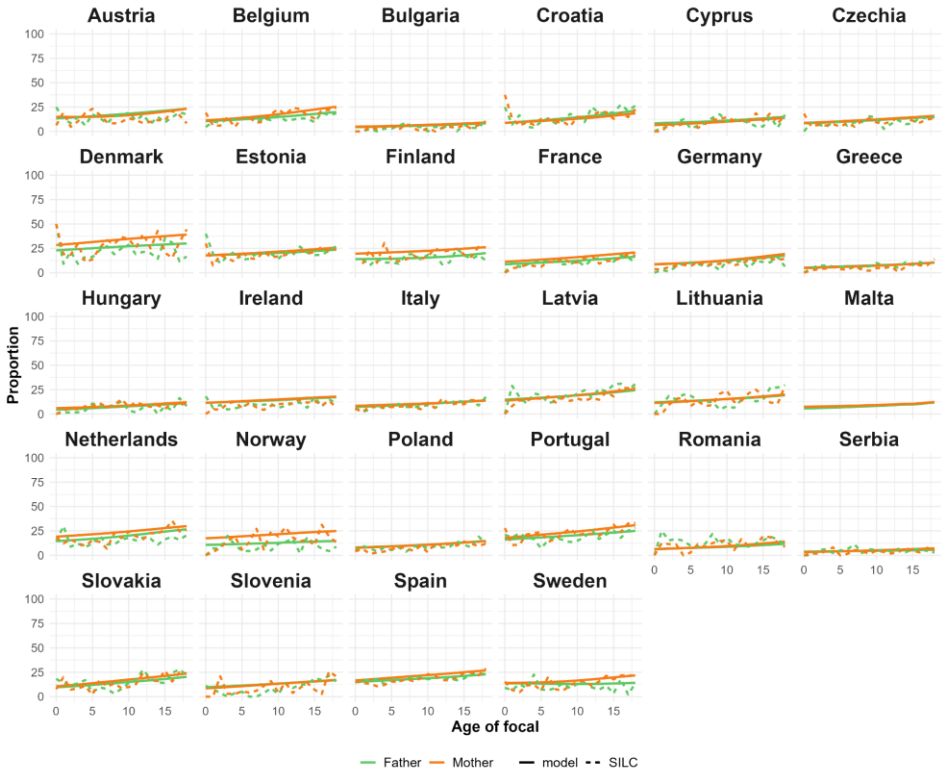


Figure A10: Proportion of parents with disability - comparison between the kinship matrix models and “empirical” ones from SILC data (based on co-resident kin)

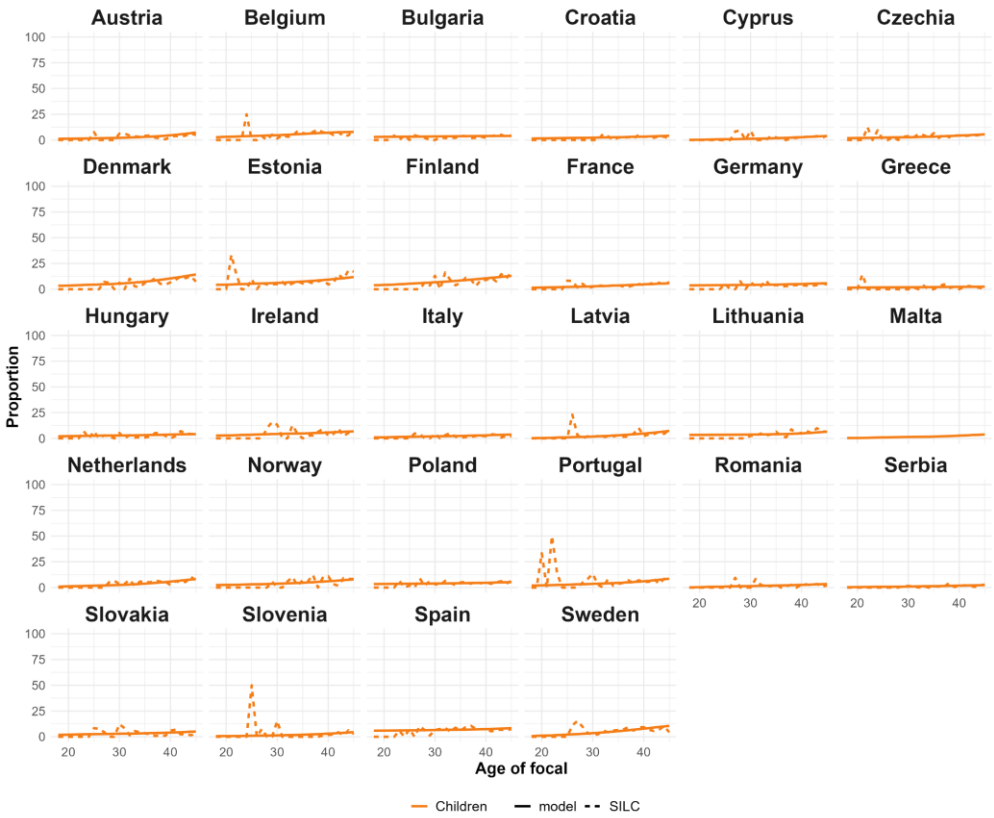


Figure A11: Proportion of children with disability - comparison between the kinship matrix models and “empirical” ones from SILC data (based on co-resident kin)

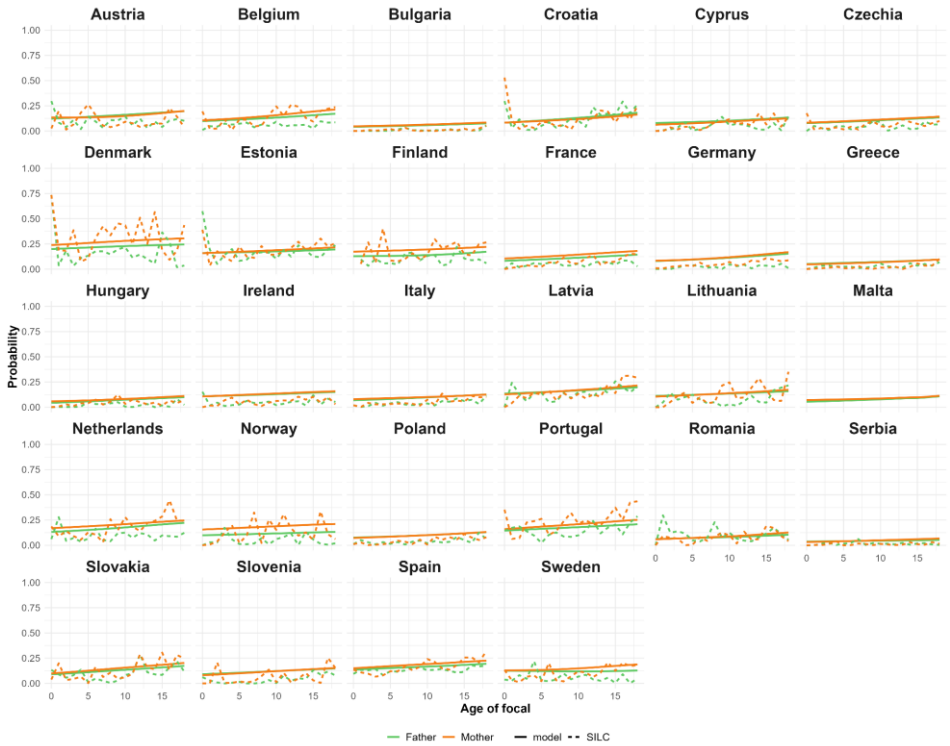


Figure A12: Probability of having at least a parent with disability - comparison between the kinship matrix models and “empirical” ones from SILC data (based on co-resident kin)

Figure A13: Probability of having at least a child with disability - comparison between the kinship matrix models and “empirical” ones from SILC data (based on co-resident kin)