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HYBRID SIMULATION OF SOCIO-ECONOMIC SYSTEMS: DEFERRED PENALTY FOR MATERNITY IN FUTURE RETIREMENT

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ABSTRACT

The paper deals with the application of hybrid simulation in the field of socio-economic systems. We present a model for assessing the extent to which interruptions in work during a woman's professional career affect the amount of her future pension. Breaks in work due to the childbirths, their upbringing, as well as shorter breaks due to emergency care of sick children significantly affect the amount of the first pension collected in defined contribution pension systems. The model is a hybrid of a demographic model developed according to the system dynamics approach and a pension model built with discrete event simulation paradigm. The experiments examine the size of the maternity penalty for different career scenarios and long-term demographic changes. The primary research objective was to examine the extent to which women's individual life-course choices affect their pension outcomes, in interaction with systemic features of pension schemes and projected demographic changes.

1 INTRODUCTION

Simulation is widely used with the goal to make better and more informed decisions. Simulation models are applied in areas such as manufacturing systems, construction, logistics, healthcare, services, and many others. Also in socio-economic sciences we find simulation models (SESM) that help to study human behavior, technology diffusion, policy implications, demographic trends, overall impact of governmental decisions on societies, to name just a few examples. SESM involves experimenting on a model that maps the interactions between social and economic systems to analyze and predict the effects of various policies, decisions or external influences. It involves modeling the behavior of individuals, organizations and markets over time, taking into account macroeconomic factors, resource allocation but also possible policy interventions. SESM combines elements of social science, computer science and mathematics.

Through the use of simulation methods, it is possible to explore the essence of emergent social phenomena that are difficult to observe directly in reality. However, the modeling of socioeconomic systems faces various specific challenges that are not as prevalent in other areas. Arnold (2010) listed several of these, such as the lack of universal background theories that would fully describe the phenomenon being modeled, or the pluralism of available paradigms, that can result in the modeler choosing only one paradigm, which can significantly distort the picture of the reality being mapped. The use of hybrid simulation (HS), combining two or more approaches, may be an attempt to mitigate these risks. There is a growing consensus among researchers (Mustafee *et al*. 2022) that combining different simulation approaches in a single hybrid model can bring unexpected benefits and partially offset the limitations of individual ones. Anagnostou *et al*. (2025) briefly reviewed papers submitted to HS sessions since the launch of this track at the 2014 Winter Simulation Conference. The authors noted the emerging trend of the use of HS for modeling human behaviors and related behavioral aspects. The authors suggested that this is probably because most of the complex systems tend to involve more humans within their processes.

One of the socio-economic areas where HS may has much to offer is pension system. The progressive aging of the population affects the financial sustainability and social adequacy of pension systems in complex and multifaceted ways, which makes the potential of simulation methods in analyzing the functioning of these systems increasingly apparent. One of the challenges discussed is the problem of non-discrimination of future pensioners, in particular the phenomenon of the *gender pension gap* (GPG). The GPG refers to the difference in retirement income between men and women, with women generally receiving lower pensions than men. One reason for women's lower earnings is that women are more likely to take career breaks and work part-time when they decide to have offspring. While the issue of the impact of motherhood on women's labor supply has been recognized and analyzed for many years in academic articles, (Jee *et al*. 2019; Jedrzychowska *et al*. 2020; Vagni and Breen 2021), whereas studies relating to the impact of having and caring for children on retirement benefits have only recently been the subject of public debate. Research conducted by Dotti and Luppi (2021) shows that the longer a woman stays out of the labor market after having children, the smaller her retirement benefit.

This paper is intended to present the results of the next stage of research work on the use of hybrid simulation to test the impact of various scenarios of women's professional careers on the amount of the first pension. In particular, the main objective is to analyze the phenomenon of penalty for motherhood in pensions. The research uses a hybrid simulation model, which consists of two interdependent models: a demographic model for predicting changes in population (Mielczarek and Zabawa 2020) and pension model, the first version of which was presented in Mielczarek (2023). The simulation model presented here focuses exclusively on public pensions. Private pensions, mandatory or voluntary – either individual or employer provided, are not considered.

The remainder of the paper is organized as follows. Section 2 provides background information on the reasons for GPG and reviews the literature on social hybrid simulation. Section 3 briefly describes the Polish pension system. Section 4 explains the essence of hybridization of the presented model. Section 5 focuses on simulation experiments and results of the study. Section 6 draws conclusions and summarizes the contributions of this research.

2 LITERATURE BACKGROUND

2.1 Gender Pay Gap and its Derived Effects

Differences in earnings between men and women translate into differences in pension payments. The gender pay gap is caused by a number of factors, such as vertical and horizontal segregation between men and women, a motherhood penalty in wages, prolonged absences from the workforce after the child birth, part-time work, availability of childcare facilities, and also cultural perceptions of roles in the family (Blau and Kahn 2017). All these factors work to the disadvantage of women by affecting their current earnings but also their accumulated retirement capital. In pension systems based on the continuous accumulation of pension capital during paid work, the gender pay gap translates directly into a GPG. According to European Commission (2024) the GPG is still about 30% on average in European countries.

The GPG is largely the result of having children. Women are often on sick leave during pregnancy; childbirth and caring for a newborn child take them out of the labor market for several months; and raising children often means having to take on limited work. This means that the labor force participation of women caring for young children is lower than that of men or women without children, which is reflected in earnings. The GPG is therefore often referred to as the *motherhood penalty* or *motherhood pension gap*.

Many European countries have some regulations in place to compensate for the lower income forced by having and raising children. However, redistribution mechanisms are only slightly fulfilling their role of bridging the GPG. As Avram and Popova have shown (2022) taxes and transfers mitigate the gender earnings gap to some extent, but they cannot eliminate it completely. Survey results averaged over OECD countries (Organisation for Economic Cooperation and Development, 2023) show that the pension of a woman who has been out of the labor market for five years and raised two children will be, on average, 95% of that of full-career worker. According to Rutecka-Góra (2016), Poland is among the countries with the weakest redistribution in terms of pension transfers. The scale of redistribution within the pension system is insufficient to compensate women for their inferior position in the labor market: the burden of raising children and lower wages.

2.2 Simulation and Hybrid Simulation in Pension Models

In pension system research, simulation models are primarily employed to develop optimal strategies for fund investment and benefit disbursement (Chen *et al*. 2020), to manage financial and longevity risks by simulating various investment strategies and their outcomes under different market conditions (Najat and Bravo 2021), and to assess the impact of regulation on retirement benefits (Kumara and Pfau 2013). A frequently used approach is microsimulation, which allows tracing the lives of both hypothetical individuals (van den Bosch *et al.* 2024), as well as lifetime trajectories for entire populations (Halvorsen and Pedersen 2019). Research is conducted from both a systemic perspective, examining the functioning of pension schemes and the influence of existing regulations on national social policy (Ståhlberg *et al.* 2006; Li and O'Donoghue 2016), and from a micro-level perspective, focusing on the impact of these regulations on the financial security of specific occupational, economic, and social groups.

Simulation models are also a valuable tool to analyze the GPG phenomenon. For instance, Palmer (2017) explores the extent to which differences in lifetime working hours, particularly those resulting from childbearing and caregiving responsibilities, drive inequalities in retirement benefits. Similarly, Villanueva-Garcia and Villalba (2025) highlight the significance of career length, income trajectories, and sectoral employment patterns in shaping pension entitlements across genders. Simulation studies address also the effectiveness of redistributive instruments – such as minimum pensions, contribution credits, or non-contributory components – in reducing gender disparities in pension outcomes. Lu and Dandapani (2023) studied the effectiveness of intra-family pension benefits transfer and enhanced tax-deductible contributions by prior employers to strengthen pension equality between genders. Van den Bosch *et al.* (2024) investigated the effectiveness of care compensation schemes in several European countries, which can be significant but can also have very little effect or even no effect on subsequent pension benefits.

While some authors (Baumgartner *et al.*2006; Antón, 2012) have examined the implications of population ageing for the sustainability of pension systems, a review of major academic databases reveals a gap in simulation-based studies on how demographic shifts affect the GPG. This research gap provides a strong rationale for employing simulation methods to examine the impact of demographic changes and gender inequality on deferred maternity-related effects in pension systems.

3 METHODOLOGY

3.1 Defined Contribution Pension System

Pension systems are diverse and differ from country to country. The main differentiating feature of mandatory (state) pension systems is that pension income is linked either to years of employment or to the level of past earnings. Over the last 20 – 30 years, a shift can be observed toward defined contribution (DC) pension schemes, in which the amount of pension benefit is closely tied to earnings over the entire period of employment. From among the European countries, the DC system has been introduced in ten countries. The Polish pension system was also radically altered in 1999 with the establishment of a new legislative act, under which a DC system came into force.

In Poland, contributions of 19.52% of the basic salary are paid into the mandatory two pillars of the Social Insurance Company (in Polish: ZUS). They are financed by the employer and the employee. The mandatory two retirement accounts differ in the method of valorization and terms of accessibility. The capital accumulated is in the form of claims against the government. The capital is valorized annually and the amount of valorization depends on the state of the economy, labor market dynamics and inflation. At retirement, the accumulated capital is divided by the average life expectancy applicable to the person's age at retirement. In short, the algorithm for determining the amount of the pension can be written as:

$$Pension_k = \frac{Pillar1 + Pillar2}{Life\ expectancy_k} \tag{1}$$

where *k* is the person's age at retirement.

3.2 The Concept of the Integrated Hybrid Approach

The hybrid model concept we have proposed belongs to the so-called sequential class, which, in addition to two other categories, has been identified and described by Swinerd and McNaught (2012). The authors studied a hybrid composed of Agent Based (AB) and System Dynamics (SD) models, but the classification given can also be successfully applied to other cooperating models built according to different simulation paradigms. In the sequential class one simulation model serves as a tool to inform the other model about the values of key parameters. It has to be run first and its output is uploaded to the second model.

In our hybrid model (Figure 1), first a demographic simulation is carried out according to the SD approach and the results of the implementation of various selected demographic scenarios are entered into the discrete model. The SD model formulates demographic projections for the following years and the results of these projections are taken into account in determining the pension capital accumulation rates (see Section 3.3). Depending on the adopted scenario, the numbers in each age cohort will vary and will affect the values of macroeconomic indicators considered in the discrete model. The discrete event simulation (DES) model performs the actual (target) simulation of pension capital accumulation for the various social groups under study.

The SD model was developed in ExtedSim©, while DES model was built using Arena© Simulation Software. Demographic simulation is carried out once, for a given scenario of projected population changes. Discrete simulation is performed for 45 years in 20 replications.

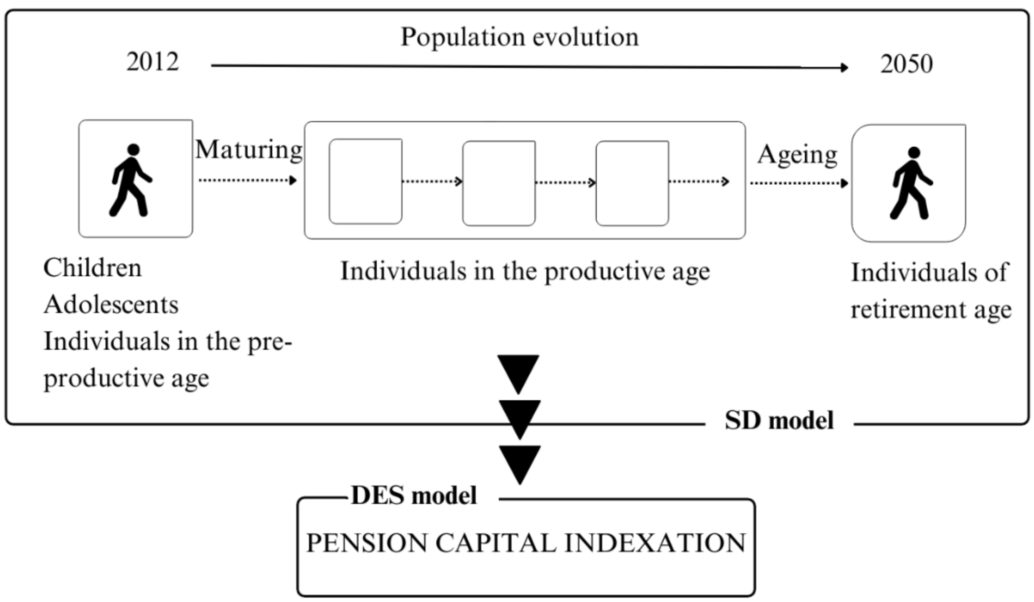

Figure 1: Modeling population evolution – general illustration.

3.3 Assumptions of Hybrid Model

3.3.1 Population Modeling

The demographic model, described in detail in the Mielczarek and Zabawa (2020), forecasts for a given assumed scenario, the numbers of each age-gender cohort. Based on the resulting data from this model, it is possible to determine, for a given year, the size of the working-age population, which in turn makes it possible to estimate the size of the pension contributions made by employed persons to the Social Insurance Company each year. The volume of premiums written is the basis for the indexes of valorization of the capital accumulated in pension accounts announced annually.

3.3.2 Modeling Macroeconomic Indicators

One of the key challenges we faced was to formulate a method for simulating the values of macroeconomic indicators, such as: average and minimum wages in the public sector at different age groups, simulated jointly and separately for both sexes; the rates of annual valorization of the capital accumulated in both pension accounts; and the projected wage index, which is used to top-down limit the amount of contributions made to retirement accounts (Table 1). This safeguard is intended to prevent the state pension system from being overburdened with payments to people who earn more than 30 times this limit.

Table 1: Vector of modeled macroeconomic inputs.

Historical year	Index of the historical year	Minimum wage increase rate	Average wage increase rate	Forecasted wage increase rate	Pillar 1 indexation factor	Pillar 2 indexation factor
2000 – 2023	1 – 24	[%]	[%]	[%]	[%]	[%]

Macroeconomic indicators must be simulated together (in vectors), because the market changes observed at a given moment correspond to simultaneous, cumulative changes in the values of individual indicators. Limited availability of historical data is an important impediment. The DC system was introduced in Poland in 1999 and the full set of indicator values covers 24 years. We therefore decided to use the bootstrapping method developed by Efron (1992) and continuously developed afterwards. The bootstrap is a statistical procedure that resamples a single dataset to create many simulated samples. The basis of the bootstrap method is the assumption that the future is similar to the past. However, instead of trying to describe the past using theoretical distributions and then simulating the future with those distributions, one can generate input data for the simulation directly from historical data. It is assumed that since an observed sample of real data contains all the necessary information about the population under study, this sample can therefore be treated as a population. There is no need to select a theoretical distribution, since input scenarios for simulation can be taken directly from the sample.

For each successive year (Figure 2), an index in the interval (1–24) is generated first, with the algorithm assigning higher probability to recent years and lower probability to earlier years. The macroeconomic indexes for a given simulated year change according to the values read from the drawn vector. The indexes for the valorization of both retirement accounts are further adjusted based on the data read from the demographic model. This is because both indicators depend on the current number of working-age people making pension contributions. A change in the volume of premiums written changes the indicators.

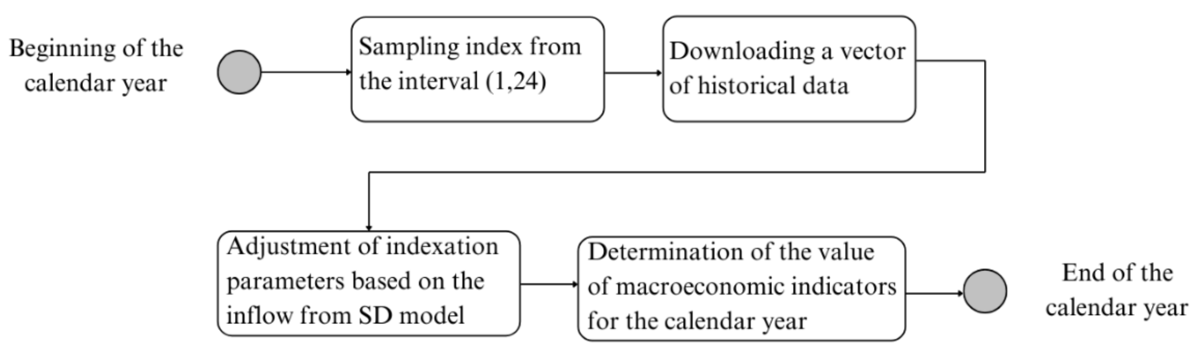

Figure 2: Modeling macroeconomic parameters.

3.3.3 Modeling Pension Capital Growth

The simulation model follows the career of a hypothetical woman from the time she starts working in 2012 at the age of 25 until her retirement (Figure 3). The timing of the start of the simulation is arbitrary, but intentionally the simulation is conducted in such a way that it is possible to verify, through comparison with historical data, the values of the obtained output parameters for several initial years of the experiment.

In the baseline scenario, a woman's first salary is equal to the 2012 national average (value averaged for men and women, combined). In this scenario, a woman works without interruption until she reaches retirement age (60 – the retirement age in Poland for women), or decides to continue working and retires only at 65 (the retirement age for men), or works until age 67 or even 70. Annually, a total amount equal to 19.52% of salary, in accordance with the law, is contributed to the two mandatory retirement accounts. In the model, the amount of both retirement accounts is updated at the end of the calendar year. At that time, the accounts are also indexed by indexation factors. This cycle repeats until the retirement. The amount of remuneration changes at the turn of the calendar year and corresponds to changes in the simulated average salary but individual deviations of -10% to +10% are taken into account.

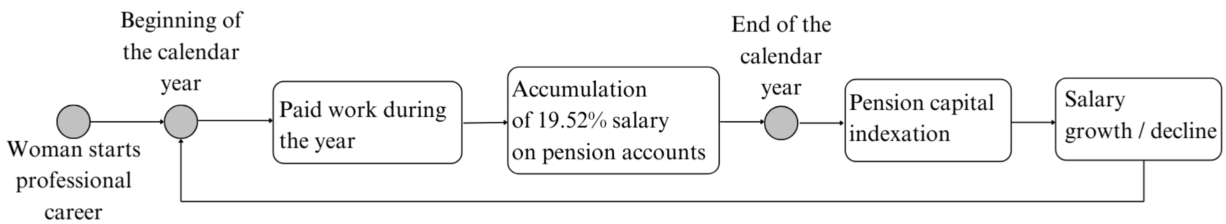

Figure 3: Modeling accumulation of pension capital.

3.3.4 Modeling the Motherhood Pension Contribution Penalty

In modeling the motherhood pension contribution penalty, we consider that during the interruption of employment, depending on the type of interruption, a woman makes fewer or no contributions to her pension accounts. Moreover, in most types of work breaks (Table 2), the woman's salary also does not increase during the interruption remaining at the same level as before the break in the employment. The lower wages are driven by a loss of job-related skills during career breaks, a lower accumulation of experience, or by employer's perception that these workers are less committed to their work (van den Bosch *et al.* 2024). After the interruption, it is assumed that the wage will increase according to the simulated wage growth rates for the given year (par. 3.3.1), but the change is related to the wage level before the work break or layoff began. Table 2 illustrates the impact of interruption type on pension contributions.

Table 2: Breaks in work (maximum values allowed by the law) and their impact on the amount of contributions paid.

Code	Interruption type	Description	Wage increase
1	Normal work	Uninterrupted work time	yes
2	Childcare (parental) leave	Period: 1095 days (3 years); Contribution: on 60% of projected average monthly salary	no
3	Maternity leave	Period: 140 days (20 weeks); Contribution: on 100% of salary	no
4	Sick leave during pregnancy	Period: 270 days; Contribution: none	no
5	Sick leave short	Period: 14 days; Contribution: none	yes
6	Sick leave long	Period: 182 days; Contribution: none	no
7	Unemployment	Period: unlimited; Contribution: none	no

3.3.5 Pension Calculation

The amount of pension is determined at the time of the decision to stop working. According to equation (1), the amount of accumulated capital is divided by the average life expectancy. Life expectancy is defined as the average number of months that people of a particular age could expect to live. In the Polish DC system this parameter is determined jointly for men and women and annually published by Central Statistical Office (2024). The model predicts changes in life expectancy in line with current projections predicting population longevity. A further proportional increase in this parameter was assumed, but taking into account the significant decline that occurred during the Covid-19 outbreak.

3.3.6 Tested Scenarios

Validation of the demographic model is discussed in Mielczarek and Zabawa (2020). Pension model was the subject of a multi-element operational validation, the results of which are described in detail in Mielczarek (2025).

We present results for a number of scenarios with varying combinations of work interruptions due to childbirth, parenting and childcare. The main goal was to analyze the relative effect of the penalty for motherhood on pensions. We studied different configurations of scenarios when there are breaks in women's work due to childbirth, parenting and childcare (Table 3). In addition, each scenario was run for four values of retirement age: 60, 65, 67, and 70. We mainly examined two baseline output indicators: the ratio of a woman's *First* collected *Pension* to her *Last Salary* (FPLS) and the ratio of a woman's *First* collected *Pension* to the *National* average *Wage* (FPNW), for the moment of retirement. In the last scenario, we included an unfavorable demographic forecast that will translate into a significant decline in the working-age population. This, in turn, will result in worse pension capital indexation rates.

Table 3: Career development scenarios considered.

Code	Scenario name	Description
BC	Base Case	Uninterrupted work; A woman’s first salary is equal to the average wage in economy.
1Ch	One Child	Interrupted work: sick leave during pregnancy, maternity leave, parental leave, two-week sick leave every year for childcare; A woman’s first salary is equal to the average wage in economy.
2Ch	Two Children	Interrupted work: twice sick leave during pregnancy, twice maternity leave, twice parental leave, two-week sick leave every year for childcare; A woman’s first salary is equal to the average wage in economy.
WP	Wage Penalty	Uninterrupted work; A woman's first salary is equal to the average salary of women in the economy; A man's first salary is equal to the average salary of men in the economy.
DEM	Demographic Changes	Lower valorization rates due to unfavorable demographic changes.

4 RESULTS

4.1 Base Case Scenario

The base case (BC) scenario refers to women working full time and without interruptions between the age 25 and the selected retirement age with a first salary equal to the national average wage (Figure 4). As the timing of retirement is delayed, the amount of individual’s retirement benefit increases. The FPLS index also increases. This indicator is a proxy for the deterioration of the economic situation at the time of retirement. The higher the value of this indicator, the smaller the difference between the material status experienced during working life and that at the time of retirement. The values of this indicator range from 30% (for retirement age of 60), to 50% for retirement age of 70. With longer working life, not only does the pension capital increase (contributions are paid for longer), but also the value of the life expectancy parameter decreases, which has a significant impact on the higher amount of pension awarded.

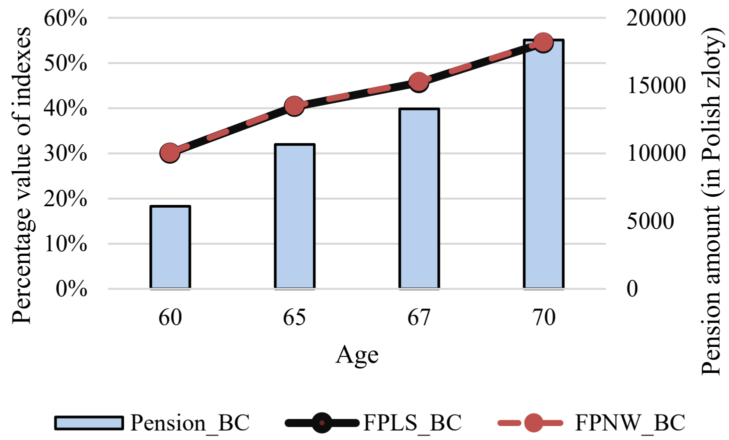

Figure 4: Effect of retiring at a later age. Note: The bars show the pensions amount (in Polish zloty, right axis) for the base case (BC). Solid lines show the values of the FPLS and FPNW indexes (left axis) to benchmark a woman's financial situation against her pre-retirement earnings (FPLS) and the country's current average earnings (FPNW). For the BC scenario, the FPLS and FPNW lines overlap.

4.2 One Child Scenario

A woman goes on sick leave during pregnancy, then on maternity leave, and then on parental leave. She returns to work but takes a two-week sick leave every year for child care (Figure 5). Upon returning to work at age 33 she is the subject to wage and the pension capital penalty. When retiring, the woman receives a significantly lower benefit than in the base case. The FPLS index is similar to that of the Base Case, but this is the result of receiving a low wage and a low pension. The FPNW index is significantly lower than the FPLS index, which indicates that the woman's material situation against the average earnings in the economy is much worse than if she had not experienced any breaks in work.

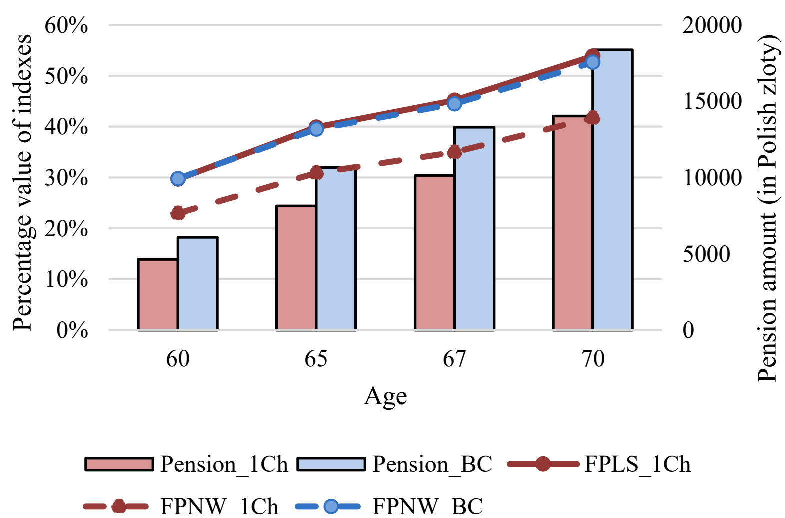

Figure 5: Effect of interrupting career for five years due to sick pregnancy leave, maternity leave, parental leave and then short sick leaves for sick child. Note: The bars show the pensions amount for the base case (BC) and for the one-child scenario (1Ch). Solid lines show the values of the FPLS and FPNW indexes to benchmark a woman's financial situation against her pre-retirement earnings (FPLS) and the country's current average earnings (FPNW).

4.3 Two Children Scenario

Giving birth to two children, raising children, and the subsequent short breaks in work due to childcare result in an even more significant reduction in the future pension (Figure 6). The FPLS_2Ch indicator slightly exceeds the value of the corresponding indicator for the one-child scenario but this is due to both a lower final salary and a lower first pension. Both of these values are lower for scenario 2Ch than for scenario 1Ch, however the ratio between them is slightly higher for 2Ch. This means only that the first pension for scenario 2Ch (although lower than for Scenario 1Ch) yields a better ratio in percentage terms compared to last salary. For example, for a retirement age of 60, the first pension is 29.5% of the last salary for scenario 1Ch and 31.4% of the last salary for scenario 2Ch. The FPNW_2Ch indicator illustrates the significant deterioration of living conditions compared to average conditions in the economy. There is also a clear deterioration in this indicator relative to the one-child scenario.

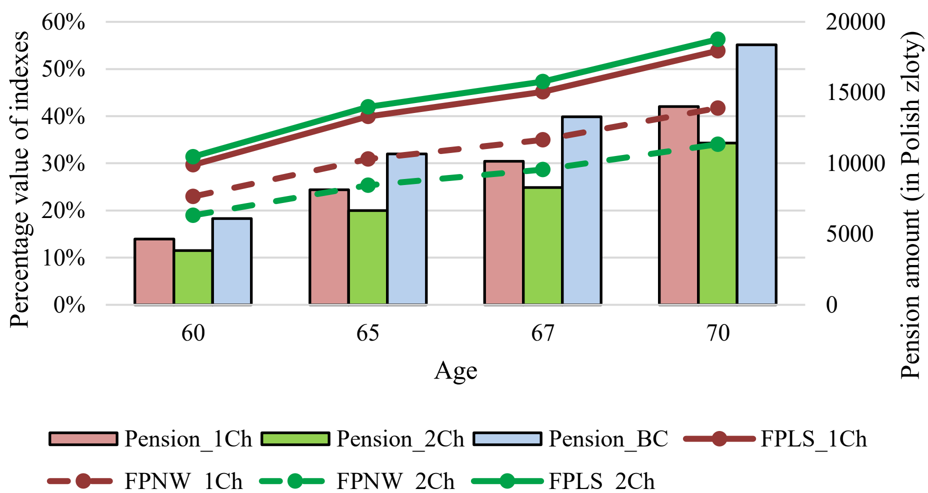

Figure 6: Effect of interrupting career for giving birth and rising two children. Note: The bars show the pensions amount for the base case (BC), the one-child scenario (1Ch), and two-children scenario (2Ch). Solid lines show the values of the FPLS and FPNW indexes to benchmark a woman's financial situation against her pre-retirement earnings (FPLS) and the country's current average earnings (FPNW).

4.4 Wage Penalty

In the case of DC systems, where pensions are so heavily dependent on former labor earnings, public pensions are a major factor driving gender income inequality among the elderly. In previous scenarios, it was assumed that a woman's wage changes similarly to the average wage in the economy, without distinction based on gender. In this scenario, the baseline scenario was repeated, but women's earnings were simulated according to changes in women's average wages, and the results were compared with a similar scenario for changes in men's average wages (Figure 7).

Even if a woman works without interruption, her pension is about 10% lower than that of a man, assuming retirement at the same age. If we take into account the different retirement age (60 for women and 65 for men in Poland), it turns out that a woman's pension will be about 50% lower than that of a man. Retirement at the same age (e.g., 65) gives a difference in the amount of pension of about 11%.

4.5 Demographic Changes

The last experiment assumed a deterioration in the value of retirement account indexes resulting from demographic changes. According to the ZUS's projections, the working-age population (men aged 18–64 and women aged 18–59) gradually decreases and in 2029 reaches a level 0.61 million people less than in

2024. In contrast, the post-working-age population (men aged 65+ and women aged 60+) increases throughout the analyzed period and in 2029 reaches a level of more than 0.35 million people than in 2024. The share of the working-age population falls from 58.1% in 2024 to 57.9% in 2029. In contrast, the share of the post-working-age population rises all the time, from 23.7% in 2024 to 25.3% in 2029.

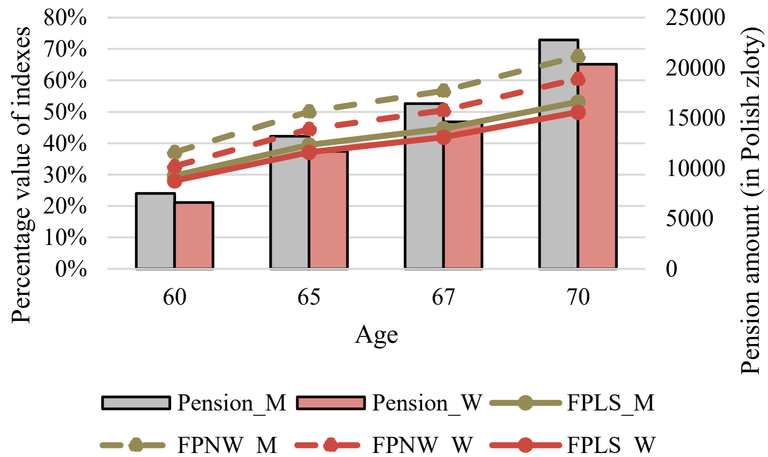

Figure 7: Comparison of the pension of a woman and a man, without work breaks. Note: The bars show the pensions amount for men (M) and women (W). Solid lines benchmark a retiree's financial situation against her/his pre-retirement earnings (FPLS) and the country's current average earnings (FPNW).

Simulation results after considering demographic changes are shown in Figure 8. The markers correspond to three variants of earning career (BC, 1Ch, and 2Ch) and various variants with lower valorization rates due to unfavorable demographic changes. As projected, each scenario has a negative impact on women's pension compared to the baseline scenario corresponding to a women's retirement age of 60. Particularly worrying is the fact that in many cases, a woman raising a child and deciding to work longer will get a lower pension than a woman who does not take breaks from work and retires earlier.

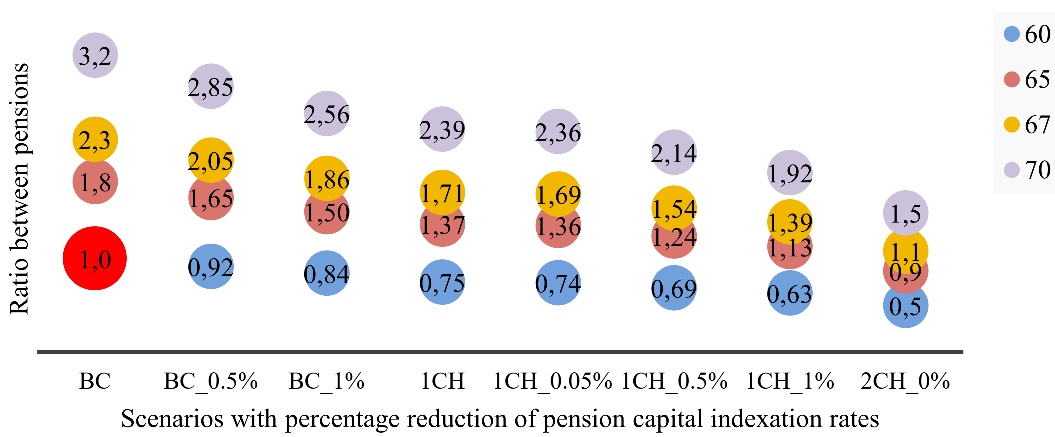

Figure 8: Scenarios assuming lower indexation rates. Note: colors correspond to the four retirement ages. The values on the markers illustrate the ratio between the pension earned and the pension that a woman with no breaks in career would receive, retiring in accordance with the legal age of 60 (big red circle). Legend: BC–Base Case scenario; 1Ch–career breaks due to caring for one child; 2Ch–career breaks due to caring for two children; % markings–reduced values of valorization indicators.

5 CONCLUSIONS

Our research can help formulate recommendations for policies that mitigate pension inequality and the risks associated with an aging population. The structure and principle of the DC system has a *motherhood penalty* already written into it. This study focuses on selected determinants of the GPG, including women's earlier retirement age, unchanged wage conditions upon return from maternity leave, and reduced pension contributions during child-related absences. These factors, along with the persistent gender pay gap, result in significantly lower pensions for mothers – up to 50% less, compared to childless women retiring at the same age. A particularly concerning finding is that even if a woman who has raised two children extends her working life to age 65, her pension entitlement would still fall short of that of a childless counterpart retiring at the statutory age of 60. Moreover, the pension of an average childless woman remains lower than that of a male retiree, highlighting the persistent and compounding nature of gender-based disparities in pension outcomes. Projected demographic trends will probably further exacerbate these disparities, although this undoubtedly requires further research. It may turn out that the shrinking working-age population will force gender pay to equalize, which will work to the advantage of working mothers.

Simulation studies make it possible to trace very different scenarios and take into account the complexity of factors affecting women's retirement financial security. The results can be useful in analyzing the effects of pension reforms from a gender perspective, in formulating policy recommendations, and could allow testing the impact of specific policies (e.g., pension credit for child care) on the level of pension inequality. Hybrid simulation of pension systems, combining different perspectives of mapping reality in a single model, allows tracking the course of individual life scenarios against the global demographic changes. Each person in the model may have individual characteristics and exhibit behaviors that result in varying career trajectories, differences in earnings, family decisions, preferences, etc., and ultimately affect the accumulation of retirement savings. However, individual decisions are also overlaid by structural factors inherent in specific pension systems (e.g., the frequency and size of contributions or the indexation mechanism) and global population-economic trends. Capturing and incorporating these complexities into the model is possible by linking different simulation paradigms. DES operates at the level of individual units, while SD models changes occurring simultaneously for the entire system. An additional rationale for building hybrid models is also the possibility of calibrating them on the basis of statistical data from various sources and the possibility of taking into account official demographic and economic forecasts.

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