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A Cross-National Comparison
Across Care Regimes**

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Measuring Kinship Dependency: A Cross-National Comparison Across Care Regimes

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Abstract

This paper introduces the Kin Dependency Ratio (KDR), a novel, multi-scalar demographic metric that quantifies the potential caregiving burden embedded in kinship networks due to population aging. Unlike the Population Dependency Ratio (PDR), which reflects aggregate societal dependency, the KDR captures how dependency pressures evolve at the family level. We analyze four countries representing distinct care regimes (Sweden, Japan, Greece, and the United States) using formal kinship network models with demographic rates estimated by the UN Population Division as inputs. We find that old-age dependency ratios (both KDR and PDR) increase steadily over time, the young-age dependency ratios are projected to remain relatively stable. This dual trend indicates that aging, rather than fertility, is the primary driver of future dependency pressures. Moreover, the KDR shifts across the individual life course and varies depending on the scope of kin networks, highlighting the dynamic structure of family-based support. Finally, we discuss how our novel measure of kin-based dependency relates to the organization of support for older adults—through the family, the state, or the market.

Keywords: kin dependency ratio, population dependency ratio, population aging, care regimes

Significant Statement

The Population Dependency Ratio (PDR) is widely used but does not capture how caregiving burdens are distributed within families. This study introduces the Kin Dependency Ratio (KDR), a new demographic measure that reveals family-level dependency and varies meaningfully across age, kin structure, and care regimes. Rather than replacing the PDR, the KDR complements it by offering a family-centered perspective on demographic aging, and its implication depends on the institutional and cultural contexts. By interpreting KDR values within different care regimes, the paper shows how the same underlying dependency may be buffered, shared, or privatized depending on institutional arrangements.

Introduction

Population aging, driven by the convergence of sub-replacement fertility and rising life expectancy, is reshaping societies globally. The Population Dependency Ratio (PDR) is a commonly used metric to understand the aging challenge by comparing non-working-age to working-age populations. The PDR's macro-level simplicity, however, is its most profound weakness. It functions as a conceptual "black box", measuring the total level of dependency while obscuring its distribution between formal

state systems and informal family care. It cannot reveal the tension or alignment between state and family responsibilities, assuming a homogenous society where the state is the default support provider. This overlooks that for much of the world, kinship networks are the primary locus of intergenerational support (Reher 1998), creating a critical blind spot: we see that a country is aging, but we cannot use the PDR to measure the corresponding pressure building within its families.

The demographic pressure on families does not exist in a vacuum; it is shaped by the institutional context. Theories of comparative political economy provide the necessary framework to analyze this context. Scholars have long debated how societies allocate welfare responsibilities. Esping-Andersen (1990) identified three worlds of welfare capitalism (liberal, conservative, and social-democratic) based on their varying levels of de commodification, or the degree to which individuals can maintain a living independent of the market. However, subsequent scholarship, particularly from a feminist perspective, criticized this framework for being largely gender-blind, as it overlooked the vast amount of unpaid care work performed within the family. Therefore, scholars introduced de-familialization as a parallel core concept: the degree to which state policies reduce individuals' reliance on the family for their well-being, especially by supporting the costs and labor of care (Lewis 1992; Orloff 1993). This new lens enabled a richer analysis, leading to the identification of a distinct Mediterranean regime (e.g., in Greece and Italy) characterized by a strong, state-endorsed "familism" where public services are underdeveloped and families are presumed to be the primary welfare providers (Ferrera 1996; Saraceno 1994). While this theory explains why different care regimes exist, it has lacked the demographic tools to precisely measure their implications on the family. Directly measuring these complex kin relationships with survey data is often impossible, as most surveys only capture a limited subset of core family members and cannot account for long-term demographic dynamics.

The application of formal kinship models, pioneered by Goodman et al. (1974), was long challenged by the mathematical complexity of the initial approaches. This difficulty led many caregiving researchers (Wachter 1997) to rely on computationally intensive microsimulation. A key methodological advancement by Caswell (2022) reformulated this foundational theory into a tractable, matrix-based framework, making kinship calculations from standard demographic rates far more accessible. This renewed accessibility has spurred new research, such as the "Dementia Dependency Ratio" (DDR) by Feng et al. (2024). Yet, a general, purely age-based kin dependency ratio analogous to the PDR is still lacking. Age is the most basic dimension of dependency, and demographic rates (such as fertility and mortality) are widely available by age across all nations. Therefore, an age-based kin dependency ratio can overcome the scarcity of comparable data on more specific indicators like health or economic status and provide the essential baseline for a direct, conceptually parallel comparison between the pressures on the state and the family. Such a comparison is critical, as research has shown the link between demographic change and kinship structures to be complex, with the resulting effects being non-linear (Jiang et al. 2023) and sensitive to the speed of demographic transition (Jiang et al. 2025).

In this paper, we introduce the Kin Dependency Ratio (KDR), defined as the ratio of dependent-aged kin to working-aged kin within an individual's family network. The KDR measures the potential for informal, kin-based support, just as the PDR reflects the pressure on formal support systems, such as public pensions and healthcare, administered by the state. Methodologically, we demonstrate how the KDR can be calculated for various nested family definitions (nuclear, lineal, and collateral). Theoretically, we examine both the Population Dependency Ratio (PDR) and the Kin Dependency Ratios (KDRs) to understand how aging-related dependency is structured at both the societal and family levels. We draw on the insights of welfare regime theory to assess how different countries allocate caregiving responsibilities through public institutions or familial arrangements. Empirically, we apply this framework to a comparative analysis of four countries:

Japan, Greece, Sweden, and the United States. Each country represents a distinct care regime characterized by specific combinations of state provision and family involvement in caregiving. These regimes are outlined in our analytical framework in Table 1 and discussed in the following section. In this paper, we answer two central questions: (1) How can we systematically measure kin-based dependency, a dimension of care responsibility not captured by conventional demographic metrics? (2) How does the meaning of this kin-based dependency differ across care regimes, depending on how caregiving is organized between families, public systems, and markets?

Conceptualizing Dependency: From PDR to KDR

To understand the full scope of population aging, we must distinguish between two levels of dependency. The conventional Population Dependency Ratio (PDR) captures demographic pressure on a society’s formal support systems, such as public pensions and healthcare, which are funded collectively through public institutions. In contrast, the Kin Dependency Ratio (KDR) introduced here measures potential dependency within informal support systems embedded in kinship networks. While the PDR aggregates age structure at the population level, the KDR reflects the average experience of individuals situated within their family networks.

It is important to clarify that the KDR does not represent actual caregiving behavior or experienced need. Rather, it reflects the demographic structure of intergenerational support potential: the number of dependent-age kin (young or old) relative to working-age kin. However, not all dependent-age kin require assistance, and not all working-age kin are equally able to provide it. Whether this potential translates into care-related needs depends on within-family factors such as health status, co-residence, education, financial capacity, gender, and relational proximity (Dwyer and Coward 1991; Marks 1996; Silverstein and Bengtson 1997). Among those with unmet needs, the degree to which care is provided by the family is further shaped by institutional context, including the availability of public services and the broader organization of care responsibilities (Esping-Andersen 1990; Bettio and Plantenga 2004). In this paper, we consider the foundational demographic structure of support through measurements like PDR and KDR. This structure exists alongside social, economic, or policy factors. By comparing the PDR and the KDR across settings, we highlight the demographic basis of support at both societal and family levels, providing a starting point for understanding how different systems experience and respond to aging.

To interpret national variation in family-based dependency, we draw on comparative welfare state theory. Building on Esping-Andersen’s classification and its feminist extensions, we conceptualize four ideal-typical care regimes, each reflecting a different combination of public support and cultural expectations about family caregiving. We formalize these differences in a two-dimensional framework (see Table 1) to guide our case selection and comparison. The first dimension is cultural and refers to the strength of familism, defined as the expectation that families are primarily responsible for providing care. The second dimension is structural and reflects the degree of formal state support. For this, we use public long-term care (LTC) expenditure as a share of GDP, which serves as a cross-nationally comparable proxy for state commitment to funding intensive and costly aspects of elder care. The intersection of these two dimensions produces a four-fold typology of care regimes.

The selection of Japan, Greece, Sweden, and the United States is strategic, as each case represents one care regime. **Sweden** represents the typical de-familialized state. Here, the KDR helps us measure the scale of the potential kinship challenge that has been almost entirely socialized and absorbed by the state, rendering the family support system a demographic “ghost”. This is codified in its Social Services Act (Socialtjänstlagen), which makes municipalities legally responsible for

providing universal, tax-funded care. At the opposite pole, **Greece** embodies unsupported familism. It is a regime of familism by default, where relatively low state support combined with high cultural expectations creates an intense “kinship squeeze” that the KDR is uniquely positioned to quantify. This situation arises from fragmented public services that leave the vast majority of care responsibilities implicitly on the family (Ferrera 1996).

The United States illustrates a liberal regime of “privatized risk”. While culturally defined by low-familism, its system paradoxically shifts immense care responsibility onto kin. This is because limited public support, largely restricted to means-tested Medicaid, combined with expensive market solutions, often leaves families with no other viable option. The resulting reliance on kin is therefore a product of institutional default, not cultural expectation. In this context, the KDR quantifies the scale of this “privatized risk” by measuring the latent demographic pressure families are forced to absorb. Finally, **Japan** presents the most complex puzzle of supported familism. Policy is designed not to replace family care but to enable it. This creates a “dual dependency challenge”, with pressure on both the state and the family. The KDR therefore measures the enduring weight of kinship obligations even in a high-spending state, whose Long-Term Care Insurance (LTCI) system, for example, is explicitly designed to support and enable, rather than fully replace, family caregivers. (Peng 2000).

To analyze dependency pressures, we construct and compare two metrics using UN demographic data from 1950 to 2100 (United Nations 2022): the societal-level Population Dependency Ratio (PDR) and our novel, multi-scalar Kin Dependency Ratio (KDR). Estimated with formal kinship models (Caswell and Song 2021), the KDR is the ratio of dependent-aged to working-aged kin within different family networks (e.g., nuclear, lineal, and collateral). This dual-metric approach allows for a direct comparison between dependency at the state and family levels. Detailed mathematical formulations are available in the Data and Method section at the end of the paper.

Table 1: A Framework for Country Case Selection and the Analytical Power of KDR

	High Formal Support (High public LTC expenditure as % of GDP)	Low Formal Support (Low public LTC expenditure as % of GDP)
High Familism Culture	Regime I: Supported Familism <i>e.g., Japan</i> KDR measures the substantial underlying kinship challenge that coexists with state support, which helps to analyze the tension within Japan’s “dual dependency challenge”.	Regime II: Unsupported Familism <i>e.g., Greece</i> KDR quantifies the intense and often invisible “kinship squeeze” that results when state support is minimal and family obligations are high.
Low Familism Culture	Regime III: De-familialized State Support <i>e.g., Sweden</i> KDR reveals the “ghost” of a family support system that has been institutionally supplanted by the state, making the PDR the most relevant metric for the dependency challenge.	Regime IV: Liberal System <i>e.g., United States</i> KDR quantifies the scale of “privatized risk” by measuring the latent dependency challenge falling on families to be resolved through a mix of direct kin support, personal resources, and market choices.

Note. Classification is based on total long-term care (LTC) spending as a share of GDP, sourced from the OECD’s *Health at a Glance 2023* report (Organisation for Economic Co-operation and Development 2023). This report notes that public funds constitute the vast majority of LTC spending in OECD countries (approx. 80%), making total expenditure a reliable proxy for public commitment. The approximate values for the selected archetypal countries in 2021 were: Sweden (3.4%), Japan (2.4%), the United States (1.3%), and Greece (0.5%).

Results

The Life-Course Dynamics of Kin Dependency

Before comparing countries, we first show the properties of the kin dependency ratio by examining its dynamics across an individual’s life course using ASKDR in the United States during 2020 to 2025. Figure 1 shows that an individual’s potential kin dependency level is not static, but changes predictably with age. When only core kin (parents, siblings, and children) is considered, as individuals transition into early adulthood (from ages 15 to 25), the support demand of younger kin, measured by the kin-based young-age dependency ratio ($ASKDR_{young}$), decreases (see the top left panel of Figure 1). This reduction is primarily due to younger siblings entering the workforce. As individuals enter middle age (approximately from ages 25 to 45), the $ASKDR_{young}$ rises. This increase reflects the growing number of children born during this period, as shown by the expansion of young-age kin in Figure 2. After this phase, the young dependency ratio declines as children age out of the dependent category.

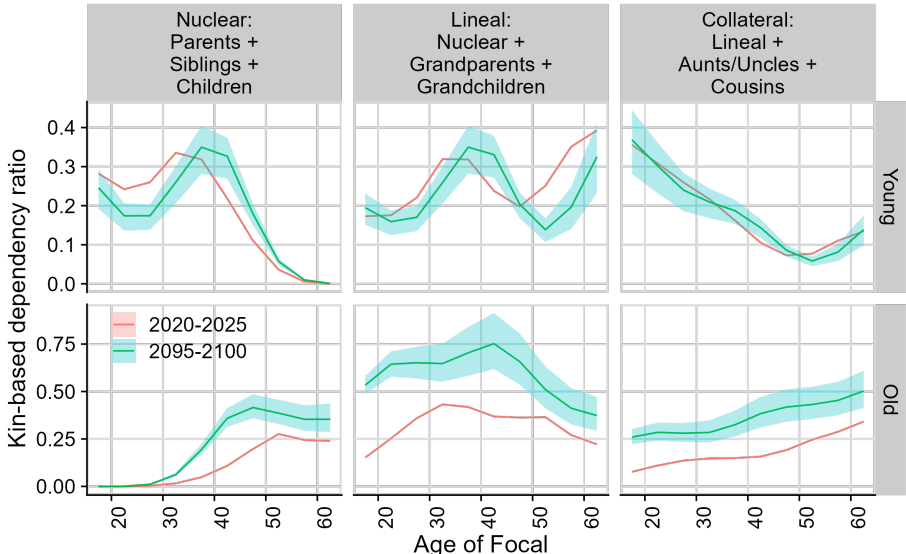


Figure 1: Kin-based dependency ratio by age of Focal in the USA, 2020-2025 (red lines) and 2095-2100 (green lines). Shaded areas show the lower and upper 80% projection intervals around the median of the 1000 country-level probabilistic trajectories. Columns represent results when different types of kin are considered. Rows represent the young and old kin-based dependency ratios.

Meanwhile, the old-age dependency ratio ($ASKDR_{old}$) increases steadily throughout adulthood (approximately ages 15 to 45) and remains high into later adulthood (see the bottom left panel of Figure 1). This reflects the aging of parents, as shown by the increasing number of parents in the old-age kin category in Figure 2. Projections for the period 2095–2100 suggest that these life-course patterns will shift due to demographic changes, including delayed childbearing and continued declines in fertility and mortality. These changes alter the timing and magnitude of kin availability across the life span, reshaping both young and old-age dependency structures in future cohorts.

This section also highlights why the definition of the family network is crucial. The remaining two columns in Figure 1 show how the ASKDR changes when the kin network is expanded from the nuclear family (left column) to include lineal kin (grandparents and grandchildren, middle

column) and collateral kin (aunts/uncles and cousins, right column). Including grandparents, for instance, significantly increases the $ASKDR_{old}$ for younger adults (ages 20 to 50), while including grandchildren increases the $ASKDR_{young}$ for older adults (aged 50 to 65). This demonstrates that the scale of the family network used for calculation fundamentally shapes the measured dependency level, justifying our multi-scalar approach.

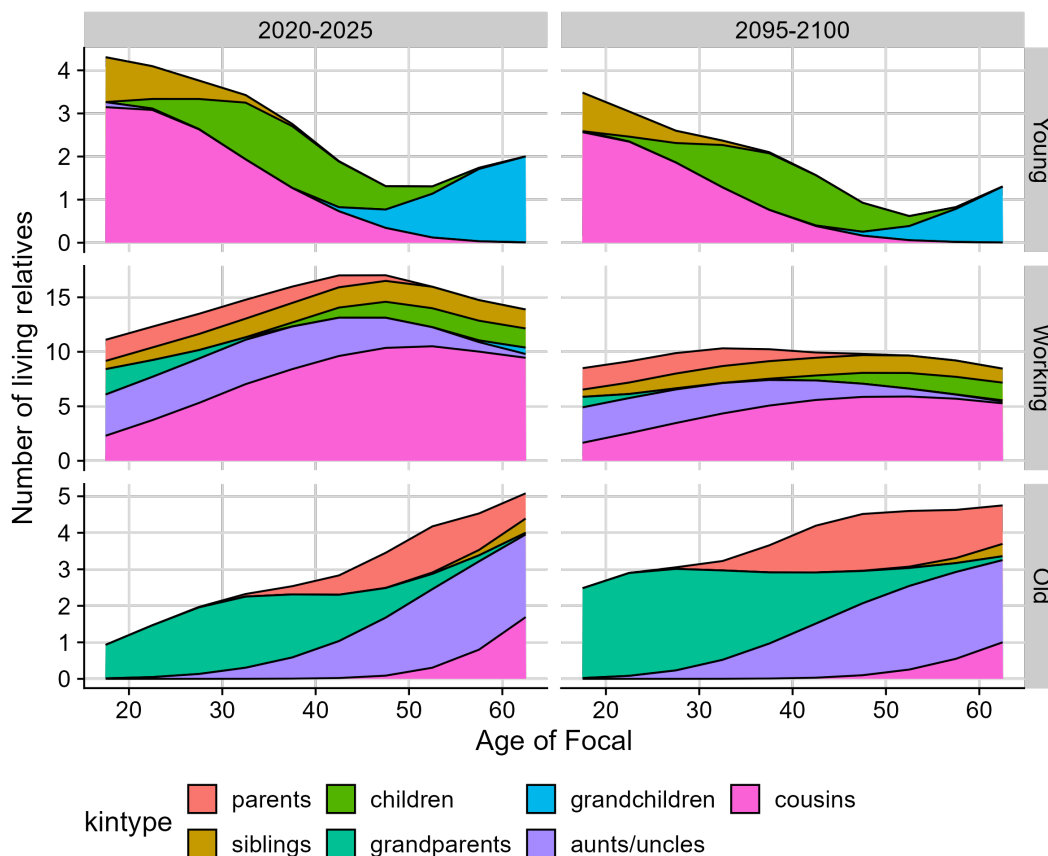


Figure 2: Expected number of kin by age of Focal in the USA. Columns represent results in 2020-2025 and 2095-2100. Rows represent kin of different age groups: 0–14 for young, 15–64 for working-age, and 65+ for old ages.

Kin-based vs. Population-level Dependency Ratios

Figure 3 presents the central empirical findings of this study, plotting the conventional Population Dependency Ratio (PDR) against our three nested KDRs for the four representative countries from 1950 to 2100. In this context, a value of 0.5 in the old-age PDR indicates that, on average, there are 0.5 individuals aged 65 and older for every working-age person in the population. Similarly, a value of 0.5 in the old-age KDR means that, on average, each working-age individual has 0.5 old relative within their family network who may need support. A primary observation is the universal dynamic of population aging: in all four countries, the old-age dependency ratios, whether measured by PDR (gray line) or any KDR (other colored lines), show a projected increase throughout the 21st century. For young-age dependency ratios, a contrasting pattern emerges: after 2025, these ratios are projected to remain relatively stable across all measurement types. This stability reflects the assumption by the UN Population Division that the Total Fertility Rates (TFR) in these countries

will stay relatively constant throughout the projection period.

Beyond this universal temporal trend, our results reveal a crucial structural pattern in the composition of kinship dependency. Across all four countries, the KDR-Lineal consistently emerges as the highest of the three KDRs. This finding directly reflects the life-course dynamics examined previously (see Figure 1), where including grandparents and grandchildren adds a significant dependency load to working-age individuals at various life stages. The KDR-Lineal is highest because it focuses the dependency demands of multiple generations (e.g., aging parents and young grandchildren) onto a structurally narrow set of providers within the direct vertical lineage. In contrast, the other two ratios are lower for distinct reasons. The KDR-Collateral expands the family network to include a wide pool of horizontal kin such as aunts, uncles, and cousins, which adds a much larger pool of working-age providers to the denominator, effectively spreading the potential responsibility. The KDR-Nuclear is also lower than the KDR-Lineal because it includes a smaller pool of dependents by restricting the scope to parents and children.

Another important observation is that the relative positioning of the societal-level (PDR) and family-level (KDR) dependency ratios reveals divergent cross-national patterns for old-age support but convergent patterns for young-age support.

For young-age dependency, the pattern is consistent across all four nations: the KDR-Lineal and PDR track each other closely, with the PDR being slightly higher for most of the period (see top row of each panel in Figure 3). In contrast, the relationship between these ratios varies when comparing the countries for old-age dependency (bottom row of each panel). In Japan and Greece, the KDR-Lineal is lower than the PDR throughout the projection period, whereas in Sweden and the United States, the KDR-Lineal remains higher than the PDR most of the time.

These patterns reflect how population aging manifests differently across societal and family-level measures of dependency, with cross-national variations being far more pronounced for the old. However, it is important to note that because the PDR and KDR are based on different conceptual units, with the PDR reflecting population-level age structure and the KDR capturing kinship-based dependency from the perspective of an average individual, their absolute difference does not carry a directly interpretable meaning.

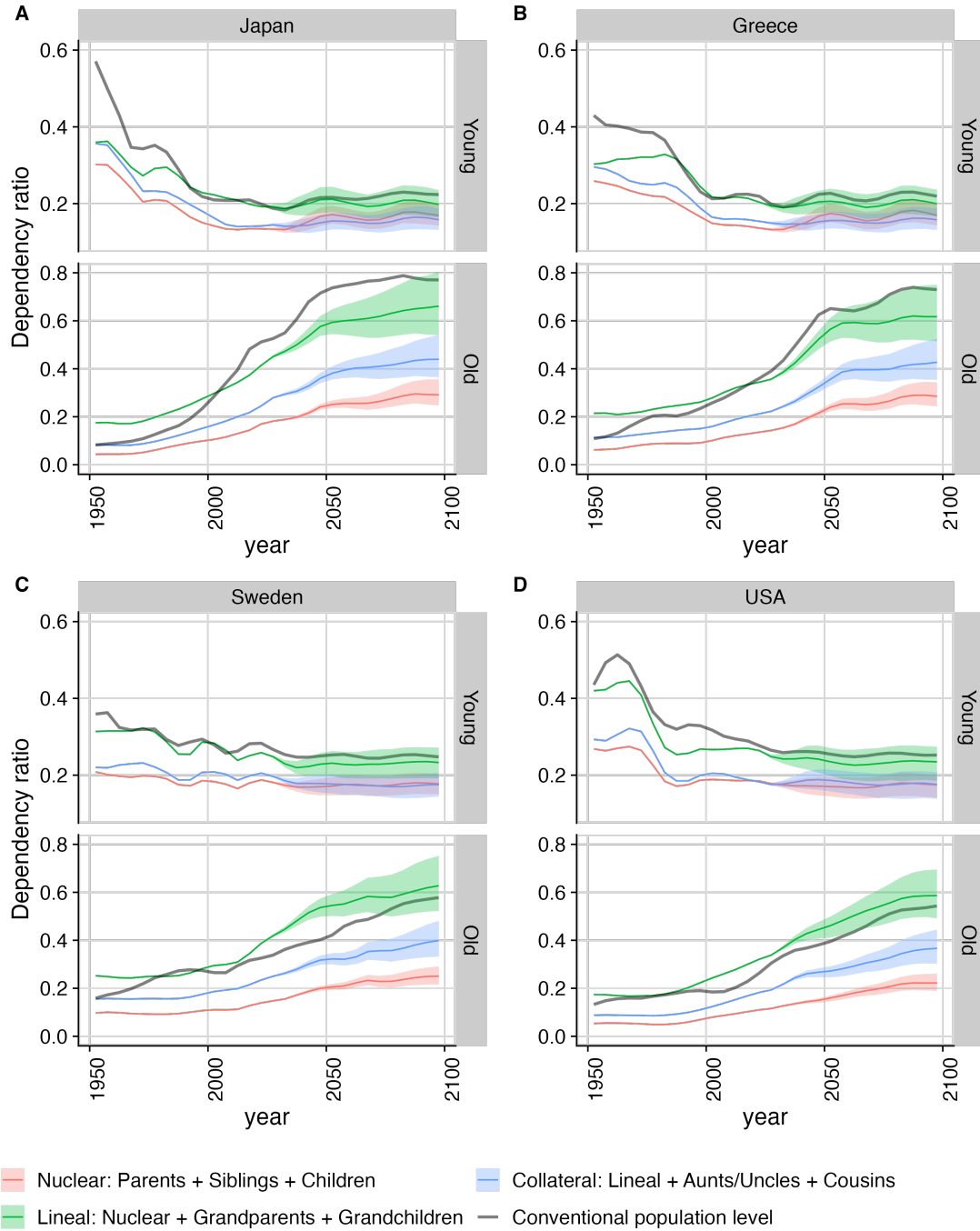


Figure 3: Kin-based (nuclear; lineal; collateral) and population-level dependency ratios, represented by different colors. Shaded areas show the lower and upper 80% projection intervals around the median of the 1000 country-level probabilistic trajectories. Columns show different countries, and rows show old and young dependency ratios. Shaded areas represent results using estimated demographic rates.

Discussion

This study's primary contribution is the development of the Kin Dependency Ratio (KDR), a flexible, multi-scalar demographic metric that reveals potential caregiving responsibilities embedded in kinship networks. While the Population Dependency Ratio (PDR) captures aging pressure at the societal level, it does not show how this pressure is distributed within families. The KDR offers a complementary view by focusing on intergenerational dependency from the perspective of kin availability.

Our findings reveal several key demographic patterns. First, the old-age KDR increases steadily over time in all four countries, mirroring the rise in the PDR. This parallel growth highlights that population aging creates pressure at both societal and family levels. However, for young-age ratios, both the KDR and PDR are projected to remain relatively stable after 2025, a trend reflecting the UN Population Division's projection of relatively constant Total Fertility Rates for these countries. Because the KDR is calculated from the perspective of individuals and reflects the structure of available kin, it helps identify demographic pressures that may be more concentrated at the family level, especially in contexts where formal support is limited. In such settings, the KDR offers insight into care responsibilities that remain invisible in aggregate population measures like the PDR.

Second, the age-specific KDR (ASKDR) varies across the life course, reflecting the dynamic nature of kin-based support. For example, younger adults (around ages 15 to 25) mainly support young siblings and grandparents; middle-aged adults (around ages 25 to 45) mainly care for children and grandparents; and older adults (around ages 45 to 64) often assist grandchildren and parents. The measured level of kin dependency (both ASKDR and KDR) is also highly sensitive to how family is defined. Expanding the network to include non-working-age relatives, such as grandparents and grandchildren, could increase dependency, while including more working-age collateral kin could dilute it. Among the three specifications (nuclear, lineal, and collateral), the lineal KDR, defined to include grandparents, parents, siblings, children, and grandchildren, consistently shows the highest values, as it concentrates intergenerational obligations across multiple generations. Besides, this definitional choice is not only technical but substantively shaped by caregiving norms and living arrangements. In countries where informal care is typically provided within nuclear households, a narrow definition may be more realistic. In contrast, where multigenerational co-residence or extended family involvement is common, broader kin definitions may better reflect caregiving units.

Finally, we emphasize that the interpretation of the KDR depends on the institutional context. In countries where care is highly de-familialized, such as Sweden, a high KDR does not imply increased responsibility for families, since public services cover most care needs. In such settings, the KDR reflects the demographic demand that has been largely absorbed by formal systems. In contrast, in countries like Greece, where formal long-term care is limited and family obligations remain strong, a high KDR is more likely to correspond to caregiving responsibilities that fall directly on families. In this case, the KDR highlights the extent of private exposure to population aging under low-support conditions. In liberal systems such as the United States, where public provision is minimal and care is often mediated through the market, the KDR helps reveal unequal exposure: families with fewer resources may be less able to rely on paid care and more likely to provide support themselves. Finally, in hybrid systems like Japan, where policies are designed to support rather than replace family caregiving, the KDR reflects a shared structure of responsibility. In these contexts, families remain central providers of care but are assisted by formal services.

Taken together, these findings show that the Kin Dependency Ratio (KDR) varies not only by age and kin network definition, but also in how its meaning is shaped by institutional context. While the KDR and the Population Dependency Ratio (PDR) reflect different aspects of demographic aging, their parallel upward trends point to increasing pressures in both public and family settings.

The KDR does not replace the PDR, but complements it by offering a kinship-based perspective on support needs that population-level indicators cannot capture.

In addition, as defined in this study, the KDR reflects potential caregiving responsibilities within families based only on kinship structure. It does not capture actual care arrangements, which are shaped by behavioral and relational factors such as health status, co-residence, and kin availability. For example, a health-adjusted KDR could account for which kin actually need care, while a co-resident KDR could reflect support that is more readily accessible. In addition to family dynamics, the role of formal care provision should also be considered, as it may reduce or redistribute the responsibilities implied by the kinship structure. Furthermore, the KDR is calculated using a deterministic model and represents the expected kinship structure for an average individual in the population. Therefore, it does not capture the variation in dependency across families. Future research could build on this work by incorporating stochastic kinship models to explore how caregiving potential varies across individual family constellations (Caswell 2024). These extensions would help bridge the gap between demographic structure and actual caregiving patterns more directly.

Data and Methods

This section describes the construction of our central metric, the Kin Dependency Ratio (KDR), and its conventional counterpart, the Population Dependency Ratio (PDR). Our KDR calculation builds upon the comprehensive kinship network projections from Albrez-Gutierrez et al. (2023). That foundational study provides kinship projections for all countries in the UN World Population Prospects from 1950 to 2100, estimating the expected number and age of various types of kin for an average female individual. These estimates were generated by applying the time-varying two-sex kinship model (Caswell 2022) to demographic rates from the UN Population Division (United Nations 2022) which was implemented using the `DemoKin` R package (Williams et al. 2021). Moreover, Albrez-Gutierrez et al. (2023) used 1000 individual trajectories of each demographic indicator projected for each country generated using Bayesian methods, which yields the median value and 80% projection interval for the number of kin. Leveraging this data, we calculated the KDR for all available countries. However, to illustrate our theoretical framework, the main analysis focuses on four representative countries, with the complete results presented in the Appendix.

The Kin Dependency Ratio (KDR)

- **KDR-Nuclear:** Calculated for the nuclear family (parents, siblings, children). This represents the tightest circle of caregiving obligation.
- **KDR-Lineal:** Adds grandparents and grandchildren to the nuclear family. This network captures the primary vertical axis of intergenerational transfers, including care, wealth, and social capital.
- **KDR-Collateral:** Adds aunts, uncles, and cousins to the lineal group. This represents the broader, more diffuse network of kin who can serve as a reserve source of support, particularly when immediate family resources are scarce.

For a focal individual of age x at time t , let $N_k(a, x, t)$ be the number of living kin of type $k \in \mathcal{K}$ who are age a . Following international conventions in demographic research, we define the working-age population as those aged 15-64, while acknowledging that effective ages of entry into and exit from the labor force vary across countries and over time. Therefore, the potential support

network consists of all working-age kin (15-64). The level of dependency comes from young kin (0-14) and old kin (65+).

For a given kin set \mathcal{K} , the age-specific KDR (ASKDR) for a focal person of age x at time t is thus defined as:

$$\text{ASKDR}_{\text{young}}(x, t, \mathcal{K}) = \frac{\sum_{a=0}^{14} \sum_{k \in \mathcal{K}} N_k(a, x, t) + I_{\text{young}}(x)}{\sum_{a=15}^{64} \sum_{k \in \mathcal{K}} N_k(a, x, t) + I_{\text{working}}(x)} \quad (1)$$

$$\text{ASKDR}_{\text{old}}(x, t, \mathcal{K}) = \frac{\sum_{a=65}^{\omega} \sum_{k \in \mathcal{K}} N_k(a, x, t) + I_{\text{old}}(x)}{\sum_{a=15}^{64} \sum_{k \in \mathcal{K}} N_k(a, x, t) + I_{\text{working}}(x)} \quad (2)$$

where ω is the highest attainable age. The terms $I(x)$ are indicator functions to include focal herself into the calculation of kin dependency ratio, which depends on focal individual's own age x : (1) $I_{\text{young}}(x) = 1$ if $0 \leq x \leq 14$, and 0 otherwise; (2) $I_{\text{working}}(x) = 1$ if $15 \leq x \leq 64$, and 0 otherwise; (3) $I_{\text{old}}(x) = 1$ if $x \geq 65$, and 0 otherwise.

These age-specific kin dependency ratios (ASKDR) can be aggregated to obtain a summary measure for any chosen focal age group. In the general case, the summary KDR is computed as a weighted average of the age-specific ratios for ages x within the selected range \mathcal{A} , with weights $\pi(x, t)$ given by the proportion of the female population aged x at time t within \mathcal{A} , such that $\sum_{x \in \mathcal{A}} \pi(x, t) = 1$:

$$\text{KDR}_g(t, \mathcal{K}, \mathcal{A}) = \sum_{x \in \mathcal{A}} \text{ASKDR}_g(x, t, \mathcal{K}) \cdot \pi(x, t) \quad (3)$$

where g indicates the type of dependency considered (e.g., young or old).

In this study, to construct a KDR that is conceptually parallel to the Population Dependency Ratio (PDR), which measures dependency from the perspective of the working-age population, we restrict \mathcal{A} to the working-age range (15-64). The resulting summary measures are:

$$\text{KDR}_{\text{young}}(t, \mathcal{K}) = \sum_{x=15}^{64} \text{ASKDR}_{\text{young}}(x, t, \mathcal{K}) \cdot \pi(x, t) \quad (4)$$

$$\text{KDR}_{\text{old}}(t, \mathcal{K}) = \sum_{x=15}^{64} \text{ASKDR}_{\text{old}}(x, t, \mathcal{K}) \cdot \pi(x, t) \quad (5)$$

The Population Dependency Ratio (PDR)

For comparison, we calculate the conventional PDR, which measures dependency at the societal level. Let $P(a, t)$ be the size of the population aged a at time t . Using the same age thresholds for consistency, the PDRs are defined as:

$$\text{PDR}_{\text{young}}(t) = \frac{\sum_{a=0}^{14} P(a, t)}{\sum_{a=15}^{64} P(a, t)} \quad (6)$$

$$\text{PDR}_{\text{old}}(t) = \frac{\sum_{a=65}^{\omega} P(a, t)}{\sum_{a=15}^{64} P(a, t)} \quad (7)$$

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