Social and Child Care Provision and Kinship Networks: an ABM Model*

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Abstract. Providing for the needs of the vulnerable is a critical component of social and health policy-making. In particular, caring for children and for vulnerable older people is vital to the wellbeing of millions of families throughout the world. In most developed countries, this care is provided through both formal and informal means, and is therefore governed by complex policies that interact in non-obvious ways with other areas of policy-making. In this paper we present an agent-based model of social and child care provision in the UK, in which agents can provide informal care or pay for private care for their relatives. Agents make care decisions based on numerous factors including their health status, employment, financial situation, and social and physical distance to those in need. Simulation results show that the model can reproduce the observed patterns of care need and availability, and therefore can provide an important aid to this complex area of policy-making. We conclude that the model's use of kinship networks for distributing care and the explicit modelling of interactions between social care and child care will enable policy-makers to develop more informed policy interventions in these critical areas.

Keywords: Social Care · Child Care · Kinship Network · Social Policy

"The moral test of government is how it treats those who are in the dawn of life, the children; those who are in the twilight of life, the aged; and those in the shadows of life, the sick, the needy and the handicapped."
— *Hubert Humphrey Jr.*

1 Introduction

One of the most critical, and the most testing, tasks of modern society is the provision of personal and medical care for people in need of assistance due to age, disability or other factors. In particular, every society must provide *child care* for the care needs of their children, and *social care* for adults who need some kind

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of help with their activities of daily living (ADLs). In most developed countries, the state plays an important role in the provision of care for these vulnerable groups. However, formal and informal care provided within the household or broader kinship network is often critical to the health outcomes of vulnerable people. As human lifespans lengthen and birth-rates drop in developed countries, some governments are confronted by a substantial increase in the demand for care.

In the UK, for example, the supply of carers is decreasing over time as birth-rates drop, even while the increasing elderly population requires ever more support [1]. A recent Age UK report states that almost 50% of over-75s are living with a long-term illness that limits their ADLs [2]. Given that this age group is among the fastest-growing in the country, expectations are that the demand for care will outpace the available carer population.

Consequently, *unmet care need* is of critical importance to health and social care policy-making in the UK. Ipsos MORI reports that a majority of the aged with care needs have at least some unmet care needs [3], while Age UK estimates that 1.2 million people received insufficient care in 2017 [2]. Carers UK estimates that in order to meet the skyrocketing levels of care demand, the population of carers would need to increase by 40% over the next 20 years [4]. According to Wittenberg and Hu (2015), demand for privately-funded social care is also expected to rise significantly over a similar period, with expenditure on private care to nearly triple by 2035 [5].

For the majority of households with social care needs, the problem of meeting their social care needs is compounded by the need for meeting their family's child care needs. According to FullFact, 79% of families in England with children aged 0 to 14 used some form of childcare, with 66% of them using formal childcare, 40% using informal childcare and 28% using both [6]. Moreover, according to the OECD report *Society at a Glance 2016*, UK families spend over 30% of their income on childcare [7]. According to LaingBuisson, the UK market for formal childcare amounted to £5.5 billion in 2018 [8].

The provision of social care in the UK, is largely dependent on informal care, or care provided on a volunteer basis by family members. A 2018 report from the National Audit Office estimates the value of UK informal care in UK at £100 billion per year [9]. Aldridge and Huges, using data from The Family Resources Survey 2013/14, report that there were 5.3 million informal carers in the UK [10] and the Health Survey for England 2017 states that 68% of participants aged 65 and over reported receiving help from unpaid helpers, while 21% said they had received help from both unpaid helpers and paid helpers [11]. In this regard, the importance of support and care-giving networks has long been recognized [12]. Keating et all. (2003) reported that informal care is provided mostly through networks of carers with an average of three to five members, predominantly composed of an individual's close relatives [13].

Given the demographic trends outlined above, an increasing number of households will need to manage their resources to provide for both child care and social care needs, meaning that in these cases these two types of care are deeply in-

terrelated. In addition, both the social and child care provision processes taking place within these households, and their connected care-giving networks, are affected both directly and indirectly by the current government's child and social care policies. With that in mind, we propose that understanding how child and social care need evolves over time, and the socioeconomic processes that underline the provision of care, are a vital component in any attempt to develop and implement effective and sustainable care policies.

In this paper, we propose an agent-based model (ABM) of the UK informal and privately-funded formal care system, with the goal of capturing the complex relationships between social and child care, and the impact of social policies on these processes. This model provides a theoretical framework that enables us to improve our understanding of the complex care allocation system, where demographic, social and economic factors interact to determine the dynamics of care demand and supplies. Further, using ABMs enables us to model scenarios of economic and social policy change, providing a means to test social policies which are meant to affect child and social care provision, and reveal any possible unintended side-effects (spillover effects) of those policies prior to implementing them in the real world. Previous work has explored social care provision and policy solutions using ABMs [14, 15]. This simulation extends these efforts significantly, and models the provision of care not just as a simple transaction from one agent to another, but as a negotiation conducted across kinship networks with reference to numerous social, economic and geographical factors. As a result, we propose that this model can support inform child and social care policy-making more comprehensively than other methods.

2 Basics of the model

In this section we provide a summary of the model's core economic and social processes. This model is an extension of previous work in Noble et al. [14] and Silverman et al. [15], adding numerous processes and sub-processes to that basic framework[1]. Agents in the virtual UK depicted in this model occupy households, clusters of which form towns. The sizes of these towns are set with rough correspondence to real UK population densities, scaled down by a factor of 1:10,000. The simulation runs in one-year time steps; within each year processes taking place on a weekly scale are modelled. The simulation begins in the year 1860, which allows sufficient time for the population dynamics to stabilise before 1951, at which point UK Census data is incorporated into the simulation. The simulation finishes in the year 2050.

Given the complexity of this simulation, and the space limitations of this paper, we provide only brief summaries of some aspects which are explained in detail elsewhere, and refer readers to those papers for further information. Changed and additional aspects of the current model are explained here in full.

[1] Complete Python 2.7 source code for the simulation is available here: https://github.com/UmbertoGostoli/CareSim—-Informal-and-Formal-Child-and-Social-Care/releases/tag/v0.8

2.1 Agent Life-Course

Agents are classified as children until they reaching the working age of 16. At this point they can either start looking for work, or continue in education. When agents reach the retirement age (set by a simulation parameter, with 65 as the default), they retire from employment and begin receiving a pension based on their previous income. Mortality rates in the model follow Noble et al. [14] and use a Gompertz-Makeham mortality model until 1951. From that point we use mortality rates drawn from the Human Mortality Database [16]. Lee-Carter projections generate agent mortality rates from 2009.

2.2 Partnership Formation and Dissolution

Once they reach working age, agents can form partnerships. Agents are paired randomly with probabilities depending on agents' age, distance from one another, and socioeconomic status. Model parameters set the relative weights of these factors. Divorce probabilities are age-specific and are checked yearly to determine whether agents decide to divorce. Age-specific annual divorce probabilities determine whether a couple dissolves their partnership. Fertility rates are computed similarly to mortality rates, in which data from the Eurostat Statistics Database [17] and the Office for National Statistics [18] are used from 1950–2009, with Lee-Carter projections taking over thereafter.

2.3 Internal migration

Agents can migrate domestically for several different reasons. Household relocations happen most frequently due to agents finding a partner or a new job in a different town. Male agents will also relocate to new houses once a partnership dissolves, and any children produced by that partnership stay with the mother. Retired agents with care needs may move in with their children, with a probability determined by the available care in that household. Orphaned children are adopted by a household in their kinship network, or by a random family if there are no available households in their kinship network.

2.4 Health status and care need

Agents start their lives in a state of good health, and later may enter a state of care need according to gender- and age-specific probabilities. The five categories of care need and the amount of hours per week of care required at each level are shown in Table 1. Once agents have care needs, they do not recover but continue to progress to higher levels of need over time. The chance of agents progressing to higher levels of need increases with age and with the sum of the agent's past unmet care needs, and decreases with higher socioeconomic status. We thus assume that long periods of unmet care needs will increase frailty, and that higher income and wealth allows for high-quality care to be purchased to increase quality-of-life.

Table 1. The different care need categories, with the number of hours of care required per week

Care need category	Weekly hours of care required
None	0
Low	12
Moderate	24
Substantial	48
Critical	96

3 Model Enhancements

This updated version of the Linked Lives model presented in Silverman et al. [15] has been rewritten from the ground up and substantially extended for greater detail and realism in Gostoli and Silverman [19], where the following features have been introduced: socio-economic status (SES) groups; kinship networks; formal (i.e. privately paid-for) care; a salary function; and hospitalization probabilities (which depend positively on levels of unmet care need). We provide very brief summaries of the SES, kinship network and formal care provision aspects here, and refer the reader to Gostoli and Silverman [19] for more details.

3.1 Socioeconomic Status Groups

Agents are placed in one of five socioeconomic status groups (SES groups), based on the Approximated Social Grade from the Office for National Statistics. These groups were redistributed as in Gostoli and Silverman [19]. Wealth is assigned to agents according to their accumulated income. Agents can move to different SES groups by staying in eduction for longer; each SES group is associated with an education level, which roughly correspond to UK education stages from A-levels to postgraduate degrees.

3.2 Kinship Networks

Households have kinship networks, which are networks of households having a kinship relation with any of the household's inhabitants. We define 'degrees' of kinship based on the network distance between households in the network; this kinship distance value ranges from 0 (same household) to III (uncles/aunts/nieces /nephews).

When an agent is in a state of care need, the kinship network determines the supply of care available to that agent. Physical distance also affects care provision; only households in the same town as the care receiver can provide informal care. Formal care is restricted by kinship distance, with provision occuring only at distances 0 and I. Kinship also influences agents' relocation decisions – agents prefer to relocate to towns where more of their kinship network is living.

3.3 Formal Care

Formal care is also allocated through the kinship network. Households can allocate a share of their income to buying formal care; this share increases as the household's per-capita income increases. This share also determines the amount of income the household is prepared to give up to provide formal care; in other words, agents can elect to reduce their working hours to allow for informal care provision. In the case of child care, formal care is provided only by the child's own household; formal social care, however, can also be provided by the receiver's children and parents residing in other households.

4 Child Care

In this updated version of the social care model from Gostoli and Silverman [19], we included another critical aspect of understanding care provision, which is child care provision [2]. In our model, we assume that all children, except the newborns (agents of age 0), have the same child care need[3]. However, the *net* care need of each child depends on his age, due to the presence of child care and education policies, which determine the quantity of child care provided by the state through nurseries and schools. Newborns are treated as a special case, as they have a much higher need which is entirely supplied by their mother, who allocates all of her available supply of care to meet the newborn's care need.

Although child care and social care seem similar on a surface level, there are deep differences between these two kinds of care which require us to consider them and their supply as two separate but interrelated processes. First, in the UK and most other developed countries there is a parental duty of care defined by law, while social care mostly rests on a social/moral obligation to care for one's relatives. Second, while child care is defined purely by the age of the recipient, social care implies a pathological condition which limits the recipients' ADLs. Consequently, child care need is usually more predictable than social care need and can be supplied on a one-to-many basis, whereas social care usually is delivered on a one-to-one basis. These differing characteristics mean that child and social care provisions are different, although interrelated, processes, the computational implementation of which is discussed in the next section.

5 The care allocation process

The care allocation begins by allocating the available care supply to child care first, with the remaining resources then used to satisfy social care needs. In each stage the allocation mechanism randomly samples a receiving household with a probability proportional to the unmet care need, then a supplying household is sampled with a probability proportional to the available care supply. A

[2] In this model, children are agents of age 0 to 11.

[3] We assume that child care need for children aged 1 to 11 is equal to 56 hours per week.

care 'quantum', equal to 4 hours of care, is then transferred from one member of the supplying household with available supply to a member of the receiving household with care need. The type of care transferred is chosen randomly with probabilities reflecting the relative residual availability of time and income available for care provision in the sampled care supplying household (unless the supplier lives in a different town, in which case only formal care supply is possible). This process repeats until no households with both unmet care need and residual care supply exist within the current kinship network.

When a household has both child and social care need, the household will preferentially allocate informal care to the most expensive variety and formal care to the least. The cost of child care to consider, however, is not the price of formal child care: because of the possibility of satisfying child care needs concurrently for multiple children, the relevant cost of child care is instead equivalent to the hourly rate for formal child care multiplied by the number of children with care need, a value which we call *informal child care value* (ICV). If an household has children with different net child care needs (because of their different ages), its total child care need can be grouped in child care needs associated with different ICVs. For the care allocation process, the household will separate its child care needs into two groups: child care need with ICV higher than the social care hourly rate; and child care need with ICV lower than the social care rate. The higher-cost child care will be satisfied with informal care as much as possible; when the available supply is exhausted, the remainder will be satisfied with formal care when the ICV is higher than the supplier's hourly wage, and with informal care otherwise (provided by taking time off work). Once the higher-cost child care need is satisfied, the lower-cost care will be preferentially satisfied with formal care, unless enough informal supply exists to cover the need.

Once all the household's child care needs are satisfied, the remaining availability of time and income for care within the household's kinship network will be used to satisfy the household's social care need.

6 Social Policy Experiments

Given the importance of child and social care provision to many families, most developed nations design and implement social policies intended to facilitate the provision of care. Education policy also affects child care provision, in that it affects the number of hours children spend in school. In this model, we included the current child care, education and social care policies in force in the UK. By altering related parameters within the model, we can simulate care outcomes and costs under alternative social care policies, which makes this model a unique tool for developing and evaluating policy interventions in this area.

In these early-stage results, we investigated the effect on social care of four policy interventions related to some key policy 'levers' where policy-makers attempt to influence social care outcomes. We developed four potential policy interventions in which some key aspects of UK social care policy are altered in an attempt to reduce overall social care costs to UK society. In the first inter-

vention, we increase the public social care cost contribution from 20% to 80%; in the second, the hours of free government-funded childcare provided for children aged 3 and 4 is increased from 20 to 32 per week; in the third, the level of care need required to receive government-funded social care is decreased from 4 to 3; and in the fourth, a new scheme is introduced in which the state pays 50% of all social care costs. These four policy interventions are labelled Policy 1 through Policy 4 in the Results section below,.

We assume that the four policies are implemented from simulation year 2020 and compare the outputs of these four policy scenarios with the benchmark no-policy scenario over the period 2020–2050.

7 Results

Here we present the outcomes of a representative 'benchmark' simulation and compare these to the effects of possible social policy interventions.

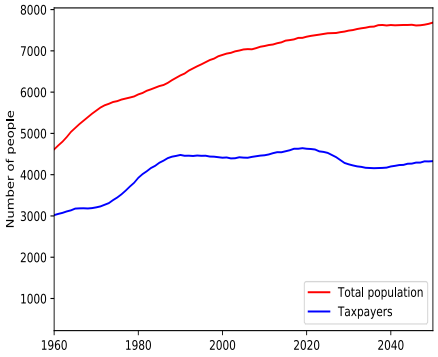

Fig. 1. Population and tax payers.

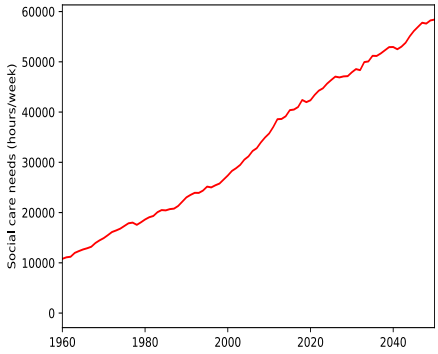

Fig. 2. Total social care need.

Figure 1 shows the population and the proportion of tax-paying agents. Although the population keeps growing from 1960 to 2050, it grows at a decreasing rate. The working-age population grows more slowly, with a noticeable decrease after 2020. The social care effects of these demographic trends can be seen in Figure 2, where we can see the relentless and steady growth of social care need, with a slight increase in the growth rate around the year 2000. Our simulations show social care need reaching a level almost six times higher than 1960 by the year 2050.

Figure 3 shows the dynamics of the per capita hours of social care received. The growth in the average social care received is generally in line with social care need until the final 10-12 years of the simulation, where a declining trend begins. This decrease is reflected in the rapid growth of unmet social care need shown in the same period in Figure 4. In this figure, we can clearly distinguish

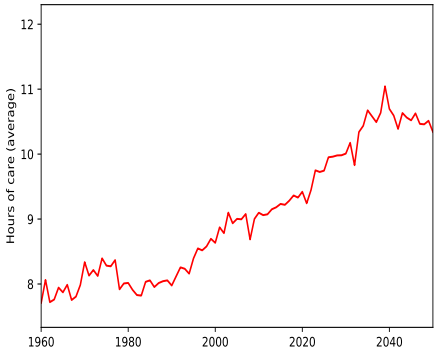

Fig. 3. Average hours of social care delivered per week.

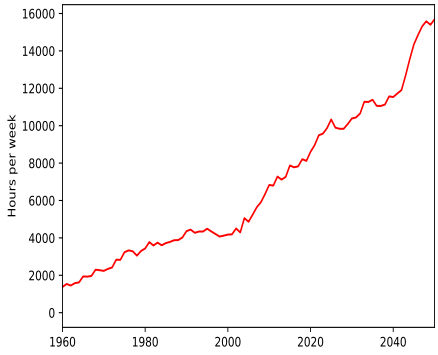

Fig. 4. Hours of unmet social care needs per week.

three periods: a period of slow growth before 2000; a period of rapid but steady growth in the period 2000-2040; and a sudden increase in the last decade of the simulation.

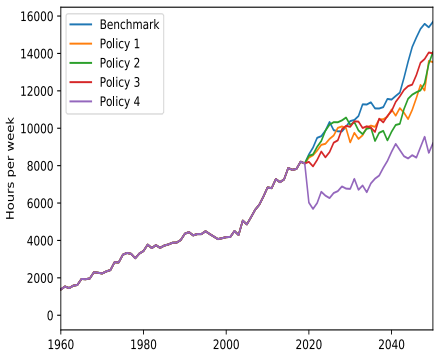

Fig. 5. Unmet social care need by policy.

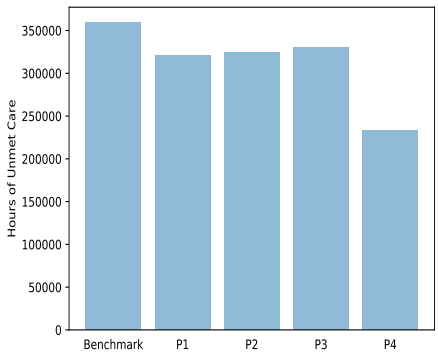

Fig. 6. Total unmet social care need (2020-2050).

In the next six figures, we will consider the effects of our social policy experiments on some social care related outcomes and will compare these outcomes with those of the benchmark scenario. For each outcome considered, we will present two figures: the first shows the dynamics over time; and the second summarizes the overall post-intervention effect (i.e. the sum of the outcome of interest over the period 2020-2050). Figure 5 shows the policy interventions' effects on unmet social care need. We can see that all the policy interventions reduce unmet social care need, although the 50% government contribution to

social care costs (Policy 4 in the graph) is clearly the most effective intervention in this regard. Figure 6 shows clearly that the total effects of the first three policy interventions on unmet social care need over the period 2020-2050 are roughly similar. The fact that the two child care policies (Policy 1 and 2 in the graphs) have a positive effect on unmet social care need, is a clear example of policies' *spillover effects* – unexpected side effects of a policy intervention that can be difficult to spot prior to implementation.

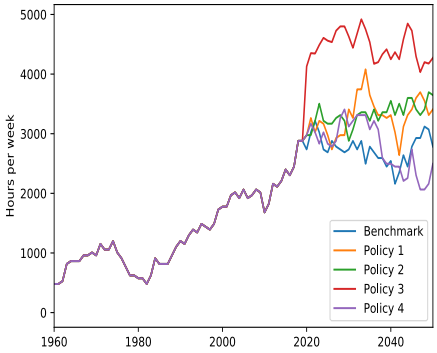

Fig. 7. Public social care by policy.

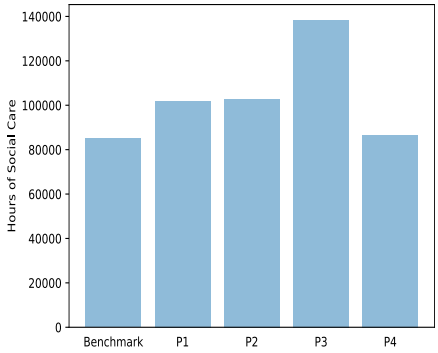

Fig. 8. Total public social care (2020-2050).

Another example of a spillover effect can be observed in Figure 7 and Figure 8, showing the policy interventions' effects on public social care. The reduction of the care need level required to get public social care (Policy 3 in the graphs) is clearly the intervention that most affects the amount of public social care provided. However, the two child care policies (Policy 1 and 2 in the graphs) have a similarly sizable effect on this outcome. The reason for this spillover effect is that, as shown in Figure 5 and Figure 6, these two child care policies have a positive effect on unmet care need, which affects the agents' progression to the most critical level of care need and thus reduces the number of people who are eligible to receive public social care. Although the government contribution to the cost of social care (Policy 4 in the graphs) has a similar effect on the level of unmet care need, this effect is counterbalanced by the fact that making social care cheaper increases the number of people who are not eligible for public social care (because they can now pay it by themselves).

Having seen the effects of these policies on care provision, we now turn our attention to the policies' cost. Figure 9 shows that although the 50% government direct contribution to social care cost is the most effective policy for reducing unmet social care need, it is also the most expensive. Moreover, we can see that the 80% government contribution to child care is the least cost-effective intervention among the first three interventions: its cost is notably higher than

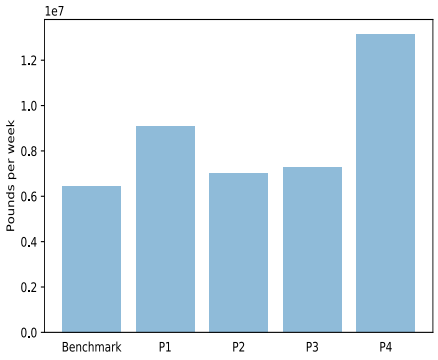

Fig. 9. Total policy cost (2020-2050).

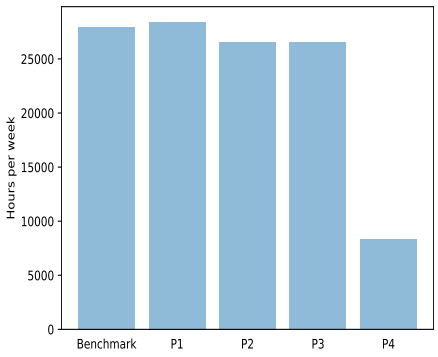

Fig. 10. Hours off work to provide for social care (2020-2050).

the cost of Policy 2 and 3, although its effect on unmet social care need is not significantly different.

Figure 10 shows the effects of the policy interventions on the hours the agents take off work in order to provide social care. We can see that while the 50% government direct contribution to social care cost is the most expensive policy intervention, it also reduces by about a factor of four the number of hours that working people take off work to provide for social care (because under this policy, it becomes more convenient for households to pay for care than to take time off work). This example shows that comparisons of policy cost-effectiveness must take into account social and economic effects, as well as direct financial costs. Further, this example shows that ABM can be a valuable tool for social policy evaluation by enabling more nuanced comparisons of policy effectiveness and cost.

8 Conclusions

Here we have presented a detailed agent-based model of child and social care in a simulated UK population. We propose that this model can serve as a valuable tool for policy development and evaluation, as it explicitly models the complex interactions between child care and social care provision, as well as the negotiations that happen within families as they decide whether and how to allocate their time and money to care provision. The results show that, as a consequence of this detailed modelling of individual-level decision-making and the effects of macro-level social policies, we are able to provide more sophisticated evaluations of policies that illuminate not only their impact on government finances, but their social and economic impact as well.

In future work, we intend to continue to refine this modelling framework to allow users to more easily construct policy scenarios for evaluation. We will also collaborate with social care policy experts and researchers to more accurately

parameterise model processes. Once the simulation framework is more mature, we will seek to provide more detailed and robust analyses of proposed real-world policy interventions directed at child and social care, both within the UK and elsewhere.

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