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Policy levers for household efficiency: an evolutionary game analysis of multigenerational living and healthcare access

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This study models evolutionary game dynamics among three-generation families and family physicians (FPs) to optimize resource sharing in high-cost, increasingly individualistic societies. While FPs deliver vital preventative care and multigenerational households offer economic and social resilience, rising individualism undermines these structures by prioritizing autonomy over collective bonds, eroding intergenerational support, increasing isolation, and weakening shared legacy. In such contexts, multigenerational living becomes an active, difficult choice rather than a cultural norm in many nations. To counter this, we introduce a novel five-player evolutionary game involving government (G), grandparents (R), parents (P), children (C), and FPs (D), analyzing how policy can stabilize cooperation. Using stability analysis of evolutionarily stable strategies (ESS) and MATLAB simulations based on Hanoi, Vietnam data, we identify key drivers: government subsidies, cost-sharing mechanisms, healthcare collaboration, and mutual benefits. Results show that without government intervention, individualism destabilizes cooperation; with targeted policy support, however, a self-sustaining equilibrium emerges where resource efficiency, lower costs, and improved wellbeing arise organically from structural incentives, not continuous coordination. Government thus plays a pivotal, active role: not merely enabling, but anchoring multigenerational resilience against cultural fragmentation. When incentives align family cost-sharing with FP collaboration, all actors benefit, enhancing health outcomes, financial stability, and caregiving capacity. This framework offers policymakers a pathway to reinforce intergenerational ties while strengthening community-based healthcare. Strategic government action can transform resource-sharing from a fragile, voluntary act into a robust, systemically supported norm, countering individualism's erosion of family and health systems, and fostering sustainable, cooperative solutions for aging populations, childcare, and rising healthcare costs.

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Introduction and literature reviews

The global landscape is undergoing a profound transformation driven by three converging forces: accelerating climate change, persistent economic instability, and the cultural ascendancy of individualism. While these phenomena affect populations universally, their consequences are not evenly distributed. Middle-income households, too affluent to qualify for public safety nets, yet too financially constrained to absorb systemic shocks, bear a disproportionate burden (Reeves et al. 2018).

Climate-related hazards, from extreme heatwaves to vector-borne disease expansion and forced displacement, intensify health vulnerabilities, particularly among those without the means to relocate, retrofit homes, or access private healthcare (WHO 2023). Simultaneously, global economic volatility, marked by inflation, wage stagnation, and eroding job security, has rendered healthcare increasingly unaffordable for middle-income families, even in high-income nations. These households often fall into what scholars term the "coverage gap": ineligible for state subsidies, yet unable to sustain out-of-pocket medical expenditures. Middle-income households, too affluent to qualify for public safety nets, yet too financially constrained to absorb systemic shocks, bear a disproportionate burden (Plotke et al. 2024).

Alongside this, the spread of individualism has promoted the prevalence of the nuclear family model, which is separated from the grandparent generation. A global study found a marked decline in extended family coresidence across ~90 countries over the past five decades, especially in societies with high socioeconomic development (Esteve et al. 2024). Similarly, in China, a study demonstrated that while multigenerational family structures were historically prevalent, household sizes have progressively diminished, and divorce rates have risen, indicating a shift towards individualism (Ogihara 2023). Average household size shrank from 4.3 persons in 1953 to 3.1 in 2017, a demographic shift reflecting rising divorce rates, urbanization, and the normalization of nuclear family living (Ogihara 2023).

Although individualism promotes autonomy and innovation, its unintended consequences are becoming increasingly evident:

- Social Isolation and Loneliness: While individualism champions personal freedom and self-reliance, it often comes at the cost of human connection. As communal ties weaken and social structures, from extended families to neighborhood networks, dissolve, more people find themselves socially isolated, even in densely populated cities (Bruss et al. 2024). According to the U.S. Centers for Disease Control and Prevention, approximately one-third of adults in the United States frequently feel lonely, while one-quarter of the population lacks adequate social and emotional support systems. These rates are notably higher among youth and older adult groups (CDC 2024).
- Mental and Physical Health Impacts: The assertion that increased individualism and social isolation are linked to poorer mental health outcomes, including loneliness and despair, is supported by a growing body of research (Pengpid et al. 2023). Studies indicate that individualistic cultures, which prioritize personal goals and independence, may be more susceptible to the detrimental effects of social isolation (Bruss et al. 2024). Additionally, loneliness has been associated with various health risks, including increased mortality, cardiovascular disease, and cognitive decline (Pengpid et al. 2023).
- Higher Healthcare Expenditures: Research indicates that loneliness contributes to increased healthcare expenditures. A study in the Netherlands found that loneliness is directly associated with higher general practitioner and mental healthcare costs, with the impact being more pronounced in younger adults. (Meisters et al. 2021). In the United States, older adults experiencing social isolation incur higher Medicare spending, primarily due to increased hospitalization and institutionalization (Shaw et al. 2017).
  In this context, Family doctors (FDs), also known as general practitioners, serve as gatekeepers to primary medical services by offering health management, basic public health services, disease diagnosis and treatment, and facilitating referrals within the healthcare system (Moore et al. 1983). Family doctors (FDs) serve as a fundamental component in the realization of Sustainable Development Goal (SDG) 3, which seeks to "ensure healthy lives and promote well-being for all at all ages," by comprehensively addressing critical health priorities, including reproductive, maternal, child, and adolescent health, as well as the prevention and management of communicable and non-communicable diseases (Renganathan et al. 2023).

Amid such climate change and economic instability, family medicine is more crucial than ever (Wellbery 2019). FDs and FPs with their holistic, preventative care approach can address the health impacts of these crises, ensuring access to care for vulnerable populations and promoting community resilience (Boeckxstaens et al. 2020).

This study critically examines the intersection between health promotion and the optimization of healthcare expenditures through an analysis of the dynamic intra-household interactions within multigenerational families and their collaborative engagement with family physicians. While existing literature documents the challenges of climate, economy, and social fragmentation, few studies examine how middle-income households strategically reorganize into multigenerational units to collaborate with family physicians, particularly in resource-constrained settings where formal systems are overstretched. It further investigates the potential of multigenerational households to function as efficient, time- and cost-effective adjuncts to primary care provision, particularly in contexts where healthcare systems are under significant strain, as is frequently the case in many developing countries.

Family doctors play a crucial role in supporting middle-income households, highlighting the vital importance of family medicine in today's healthcare system.

- **Climate Change Impacts:**
  Climate change intensifies existing health challenges and introduces new ones, including more frequent and severe heatwaves, the expanded transmission of vector-borne diseases, and population displacement resulting from natural disasters (WHO 2014). FPs/doctors (FP/FD)can play a vital role in:
- **Early Detection and Management:**
  Climate change intensifies health risks such as heatstroke, respiratory illness, and mental disorders, disproportionately affecting vulnerable groups like women, children, the poor, migrants, older adults, and those with pre-existing conditions by interacting with existing social determinants of health (WHO 2023). Addressing these challenges requires not only clinical care but also early detection, community preparedness, and resilience building (Traylor et al. 2024).
- **Promoting Adaptation and Resilience:**
  Promoting adaptation and resilience means raising community awareness of climate change impacts and encouraging healthy behaviors to reduce risks (Katzman et al. 2022). The CCHH ECHO telementoring program successfully improved participants' knowledge, confidence, and

skills in applying climate-related health practices. At a time when training for public health professionals is limited, the course provided essential guidance to help them better serve patients and communities. Strengthening knowledge and communication on extreme heat, poor air quality, disaster preparedness, and mental health remains especially important.

- **Advocating for PolicyChanges:** Working with policymakers to address the root causes of climate change and ensure equitable access to healthcare. In 2017, the American Academy of Family Physicians (AAFP) collaborated with other medical organizations to establish the Medical Society Consortium on Climate and Health (MSCCH), representing over 600,000 physicians advocating for climate solutions (Haq et al. 2023). By 2019, the AAFP joined more than 100 organizations in urging government and business leaders to recognize climate change as a health emergency and to develop a Climate, Health, and Equity Policy Action Agenda (Haq et al. 2023).
- **Economic Crisis Impacts:**
Economic instability can lead to increased stress, poor nutrition, and limited access to healthcare, further straining healthcare systems. Family doctors can:
- **Provide Essential Care:** During times of economic uncertainty, family physicians play a critical role in ensuring that individuals receive the health care services they need, regardless of their financial circumstances. They provide affordable and accessible primary care, which is essential to maintaining public health during difficult economic times (Henry et al. 2022). According to Henry et al. (2022), implementing alternative payment models in primary care, which are risk-adjusted, encourages comprehensive care delivery and efficient service delivery for all patients, regardless of payment source.
- **Address Social Determinants of Health:** Social determinants of health (SDOH) include living, working, and learning conditions, and they play a major role in shaping health outcomes. Factors such as poverty, food insecurity, and lack of education are major drivers of health inequalities within communities (Whitman et al. 2022). Family doctors play a pivotal role in identifying and addressing factors that impact patients beyond the clinical environment. Social determinants of health (SDOH) are contextual environmental elements that can lead to health disparities; they encompass poverty, educational quality, food insecurity, access to transportation, affordable housing, unemployment, maintenance of basic utilities, violence, and public safety (Sherin et al. 2019).
- **Promote Mental Health:** Under the Patient Protection and Affordable Care Act (ACA), a significant number of Americans have gained health insurance coverage that includes mental health services as an essential health benefit (CMS 2022). Based on research, mental health support for individuals and families facing economic hardship is essential. Research shows that psychological factors such as personal autonomy, self-esteem, and coping skills can be impaired by financial hardship, increasing the risk of mental health problems (Frankham et al. 2020). FPs provide mental health support to individuals and families struggling with the economic hardships caused by the crisis.
- **Holistic Approach:**
The family physician's focus on the whole person and family unit makes it well-suited to address the complex health problems caused by climate change and economic crises.
- **Preventative Care:** Family doctors are uniquely positioned to leverage their trusted relationships with individuals, families, and communities to educate and provide resources that promote health and prevent diseases exacerbated by climate change. They can utilize these relationships to raise community awareness about the health impacts of climate change and encourage healthy behaviors to mitigate risks (Haq et al. 2023). Family doctors can implement preventative measures, such as vaccinations, health screenings, and lifestyle counseling, to reduce the risk of developing chronic diseases and other health problems (Crabtree et al. 2005).
- **Coordination of Care:** Family doctors can coordinate care with specialists and other healthcare providers to ensure that patients receive comprehensive and integrated care. Delivering high-quality, integrated care to patients with complex medical conditions necessitates effective collaboration among primary care providers, specialists, and various components of the healthcare system (Lockhart et al. 2019). As Lockhart et al. (2019) wrote, the Patient Experience Optimization Project (SCOPE) is an innovative architecture that enhances the role of the primary care physician (PCP) in coordinating care for patients with complex medical conditions. SCOPE provides essential tools and resources, including: a navigation center, links to general practitioners, and online access to patient outcomes.
- **Community Engagement:** Family doctors can work with community organizations to address the health needs of vulnerable populations and promote community resilience. The survey had a 66.6% response rate, with physicians assessing their level of confidence in carrying out 15 community-focused activities (Crump et al. 2016). A strategy to promote increased physician engagement in the community through the integration of medical training with community-based organizations (Community-Based Organizations, CBOs) (Crump et al. 2016). This model program, developed at a family medicine training program in Harlem, New York City, allows residents to partner with organizations that address the social, political, economic, and environmental factors that influence health in underserved communities. The program also provides opportunities for residents to assume leadership roles in community health care (Crump et al. 2016).

A family physician treats patients regardless of their age, gender, or symptoms, dealing with a broad spectrum of health issues that adds variety and interest to his/her work. He/she focuses on prevention, positioning themselves as health educators, and they also serve as coordinators and leaders within the healthcare team. While these are the strengths of family practice, there are some limitations faced by an FP in clinical practice (Hellenberg et al. 2018).

Family physicians (FPs) frequently encounter patients who present with vague or unclear symptoms rather than a definitive diagnosis. As a result, they must consider all potential causes, explore various factors, and be vigilant for warning signs. Being the first point of contact, FPs often deal with patients' and families' anxieties, worries, and frustrations. Many family practice environments have limited resources and restricted access to advanced technology. Additionally, maintaining accurate health records is crucial but can be challenging for FPs due to the lack of resources and technical assistance. Keeping up-to-date with the latest knowledge requires more effort compared to specialists working in hospital settings (Hellenberg et al. 2018).

The family physician holds a variety of roles, including providing medical care, educating others, overseeing clinical quality, and engaging in research. The development and implementation of these areas within family medicine differ across regions globally (Hellenberg et al. 2018).

Nevertheless, a significant shortage of family physicians has been reported in many studies and publications, even in high-income countries like the United States, highlighting ongoing barriers to accessing primary care. In the United States, primary care physicians make up only about 25% of the physician workforce, leaving over 100 million Americans without consistent access to primary care services (Rosenthal 2023).

Thirty-three empirical studies were reviewed, all of which reported on the prevalence of burnout among family physicians (FPs) in the United States and/or examined the associations between burnout and various personal and contextual factors. On average, the reported prevalence of burnout among FPs across the studies that assessed it was 35%. Nearly half of these studies found that at least one-third of their FP participants met the criteria for burnout (Hoff et al. 2023).

The FP model has also been facing many major challenges, of which fragmentation and lack of linkage in the health system are notable issues. Although the FP model has been developed in some localities and has the potential to help improve the quality of primary health care for the people, the actual implementation still faces many difficulties. Fragmentation and lack of linkage between the database and facility management have created barriers to the development and maintenance of this model.

In contrast, many countries of the Global South continue to uphold strong collectivism, characterized by a deep sense of community spirit and interdependence, which sustains multigenerational family models. These living arrangements are increasingly adopted worldwide, not merely as a cultural norm but as a pragmatic adaptation strategy rooted in collectivist values. A study by Chang (2020) shows that filial piety traditions in Taiwan foster a system in which children and younger generations bear moral responsibility for older adults. In Southeast Asia, 50.29% of respondents say their life purpose is caring for family (kin-orientation), indicating strong communal values in the region (Lomas et al. 2022). Even in Western contexts, immigrant and suburban middle-class families adopt multigenerational models to offset childcare, eldercare, and housing costs (Cohn et al. 2022). As of March 2021, about 59.7 million people in the U.S. lived in multigenerational households, up from 58.4 million in 2019. This corresponds to about 18% of the U.S. population, more than double the share since the 1970s (Cohn et al. 2022). This practice not only strengthens intergenerational bonds but also supports primary healthcare, particularly in resource-limited settings. Consequently, multigenerational families play a vital role in regions with less advanced medical systems by providing shared resources, emotional support, and collaborative care for elders and young children while helping to reduce healthcare costs.

Therefore, with a less advanced medicine system, in the Global South, multigenerational families play a crucial role in supporting family medicine by providing shared resources, emotional support, and collaborative care, particularly for elders and &&young children, and can also help mitigate healthcare costs.

Here's a more detailed look at how multigenerational family support impacts family medicine in the Global South:

Benefits of Multigenerational Family Support:

- **Shared Resources:**
  A primary motivation for many individuals considering a multi-generational home is the associated economic advantage. One of the most notable benefits of this living arrangement is the opportunity for considerable financial savings (Bob et al. 2024). Multigenerational households often pool resources, including finances, housing, and childcare, which can ease the financial burden of healthcare and improve access to care. For instance, Americans living in multigenerational households are less likely to fall into poverty than those living in other types of households (Cohn et al. 2022).
- **Emotional Support:**
  Family members can provide emotional support to each other, especially during times of illness or stress, which can improve patient well-being and adherence to treatment plans. Living together in a multigenerational household enables members to support each other emotionally and practically, from caring for young children to assisting the elderly (Harrigan 1992).
- **Collaborative Care:**
  Grandparents and other family members play a crucial role in assisting with childcare, eldercare, and various aspects of healthcare, thereby enabling parents to maintain employment and access necessary healthcare services. This collaborative caregiving arrangement not only supports the well-being of the elderly and children but also alleviates the caregiving burden on parents. By sharing caregiving responsibilities, families can create a more balanced and sustainable living environment (Musil et al. 2006).
- **Cultural Context:**
  Family medicine in the Global South often requires a culturally sensitive approach to effectively address the diverse health beliefs and practices of local communities. Integrating cultural understanding into healthcare delivery enhances patient engagement and outcomes, particularly in low- and middle-income countries (LMICs) where cultural factors significantly influence health behaviors. (Cipta et al. 2024). Multigenerational families serve as cultural bridges, facilitating healthcare that aligns with community-specific needs. By encompassing diverse age groups and cultural experiences, these families can enhance communication between patients and healthcare providers, leading to more culturally competent care (Kamal et al. 2020).
- **Continuity of Care:**
  Family physicians building long-term relationships with patients improve continuity of care and allow for a more holistic approach to health. Research shows that when patients develop long-term relationships with their family physicians, they often expect longer between visits without requiring longer consultation times, which is especially beneficial for older adults, those with chronic conditions, and mental health issues (Nowak et al. 2021).
- **Reduced Healthcare Costs:**
  Living in a multigenerational household can reduce healthcare costs by sharing medical resources and caregiving responsibilities. This arrangement allows families to pool funds for healthcare expenses and share medical equipment, ensuring that all members have access to necessary care (Friedman et al. 2019).
- **Improved Access to Care:**
  Family members can help patients navigate the healthcare system, access transportation to medical appointments, and ensure that they receive the necessary care. Living in a multigenerational household offers several health benefits, including increased life expectancy, improved mental health, and shared health resources (Xi et al. 2023). Second-generation individuals engaged in downward multi-generational relationships, interacting primarily with their children, exhibit higher healthy life expectancy and

overall life expectancy across all age groups compared to those involved in two-way multi-generational relationships, which include interactions with both children and grandparents (Xi et al. 2023).

- **Strengthened Family Bonds:**
  Living in the same household encourages more frequent interaction among family members, often strengthening their bonds. Eating meals together regularly and engaging in daily conversations provide chances for meaningful dialog and shared moments. This close-knit environment offers emotional and psychological support, as family members are more attuned to each other's needs and challenges (Harrigan 1992). Additionally, multigenerational living helps maintain family traditions and values, with storytelling and shared activities serving as a way to pass down cultural heritage.
- **Care for Elders:**
  Multigenerational families play an important role in caring for the elderly, helping them maintain their health. Support from family members not only eases the burden on the elderly but also strengthens family ties. According to Schulz et al. (2020), the article synthesizes and analyzes studies on the role of families in caring for older adults, involving intervention strategies to support caregivers. It emphasizes that caregiving impacts are diverse, largely depending on the intensity of care provided and the suffering of the care recipient. Successful interventions often combine addressing practical caregiving issues with alleviating the emotional burden on caregivers. Living with a multigenerational family can improve the mental health of the elderly. They are less stressed and anxious thanks to regular social interaction and emotional support from family members. This not only benefits the elderly but also helps children learn from the positive and wise examples of their grandparents (Schulz et al. 2016).
- **Care for Young Children:**
  Multigenerational families can also provide childcare and support for young children, allowing parents to work and access healthcare services. Research shows that the first birth of a child not only reduces mothers' earnings and employment rates, but also negatively affects grandmothers' ability to work. This explains why grandparents often provide informal childcare, helping their children maintain or return to work after the birth of a child (Karademir et al. 2024).

Challenges of Multigenerational Family Support:

- **Conflict:**
  Coexisting under one roof with multiple generations may give rise to conflicts, especially regarding the allocation of financial responsibilities, caregiving duties, and the establishment of household regulations (Harrigan 1992).
- **Privacy:**
  Maintaining privacy within a multigenerational household can be challenging, especially when there are multiple generations living under one roof. Living with multiple generations under one roof can reduce personal space, especially for younger adults or older adults who are used to living independently. The lack of personal space can lead to feelings of intrusion and stress (Harrigan 1992).
- **Caregiver Burnout:**
  Family members who are providing care for elders or young children can experience caregiver burnout, which can negatively impact their health and well-being. The lack of public childcare may place more burdens on grandparents, leading to reduced labor market participation. Research on the public childcare program in Quebec shows that the provision of formal childcare increases mothers' employment rates and at a lower rate for grandmothers (Karademir et al. 2024).
- **Cultural Differences:**
  Each generation may have different values, beliefs, and lifestyles, from attitudes toward work and education to how they use technology (Harrigan 1992). Cultural differences between generations can lead to misunderstandings and conflict, especially when it comes to healthcare practices and beliefs.
- **Economic Strain:**
  Caring for multiple generations can impose a considerable financial burden on families, especially in regions with limited resources. In 2015, about 2.5 million people, or nearly a quarter of all adult caregivers, were caring for both an elderly parent and a child. About 70% of them had paid work, but nearly 25% said they were experiencing severe financial hardship, and nearly half admitted to significant emotional stress (Lei et al. 2023).

Therefore, multigenerational families play a vital role in supporting family medicine in the Global South, providing shared resources, emotional support, and collaborative care. While there are challenges associated with multigenerational living, the benefits often outweigh the costs, particularly in areas with limited resources and healthcare access.

The paper has been structured into followed sections: next section on the research gaps, contributions and stated problem on the dynamic interactions among members of multigenerational family and their cooperation with physician doctors under supports/non-supports by government; section 4 and 5 focus on model building to solve such problem then the model being tested by MATLAB simulation based on real-world data at Vietnam's Hanoi; section 6 on discussion and policy implications from our research findings.

Research gaps, stated problems, and contributions

Research gaps. There's a significant lack of research in family medicine and primary healthcare within the Global South, with limited funding, resources, and research capacity compared to the Global North, hindering progress in addressing health challenges in low-income settings (Arya et al. 2017). According to Wright's (2024) shows that even in the economically advanced countries of the Global North, given the limited federal investment in primary care research, particularly studies not centered on specific organs or diseases, it is unsurprising that only 19% of family medicine departments report having sufficient funds to sustain their research capacity (Bowman et al. 2017), 80% of family medicine faculty spend less than half a day per week on research and, on average, produce fewer than one scholarly work annually (Brocato et al. 2005).

While Western models regard the nuclear, self-reliant household as the norm, much of the Global South operates within collectivist cultural frameworks, where multigenerational living, shared responsibilities, and family obligations are not relics of the past but practical adaptations (Chang 2020; Harrigan 1992).

In cultures that emphasize individualism, autonomy, and independence are highly valued, often at the cost of social cohesion. The decline of extended families has left middle-income households isolated, struggling to care for the elderly, children, and individuals with chronic illnesses without support, resulting in higher healthcare utilization and costs (Esteve et al. 2024; Meisters et al. 2021; CDC 2024). In collectivist cultures,

interdependence is the norm. Families function as informal care networks, sharing financial burdens, rotating caregiving responsibilities, and providing emotional support, making them natural partners and cost-saving allies for overburdened primary healthcare systems (Harrigan 1992).

However, clinical studies rarely capture the internal dynamics of these households, care negotiations, intergenerational decision-making, or emotional labor, even though these factors directly influence treatment adherence, cost-effectiveness, and health equity (Musil et al. 2006).

The majority of current literature focuses on analyzing the role of research in family medicine. These articles often emphasize the importance of building a strong research culture and enhancing support from professional organizations (Gotler 2019; Conde et al. 2024). Additionally, some studies, such as those by Gupta et al. (2023), highlight the critical role of family physicians in providing primary care.

There is a notable scarcity of research specifically examining the interactions between family physicians and multigenerational families. Although family doctor emphasizes understanding patients within their broader familial and social contexts, empirical studies focusing on multigenerational household dynamics in clinical settings remain limited.

While various studies have explored the challenges encountered by Family Physician Programs (FPP), there has been a lack of a comprehensive, systematic analysis addressing these issues globally. This review aims to fill that gap by identifying the worldwide implementation challenges of FPPs and examining the solutions developed to address these (Mohammadibakhsh et al. 2023).

Also, they found that the successful implementation of Family Physician Programs (FPP) necessitates a comprehensive approach that considers various facets of the health system. Key factors include political commitment, economic investment, social dynamics, and cultural contexts. Effective scientific governance, sustainable financing, appropriate payment mechanisms for healthcare workers, robust incentives, the development of strong information systems, and ensuring access to services that respect and integrate the community's cultural norms are all critical components. Addressing these elements collectively can lead to the effective establishment and operation of family physician initiatives (Mohammadibakhsh et al. 2023).

While not the primary focus of the study, it was observed that family physicians (FPs) often act as intermediaries, fostering relationships with specialist physicians to ensure comprehensive care for their patients. Such collaboration is vital for maintaining continuity and coordination across primary, secondary, and tertiary healthcare levels (Kripalani et al. 2007) (Kvamme et al. 2001). However, in countries like India, where family medicine is still emerging, tensions between FPs and specialists are prevalent. These tensions often stem from a lack of understanding regarding the complementary roles of different healthcare providers and how they can effectively collaborate within the health system (Haq et al. 1995; Hedley et al. 2005; Gupta et al. 2023). Limitations of FP mode. This research highlights how pioneering family physicians overcome these tensions and develop relationships and referral pathways with specialists (Gupta et al. 2023).

Stated problems. In the face of climate change and global economic fluctuations, middle-income households in both individualistic and collectivist societies face significant challenges in accessing and affording healthcare. In this context, family medicine is more essential than ever. Through their holistic and preventive approach, family physicians can mitigate the health impacts of these crises, ensure care for vulnerable populations, and strengthen community resilience. However, given systemic and relational challenges, particularly misaligned incentives and information asymmetry among stakeholders, traditional policy or clinical interventions alone are insufficient.

This paper examines the dynamics of interactions between middle-income multi-generational households, including grandparents, parents, children, and their family doctors under support/non-support by the government, focusing on the link between health promotion and optimizing health expenditures.

Contributions

3GFD synergy model: a coalition of 3 Generational Families with a Family Doctor under the government's regulations. This paper proposes the 3GFD model as a solution to address most challenges outlined above.

Collaboration between multigenerational families and their family physician is crucial for several reasons. It helps build strong, trusting relationships across generations, facilitates understanding of family health patterns, and promotes proactive health management. It also allows for a more holistic approach to care, considering the social and emotional context of the family, and enables better coordination of care, especially for complex or chronic conditions.

Besides that, collaborating with a family physician can help multi-generational families reduce healthcare costs by fostering preventive care, promoting early intervention, and ensuring continuity of care. This can lead to lower overall healthcare expenses compared to fragmented or delayed care. Studies have shown that primary care, including that provided by family physicians, is cost-effective and can lead to lower overall healthcare expenditures. For example, one study found that patients who maintained continuity of care with a family physician had lower total healthcare costs.

The 3GFD model proposes a framework for sustainable collaboration between FPs and households to improve the quality of community health care. However, the involvement of multiple stakeholders, including FPs, household members, can lead to uncertainty in the decision-making process. Each party operates independently and lacks information about the other's strategic choices, making it difficult to synchronize decisions and collaboration. This situation is characterized by any worthy information, requiring a deeper understanding of the process that has been decided. Conflicts of interest between FPs, households, and external health organizations can also hinder collaboration. While FPs focus on the work of providing quality health care, households are concerned about the costs and benefits of participation. Evolutionary game theory provides an analytical framework for examining how cooperation in the 3GFD model can inform repeated decisions and strategic adjustments.

These insights are particularly valuable in collectivist contexts (the Global South), where multigenerational living and family obligations are deeply embedded in the culture, turning social norms into structural advantages for primary healthcare. In individualistic contexts, this model provides a detailed framework to reconstruct "chosen families" through incentivized collaboration.

Importantly, the success of the 3GFD synergy model depends on the active and intentional participation of all stakeholders. And most notably, the model achieves optimal efficiency when generations of the family live together in the same house. However, uncertainty among the parties and the ability to decide on positions due to a lack of information can hinder rational action.

This study uses an evolutionary game model to refine strategies that can strengthen sustainable collaboration between FPs and households.

The study is guided by four main research questions:

- What conditions are necessary to realize a stable evolutionary strategy in the 3GFD synergy model?
- How do the forces determined and the strategic interactions between related images affect the stability of the 3GFD synergy model?
- What mechanisms or policy interventions can be effective in encouraging all parties to actively participate and maintain collaboration in the 3GFD synergy model?
- How can theoretical analysis and experimental simulation confirm the effective results of these strategies?

Through theoretical modeling and simulation, this study explores the dynamics of collaboration in the 3GFD synergy model and identifies key strategies to promote stability. The results found that a stable evolutionary strategy, characterized by active participation from all stakeholders, was feasible. Although there may be initial instability, the system tends to reach a rational equilibrium over time. Further analysis showed that the decision of the Family doctor is strongly influenced by both the family and external health organizations, with the participation of health organizations being an important factor in maintaining cooperation. The study also identified several factors that could promote cooperation in the 3GFD synergy model, including increasing penalties for non-participation, optimizing utility allocation, and reducing costs for both the Family doctor and the household. These insights contribute to the design of policies and work more effectively to provide sustainable rationality between the family doctor and the household. In the current context of rising costs, middle-income households are facing significant financial pressure and need to manage their spending effectively to maintain their standard of living.

3GFP synergy model building

Assumptions and parameters. **Assumption 1:** Game players

In the five-party evolutionary game, five key participants are considered: Local Government (G), Family doctor (D), Grandparents (R), Parents (P), and Children (C). Each player is assumed to be risk-neutral, operate under information asymmetry, and make decisions based on bounded rationality. Local Government has two strategic choices: "Support Policies" or "No Support Policies"; Family doctor has two strategic choices: "FP's Discount Offer for Family Package" or "FP's No Discount Offer for Family Package"; while the three other participants, Grandparents, Parents, and Children, each choose between "Support and Cooperation" or "No Support and Cooperation". These strategic interactions drive the evolutionary dynamics of the system, ultimately determining the stability and long-term viability of cooperative behaviors.

Assumption 2: Reputational benefits and Reputational risks

When the local government adopts the "Support Policies" strategy, it bolsters its public image by demonstrating effective governance, a strong commitment to sustainable development, and efficient management of academic partnerships. As a central policymaker, the government formulates strategies and allocates critical resources to ensure the smooth operation of the family healthcare system. The implementation of these support policies contributes to reducing healthcare costs by improving system efficiency and promoting cooperation among stakeholders. Through the establishment of clear guidelines and the provision of necessary support, the government plays an essential role in maintaining a sustainable and equitable healthcare framework for all families.

Conversely, if the local government adopts the "No Support Policies" strategy and any of the involved economic actors, such as family members or family physicians, refuse to cooperate, the regulatory body may face a local healthcare crisis, as well as significant reputational risks due to its inability to effectively manage non-cooperative behaviors. This may lead to a decline in public trust, a reduction in institutional credibility, and a diminished capacity to implement policies that foster long-term sustainability. The government must establish robust healthcare regulations that define service standards, ensure quality control, and uphold medical protocols. Furthermore, it should provide financial support to family physicians to sustain their practices and incentivize high-quality care. Additionally, investments in medical infrastructure are critical to ensuring the availability of essential healthcare resources and facilities.

Assumption 3: Medical subsidies

When the local government adopts the "Support Policies" strategy, it offers subsidies to family doctors, grandparents, parents, and children to encourage the adoption of cooperative strategies. These subsidies encompass financial assistance, such as the provision of free or discounted healthcare services, as well as professional training for family physicians (FPs) and improvements in healthcare infrastructure to promote collaboration. The overarching goal of this support is to establish a sustainable healthcare system in which all stakeholders contribute to and benefit from collective cooperation.

However, if any of the family members or the family doctor chooses non-cooperative strategies, the local government will impose penalties. These penalties may include increased healthcare service fees or a reduction in financial support for non-cooperative parties. Such actions are likely to lead to increased healthcare costs due to inefficiencies in resource allocation and patient care. Ultimately, this will reduce the overall effectiveness and sustainability of the healthcare system.

Assumption 4: FP's Discount Offer for Family Package

The implementation of a discount offer on family packages by family physicians (FPs) serves as a strategic incentive within the multigenerational family setting. Specifically, this discount offer is expected to lower the immediate cost barrier for families, thereby encouraging higher uptake of family-based preventive health and continuity care services. Under the evolutionary game framework, such a pricing strategy is posited to shift the equilibrium toward enhanced cooperative behavior between family members and the healthcare provider. In this model, the FP's discount offer not only signals a commitment to affordable, holistic care but also fosters an environment where intergenerational resource sharing is reinforced, ultimately facilitating sustained collaboration and mutual benefit.

Assumption 5: Support and Cooperation (Fig. 1)

Support and cooperation within multigenerational families, as well as with family doctor, are critical factors in fostering a sustainable healthcare ecosystem. In this context, support refers to both financial and health-related assistance that family members provide to one another. Financially, the pooling of resources within multigenerational households, where parents and children living in the same household as grandparents, can reduce the economic burden on individual family members. This arrangement allows grandparents to contribute by providing child-rearing support and reducing the need for external help, such as hiring a maid. Similarly, the physical and mental health benefits of having elderly family members living close to younger ones are significant. The proximity of grandparents to children allows for easier caregiving, enhancing the overall health and well-being of both generations. Grandparents can offer not only

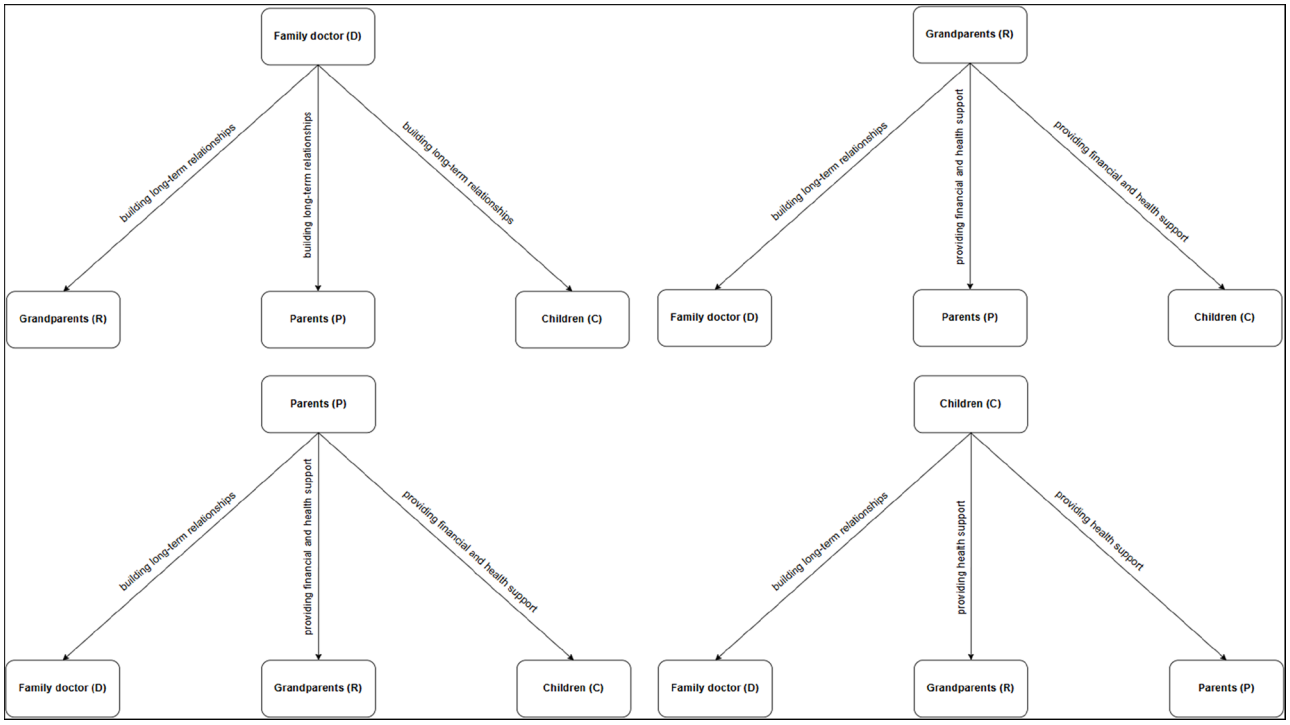

Fig. 1 Interaction diagram of 4 parties.

emotional and social support but also assist in the daily care of grandchildren, thus promoting better health outcomes.

Cooperation, on the other hand, is defined as the establishment of long-term, collaborative relationships between family members and their family physician. In this framework, it is expected that the cooperative dynamics between the generations in the family, particularly in relation to the family doctor, will lead to improved healthcare outcomes. The ongoing relationship with the family physician fosters a continuity of care, allowing the physician to develop a deeper understanding of the family's health history, needs, and preferences. This long-term cooperation with the family doctor is anticipated to result in more personalized, preventative care, which can help reduce healthcare costs and increase the efficiency of the healthcare system.

Together, the support and cooperation between family members and with family doctor are expected to promote both financial stability and improved health outcomes. It is anticipated that these factors will lead to a more sustainable and cost-effective healthcare model, particularly in the context of multigenerational families where resource sharing is integral.

Assumption 6: Additional losses

When the family doctor, grandparents, parents, and children opt for non-cooperative strategies, they are likely to experience significant economic losses due to missed opportunities for synergy.

Family doctor:

- Family doctors miss the opportunity to cultivate long-term relationships with their patients. The foundation of cooperation and trust is essential for establishing strong doctor-patient relationships. When family members do not engage, the doctor's ability to build meaningful connections is hindered, reducing the potential for long-term patient retention and satisfaction.
- In addition, family doctors face the loss of a comprehensive understanding of their patients' health when cooperation from the family is absent. Without this collaboration, family doctors lack access to crucial information such as shared medical history, daily habits, and family dynamics, which could contribute to more accurate diagnoses and effective treatments. This absence of vital data may lead to suboptimal care for individual family members, diminishing the overall quality of service provided by the doctor.
- Moreover, family doctors may incur financial losses due to the fragmentation of the healthcare system. Without cooperation, inefficiencies arise, leading to increased costs for both the doctor and the patients. The lack of collaboration also hampers the doctor's capacity to promote preventive care. When family members do not work together, it becomes challenging to ensure that everyone in the household adheres to preventive measures such as vaccinations, screenings, and lifestyle modifications, which could have been more effectively coordinated with family involvement.

Grandparents (Aged 55–65):

- Grandparents, in the absence of cooperation, lose access to comprehensive and personalized medical care. Without collaboration between the grandparents, the family doctor, and other family members, the doctor lacks essential information regarding the grandparents' daily routines, health history, and subtle changes in their condition. This lack of critical data diminishes the accuracy of diagnoses and the effectiveness of treatments, potentially resulting in redundant tests, inappropriate medications, and fragmented care.
- Furthermore, grandparents miss the opportunity to receive specialized care from geriatric professionals. Without cooperation, the family doctor may be unable to coordinate with specialists in geriatric medicine, limiting access to age-specific care for common issues such as joint pain, cardiovascular conditions, cognitive decline, or sleep disturbances. They also forgo important preventive services, including fall-risk assessments, chronic disease

screenings, and early interventions that could prevent hospitalization and prolong independence.
- Psychologically, the absence of cooperation may lead to feelings of loneliness, anxiety, or neglect. Without active involvement from parents and children, grandparents may experience emotional isolation and a lack of support. Additionally, not living with or regularly interacting with family members may reduce assistance in daily activities, such as attending medical appointments or managing medications, thereby impacting their overall health.

Parents (Aged 22–40, Working in the city):

- Parents experience the loss of coordinated healthcare services that could benefit the entire household when cooperation is absent. Without this collaboration, the family doctor is unable to fully understand the health dynamics across generations, limiting their ability to provide holistic and efficient care. This situation may lead to fragmented treatment, redundant medical tests, and more frequent visits due to unmanaged or recurring health issues, thus incurring greater time, energy, and financial costs for parents.
- Additionally, without the support of grandparents and a structured caregiving system, parents bear the full responsibility for childcare and household management. The absence of grandparents in the daily care routine may require parents to seek external childcare services, leading to increased financial strain, particularly in terms of paying for babysitters or daycare. The lack of shared caregiving responsibilities further complicates parents' ability to balance work and family life, escalating stress and diminishing the quality time spent with their children.

Children(C) (Aged 0–15):

- The losses for children are largely similar to those of parents. However, based on the assumption in the model, young children specifically require protection and direct care from their parents, making the lack of cooperation even more critical in their case. If the child is penalized, it is in fact the parents who must bear the consequences, as children cannot be separated from their parents. In this sense, penalizing either party amounts to the same outcome, since the family functions as a single unit in both responsibility and impact.

Based on the above hypotheses, the definition of relevant parameters in the game model is shown in Table 1.

Evolutionary game profit matrix. According to the hypotheses and parameters assumed in the previous section, the five-party evolutionary game profit matrix of Local Government (G), Family doctor (D), Grandparents (R), Parents (P) and Children (C) is constructed, as shown in Tables 2 and 3.

Replicator dynamics equations. Based on the five-party evolutionary game profit matrix constructed in Section 3.2, this section employs the replicator dynamics equations from evolutionary game theory to characterize the strategic evolution of Local

Table 1 Parameters and definitions.

Parameter	Definition
Local Government (G)	
x	Proportion of Local Government choosing the "Support Policies" strategy
G	Reputational benefits for Local Government when implementing support policies
C	Additional costs incurred by the Local Government when implementing support policies
S	Reputational risks for Local Government when there is no support policy and parties choose negative strategies
I	Medical subsidies from Local Government for households and FPs when choosing active strategies
K	Medical expenses will be higher when choosing negative strategies
T	Damage when not receiving support policies from Local Government
Family doctor (D)	
y	Proportion of Family doctor choosing the "FP's Discount Offer for Family Package" strategy
A_D^R	Additional profit for Family doctor when building mutually beneficial long-term relationships with grandparents
A_D^P	Additional profit for Family doctor when building mutually beneficial long-term relationships with parents
A_D^C	Additional profit for Family doctor when building mutually beneficial long-term relationships with children
Grandparents (R)	
z	Proportion of Grandparents choosing the "Support and Cooperation" strategy
A_R^D	Additional profit for grandparents when building mutually beneficial long-term relationships with Family doctor
F_R^P	Additional profit for grandparents when receiving financial support from parents
M_R^P	Additional profits for grandparents when receiving mental and physical health support from parents
M_R^C	Additional profits for grandparents when receiving mental and physical health support from children
Parents (P)	
w	Proportion of Parents choosing the "Support and Cooperation" strategy
A_P^D	Additional profit for parents when building mutually beneficial long-term relationships with Family doctor
F_P^R	Additional profit for parents when receiving financial support from grandparents
M_P^R	Additional profits for parents when receiving mental and physical health support from grandparents
M_P^C	Additional profits for parents when receiving mental and physical health support from children
Children (C)	
l	Proportion of Children choosing the "Support and Cooperation" strategy
A_C^D	Additional profit for children when building mutually beneficial long-term relationships with Family doctor
F_C^R	Additional profit for children when receiving financial support from grandparents
M_C^R	Additional profits for children when receiving mental and physical health support from grandparents
F_C^P	Additional profit for children when receiving financial support from parents
M_C^P	Additional profits for children when receiving mental and physical health support from parents

Table 2 Profit matrix of five-party evolutionary game with Local Government support policies.

Local Government (Support Policies)				
Family doctor	**Grandparents**	**Parents**		
		Children	**Support and Cooperation**	**No Support and Cooperation**
FP's Discount Offer for Family Package	Support and Cooperation	Support and Cooperation	$G-C-I^D-I^R-I^P-I^C$	$G-C-I^D-I^R+K^P-I^C$
			$A_D^R+A_D^P+A_D^C+I^D$	$A_D^R-A_D^P+A_D^C+I^D$
			$A_R^D+F_R^P+M_R^P+M_R^C+I^R$	$A_R^D-F_R^P-M_R^P+M_R^C+I^R$
			$A_P^D+F_P^R+M_P^R+M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$A_C^D+F_C^R+M_C^R+F_C^P+M_C^P+I^C$	$A_C^D+F_C^R+M_C^R-F_C^P-M_C^P+I^C$
		No Support and Cooperation	$G-C-I^D-I^R-I^P+K^C$	$G-C-I^D-I^R+K^P+K^C$
			$A_D^R+A_D^P-A_D^C+I^D$	$A_D^R-A_D^P-A_D^C+I^D$
			$A_R^D+F_R^P+M_R^P-M_R^C+I^R$	$A_R^D-F_R^P-M_R^P-M_R^C+I^R$
			$A_P^D+F_P^R+M_P^R-M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$	
	No Support and Cooperation	Support and Cooperation	$G-C-I^D+K^R-I^P-I^C$	$G-C-I^D+K^R+K^P-I^C$
			$-A_D^R+A_D^P+A_D^C+I^D$	$-A_D^R-A_D^P+A_D^C+I^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$
			$A_P^D-F_P^R-M_P^R+M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$A_C^D-F_C^R-M_C^R+F_C^P+M_C^P+I^C$	$A_C^D-F_C^R-M_C^R-F_C^P-M_C^P+I^C$
		No Support and Cooperation	$G-C-I^D+K^R-I^P+K^C$	$G-C-I^D+K^R+K^P+K^C$
			$-A_D^R+A_D^P-A_D^C+I^D$	$-A_D^R-A_D^P-A_D^C+I^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$
			$A_P^D-F_P^R-M_P^R-M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$
FP's No Discount Offer for Family Package	Support and Cooperation	Support and Cooperation	$G-C+K^D-I^R-I^P-I^C$	$G-C+K^D-I^R+K^P-I^C$
			$-A_D^R-A_D^P-A_D^C-K^D$	$-A_D^R-A_D^P-A_D^C-K^D$
			$-A_R^D+F_R^P+M_R^P+M_R^C+I^R$	$-A_R^D-F_R^P-M_R^P+M_R^C+I^R$
			$-A_P^D+F_P^R+M_P^R+M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$-A_C^D+F_C^R+M_C^R+F_C^P+M_C^P+I^C$	$-A_C^D+F_C^R+M_C^R-F_C^P-M_C^P+I^C$
		No Support and Cooperation	$G-C+K^D-I^R-I^P+K^C$	$G-C+K^D-I^R+K^P+K^C$
			$-A_D^R-A_D^P-A_D^C-K^D$	$-A_D^R-A_D^P-A_D^C-K^D$
			$-A_R^D+F_R^P+M_R^P-M_R^C+I^R$	$-A_R^D-F_R^P-M_R^P-M_R^C+I^R$
			$-A_P^D+F_P^R+M_P^R-M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$
	No Support and Cooperation	Support and Cooperation	$G-C+K^D+K^R-I^P-I^C$	$G-C+K^D+K^R+K^P-I^C$
			$-A_D^R-A_D^P-A_D^C-K^D$	$-A_D^R-A_D^P-A_D^C-K^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$
			$-A_P^D-F_P^R-M_P^R+M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$-A_C^D-F_C^R-M_C^R+F_C^P+M_C^P+I^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P+I^C$
		No Support and Cooperation	$G-C+K^D+K^R-I^P+K^C$	$G-C+K^D+K^R+K^P+K^C$
			$-A_D^R-A_D^P-A_D^C-K^D$	$-A_D^R-A_D^P-A_D^C-K^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-K^R$
			$-A_P^D-F_P^R-M_P^R-M_P^C+I^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-K^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-K^C$

Table 3 Profit matrix of five-party evolutionary game without Local Government support policies.

Local Government (No Support Policies)				
Family doctor	**Grandparents**	**Parents**		
		Children	**Support and Cooperation**	**No Support and Cooperation**
FP's Discount Offer for Family Package	Support and Cooperation	Support and Cooperation	$-G$	$-G-S^P$
			$A_D^R+A_D^P+A_D^C-T^D$	$A_D^R-A_D^P+A_D^C-T^D$
			$A_R^D+F_R^P+M_R^P+M_R^C-T^R$	$A_R^D-F_R^P-M_R^P+M_R^C-T^R$
			$A_P^D+F_P^R+M_P^R+M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$A_C^D+F_C^R+M_C^R+F_C^P+M_C^P-T^C$	$A_C^D+F_C^R+M_C^R-F_C^P-M_C^P-T^C$
		No Support and Cooperation	$-G-S^C$	$-G-S^P-S^C$
			$A_D^R+A_D^P-A_D^C-T^D$	$A_D^R-A_D^P-A_D^C-T^D$
			$A_R^D+F_R^P+M_R^P-M_R^C-T^R$	$A_R^D-F_R^P-M_R^P-M_R^C-T^R$
			$A_P^D+F_P^R+M_P^R-M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$
	No Support and Cooperation	Support and Cooperation	$-G-S^R$	$-G-S^R-S^P$
			$-A_D^R+A_D^P+A_D^C-T^D$	$-A_D^R-A_D^P+A_D^C-T^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$
			$A_P^D-F_P^R-M_P^R+M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$A_C^D-F_C^R-M_C^R+F_C^P+M_C^P-T^C$	$A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$
		No Support and Cooperation	$-G-S^R-S^C$	$-G-S^R-S^P-S^C$
			$-A_D^R+A_D^P-A_D^C-T^D$	$-A_D^R-A_D^P-A_D^C-T^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$
			$A_P^D-F_P^R-M_P^R-M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$
FP's No Discount Offer for Family Package	Support and Cooperation	Support and Cooperation	$-G-S^D$	$-G-S^D-S^P$
			$-A_D^R-A_D^P-A_D^C-T^D$	$-A_D^R-A_D^P-A_D^C-T^D$
			$-A_R^D+F_R^P+M_R^P+M_R^C-T^R$	$-A_R^D-F_R^P-M_R^P+M_R^C-T^R$
			$-A_P^D+F_P^R+M_P^R+M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$-A_C^D+F_C^R+M_C^R+F_C^P+M_C^P-T^C$	$-A_C^D+F_C^R+M_C^R-F_C^P-M_C^P-T^C$
		No Support and Cooperation	$-G-S^D-S^C$	$-G-S^D-S^P-S^C$
			$-A_D^R-A_D^P-A_D^C-T^D$	$-A_D^R-A_D^P-A_D^C-T^D$
			$-A_R^D+F_R^P+M_R^P-M_R^C-T^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$
			$-A_P^D+F_P^R+M_P^R-M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$
	No Support and Cooperation	Support and Cooperation	$-G-S^D-S^R$	$-G-S^D-S^R-S^P$
			$-A_D^R-A_D^P-A_D^C-T^D$	$-A_D^R-A_D^P-A_D^C-T^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$
			$-A_P^D-F_P^R-M_P^R+M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$-A_C^D-F_C^R-M_C^R+F_C^P+M_C^P-T^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$
		No Support and Cooperation	$-G-S^D-S^R-S^C$	$-G-S^D-S^R-S^P-S^C$
			$-A_D^R-A_D^P-A_D^C-T^D$	$-A_D^R-A_D^P-A_D^C-T^D$
			$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$	$-A_R^D-F_R^P-M_R^P-M_R^C-T^R$
			$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$	$-A_P^D-F_P^R-M_P^R-M_P^C-T^P$
			$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$	$-A_C^D-F_C^R-M_C^R-F_C^P-M_C^P-T^C$

Government (G), Family doctor (D), Grandparents (R), Parents (P), and Children (C).

a. **Local Government (G)**
The expected profit of the Local Government when choosing the "Support Policies" strategy is:

$$E_S^G = yzwl\left(G-C-I^D-I^R-I^P-I^C\right)+(1-y)(1-z)(1-w)(1-l)\left(G-C+K^D+K^R+K^P+K^C\right)$$
$$+yz(1-w)(1-l)\left(G-C-I^D-I^R+K^P+K^C\right)+y(1-z)w(1-l)\left(G-C-I^D+K^R-I^P+K^C\right)$$
$$+y(1-z)(1-w)l\left(G-C-I^D+K^R+K^P-I^C\right)+(1-y)zw(1-l)\left(G-C+K^D-I^R-I^P+K^C\right)$$
$$+(1-y)z(1-w)l\left(G-C+K^D-I^R+K^P-I^C\right)+(1-y)(1-z)wl\left(G-C+K^D+K^R-I^P-I^C\right)$$
$$+(1-y)zwl\left(G-C+K^D-I^R-I^P-I^C\right)+y(1-z)wl\left(G-C-I^D+K^R-I^P-I^C\right)$$
$$+yz(1-w)l\left(G-C-I^D-I^R+K^P-I^C\right)+yzw(1-l)\left(G-C-I^D-I^R-I^P+K^C\right)$$
$$+y(1-z)(1-w)(1-l)\left(G-C-I^D+K^R+K^P+K^C\right)+(1-y)z(1-w)(1-l)\left(G-C+K^D-I^R+K^P+K^C\right)$$
$$+(1-y)(1-z)w(1-l)\left(G-C+K^D+K^R-I^P+K^C\right)+(1-y)(1-z)(1-w)l\left(G-C+K^D+K^R+K^P-I^C\right)$$

$$=yzwl\begin{bmatrix}(G-C-I^D-I^R-I^P-I^C)+(G-C+K^D+K^R+K^P+K^C)+(G-C-I^D-I^R+K^P+K^C)+(G-C-I^D+K^R-I^P+K^C)\\+(G-C-I^D+K^R+K^P-I^C)+(G-C+K^D-I^R-I^P+K^C)+(G-C+K^D+K^R-I^P-I^C)+(G-C+K^D-I^R-I^P+K^C)\\-(G-C+K^D-I^R-I^P-I^C)-(G-C-I^D+K^R-I^P-I^C)-(G-C-I^D-I^R+K^P-I^C)-(G-C-I^D-I^R-I^P+K^C)\\-(G-C+K^D+K^R+K^P-I^C)-(G-C-I^D+K^R+K^P+K^C)-(G-C+K^D-I^R+K^P+K^C)-(G-C+K^D+K^R-I^P+K^C)\end{bmatrix}$$

$$+yzw\begin{bmatrix}(G-C-I^D-I^R-I^P+K^C)+(G-C-I^D+K^R+K^P+K^C)+(G-C+K^D-I^R+K^P+K^C)+(G-C+K^D+K^R-I^P+K^C)\\-(G-C+K^D+K^R+K^P+K^C)-(G-C-I^D-I^R+K^P+K^C)-(G-C-I^D+K^R-I^P+K^C)-(G-C+K^D-I^R-I^P+K^C)\end{bmatrix}$$

$$+yzl\begin{bmatrix}(G-C-I^D-I^R+K^P-I^C)+(G-C-I^D+K^R+K^P+K^C)+(G-C+K^D-I^R+K^P+K^C)+(G-C+K^D+K^R+K^P-I^C)\\-(G-C+K^D+K^R+K^P+K^C)-(G-C-I^D-I^R+K^P+K^C)-(G-C-I^D+K^R+K^P-I^C)-(G-C+K^D-I^R+K^P-I^C)\end{bmatrix}$$

$$+ywl\begin{bmatrix}(G-C-I^D+K^R-I^P-I^C)+(G-C-I^D+K^R+K^P+K^C)+(G-C+K^D+K^R-I^P+K^C)+(G-C+K^D+K^R+K^P-I^C)\\-(G-C+K^D+K^R+K^P+K^C)-(G-C-I^D+K^R-I^P+K^C)-(G-C-I^D+K^R+K^P-I^C)-(G-C+K^D+K^R-I^P-I^C)\end{bmatrix}$$

$$+zwl\begin{bmatrix}(G-C+K^D-I^R-I^P-I^C)+(G-C+K^D-I^R+K^P+K^C)+(G-C+K^D+K^R-I^P+K^C)+(G-C+K^D+K^R+K^P-I^C)\\-(G-C+K^D+K^R+K^P+K^C)-(G-C+K^D-I^R-I^P+K^C)-(G-C+K^D-I^R+K^P-I^C)-(G-C+K^D+K^R-I^P-I^C)\end{bmatrix}$$

$$+yz\left[\left(G-C+K^D+K^R+K^P+K^C\right)+\left(G-C-I^D-I^R+K^P+K^C\right)-\left(G-C-I^D+K^R+K^P+K^C\right)-\left(G-C+K^D-I^R+K^P+K^C\right)\right]$$
$$+yw\left[\left(G-C+K^D+K^R+K^P+K^C\right)+\left(G-C-I^D+K^R-I^P+K^C\right)-\left(G-C-I^D+K^R+K^P+K^C\right)-\left(G-C+K^D+K^R-I^P+K^C\right)\right]$$
$$+yl\left[\left(G-C+K^D+K^R+K^P+K^C\right)+\left(G-C-I^D+K^R+K^P-I^C\right)-\left(G-C-I^D+K^R+K^P+K^C\right)-\left(G-C+K^D+K^R+K^P-I^C\right)\right]$$
$$+zw\left[\left(G-C+K^D+K^R+K^P+K^C\right)+\left(G-C+K^D-I^R-I^P+K^C\right)-\left(G-C+K^D-I^R+K^P+K^C\right)-\left(G-C+K^D+K^R-I^P+K^C\right)\right]$$
$$+zl\left[\left(G-C+K^D+K^R+K^P+K^C\right)+\left(G-C+K^D-I^R+K^P-I^C\right)-\left(G-C+K^D-I^R+K^P+K^C\right)-\left(G-C+K^D+K^R+K^P-I^C\right)\right]$$
$$+wl\left[\left(G-C+K^D+K^R+K^P+K^C\right)+\left(G-C+K^D+K^R-I^P-I^C\right)-\left(G-C+K^D+K^R-I^P+K^C\right)-\left(G-C+K^D+K^R+K^P-I^C\right)\right]$$
$$+y\left[\left(G-C-I^D+K^R+K^P+K^C\right)-\left(G-C+K^D+K^R+K^P+K^C\right)\right]$$
$$+z\left[\left(G-C+K^D-I^R+K^P+K^C\right)-\left(G-C+K^D+K^R+K^P+K^C\right)\right]$$
$$+w\left[\left(G-C+K^D+K^R-I^P+K^C\right)-\left(G-C+K^D+K^R+K^P+K^C\right)\right]$$
$$+l\left[\left(G-C+K^D+K^R+K^P-I^C\right)-\left(G-C+K^D+K^R+K^P+K^C\right)\right]$$
$$+\left(G-C+K^D+K^R+K^P+K^C\right)$$

$$=yzwl(0)+yzw(0)+yzl(0)+ywl(0)+zwl(0)+yz(0)+yw(0)+yl(0)+zw(0)+zl(0)+wl(0)$$
$$+y\left(-I^D-K^D\right)+z\left(-I^R-K^R\right)+w\left(-I^P-K^P\right)+l\left(-I^C-K^C\right)+\left(G-C+K^D+K^R+K^P+K^C\right)$$
$$=-y\left(I^D+K^D\right)-z\left(I^R+K^R\right)-w\left(I^P+K^P\right)-l\left(I^C+K^C\right)+\left(G-C+K^D+K^R+K^P+K^C\right)$$

The expected profit of the Local Government when choosing the "No Support Policies" strategy is:

$$E_{NS}^G = yzwl(-G)+(1-y)(1-z)(1-w)(1-l)\left(-G-S^D-S^R-S^P-S^C\right)$$
$$+yz(1-w)(1-l)\left(-G-S^P-S^C\right)+y(1-z)w(1-l)\left(-G-S^R-S^C\right)$$

$$+y(1-z)(1-w)l\left(-G-S^R-S^P\right)+\left(1-y\right)zw(1-l)\left(-G-S^D-S^C\right)$$

$$+\left(1-y\right)z(1-w)l\left(-G-S^D-S^P\right)+\left(1-y\right)(1-z)wl\left(-G-S^D-S^R\right)$$

$$+\left(1-y\right)zwl\left(-G-S^D\right)+y(1-z)wl\left(-G-S^R\right)$$

$$+yz(1-w)l\left(-G-S^P\right)+yzw(1-l)\left(-G-S^C\right)$$

$$+y(1-z)(1-w)(1-l)\left(-G-S^R-S^P-S^C\right)+\left(1-y\right)z(1-w)(1-l)\left(-G-S^D-S^P-S^C\right)$$

$$+\left(1-y\right)(1-z)w(1-l)\left(-G-S^D-S^R-S^C\right)+\left(1-y\right)(1-z)(1-w)l\left(-G-S^D-S^R-S^P\right)$$

$$=yzwl\begin{bmatrix}(-G)+\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^P-S^C\right)+\left(-G-S^R-S^C\right)\\+\left(-G-S^R-S^P\right)+\left(-G-S^D-S^C\right)+\left(-G-S^D-S^P\right)+\left(-G-S^D-S^R\right)\\-\left(-G-S^D\right)-\left(-G-S^R\right)-\left(-G-S^P\right)-\left(-G-S^C\right)\\-\left(-G-S^R-S^P-S^C\right)-\left(-G-S^D-S^P-S^C\right)-\left(-G-S^D-S^R-S^C\right)-\left(-G-S^D-S^R-S^P\right)\end{bmatrix}$$

$$+yzw\begin{bmatrix}\left(-G-S^C\right)+\left(-G-S^R-S^P-S^C\right)+\left(-G-S^D-S^P-S^C\right)+\left(-G-S^D-S^R-S^C\right)\\-\left(-G-S^D-S^R-S^P-S^C\right)-\left(-G-S^P-S^C\right)-\left(-G-S^R-S^C\right)-\left(-G-S^D-S^C\right)\end{bmatrix}$$

$$+yzl\begin{bmatrix}\left(-G-S^P\right)+\left(-G-S^R-S^P-S^C\right)+\left(-G-S^D-S^P-S^C\right)+\left(-G-S^D-S^R-S^P\right)\\-\left(-G-S^D-S^R-S^P-S^C\right)-\left(-G-S^P-S^C\right)-\left(-G-S^R-S^P\right)-\left(-G-S^D-S^P\right)\end{bmatrix}$$

$$+ywl\begin{bmatrix}\left(-G-S^R\right)+\left(-G-S^R-S^P-S^C\right)+\left(-G-S^D-S^R-S^C\right)+\left(-G-S^D-S^R-S^P\right)\\-\left(-G-S^D-S^R-S^P-S^C\right)-\left(-G-S^R-S^C\right)-\left(-G-S^R-S^P\right)-\left(-G-S^D-S^R\right)\end{bmatrix}$$

$$+zwl\begin{bmatrix}\left(-G-S^D\right)+\left(-G-S^D-S^P-S^C\right)+\left(-G-S^D-S^R-S^C\right)+\left(-G-S^D-S^R-S^P\right)\\-\left(-G-S^D-S^R-S^P-S^C\right)-\left(-G-S^D-S^C\right)-\left(-G-S^D-S^P\right)-\left(-G-S^D-S^R\right)\end{bmatrix}$$

$$+yz\left[\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^P-S^C\right)-\left(-G-S^R-S^P-S^C\right)-\left(-G-S^D-S^P-S^C\right)\right]$$

$$+yw\left[\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^R-S^C\right)-\left(-G-S^R-S^P-S^C\right)-\left(-G-S^D-S^R-S^C\right)\right]$$

$$+yl\left[\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^R-S^P\right)-\left(-G-S^R-S^P-S^C\right)-\left(-G-S^D-S^R-S^P\right)\right]$$

$$+zw\left[\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^D-S^C\right)-\left(-G-S^D-S^P-S^C\right)-\left(-G-S^D-S^R-S^C\right)\right]$$

$$+zl\left[\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^D-S^P\right)-\left(-G-S^D-S^P-S^C\right)-\left(-G-S^D-S^R-S^P\right)\right]$$

$$+wl\left[\left(-G-S^D-S^R-S^P-S^C\right)+\left(-G-S^D-S^R\right)-\left(-G-S^D-S^R-S^C\right)-\left(-G-S^D-S^R-S^P\right)\right]$$

$$+y\left[\left(-G-S^R-S^P-S^C\right)-\left(-G-S^D-S^R-S^P-S^C\right)\right]$$

$$+z\left[\left(-G-S^D-S^P-S^C\right)-\left(-G-S^D-S^R-S^P-S^C\right)\right]$$

$$+w\left[\left(-G-S^D-S^R-S^C\right)-\left(-G-S^D-S^R-S^P-S^C\right)\right]$$

$$+l\left[\left(-G-S^D-S^R-S^P\right)-\left(-G-S^D-S^R-S^P-S^C\right)\right]$$

$$+\left(-G-S^D-S^R-S^P-S^C\right)$$

$$=yzwl(0)+yzw(0)+yzl(0)+ywl(0)+zwl(0)+yz(0)+yw(0)+yl(0)+zw(0)+zl(0)+wl(0)$$

$$+yS^D+zS^R+wS^P+lS^C+\left(-G-S^D-S^R-S^P-S^C\right)$$

$$=yS^D+zS^R+wS^P+lS^C-G-S^D-S^R-S^P-S^C$$

Then, the average profit of Local Government is:

$$E^G=xE_S^G+(1-x)E_{NS}^G$$

Therefore, the replicator dynamics equation of Local Government is calculated as follows:

$$F(x)=\frac{dx}{dt}=\mathrm{x}(E_S^G-E^G)=x\left(E_S^G-\mathrm{x}E_S^G-(1-\mathrm{x})E_{NS}^G\right)=x(1-x)\left(E_S^G-E_{NS}^G\right)$$

$$=x(1-x)\begin{bmatrix}-y\left(I^D+K^D\right)-z\left(I^R+K^R\right)-w\left(I^P+K^P\right)-l\left(I^C+K^C\right)+\left(G-C+K^D+K^R+K^P+K^C\right)\\-yS^D-zS^R-wS^P-lS^C+G+S^D+S^R+S^P+S^C\end{bmatrix}$$

$$= x(1-x)\begin{bmatrix} -y\left(I^D + K^D + S^D\right) - z\left(I^R + K^R + S^R\right) - w\left(I^P + K^P + S^P\right) - l\left(I^C + K^C + S^C\right) \\ +\left(2G - C + K^D + S^D + K^R + S^R + K^P + S^P + K^C + S^C\right) \end{bmatrix} \quad (1)$$

b. **Family doctor (D)**

The expected profit of the Family doctor when choosing the "FP's Discount Offer for Family Package" strategy is:

$$E_S^D = xzwl\left(A_D^R + A_D^P + A_D^C + I^D\right) + (1-x)(1-z)(1-w)(1-l)\left(-A_D^R - A_D^P - A_D^C - T^D\right)$$

$$+xz(1-w)(1-l)\left(A_D^R - A_D^P - A_D^C + I^D\right) + x(1-z)w(1-l)\left(-A_D^R + A_D^P - A_D^C + I^D\right)$$

$$+x(1-z)(1-w)l\left(-A_D^R - A_D^P + A_D^C + I^D\right) + (1-x)zw(1-l)\left(A_D^R + A_D^P - A_D^C - T^D\right)$$

$$+(1-x)z(1-w)l\left(A_D^R - A_D^P + A_D^C - T^D\right) + (1-x)(1-z)wl\left(-A_D^R + A_D^P + A_D^C - T^D\right)$$

$$+(1-x)zwl\left(A_D^R + A_D^P + A_D^C - T^D\right) + x(1-z)wl\left(-A_D^R + A_D^P + A_D^C + I^D\right)$$

$$+xz(1-w)l\left(A_D^R - A_D^P + A_D^C + I^D\right) + xzw(1-l)\left(A_D^R + A_D^P - A_D^C + I^D\right)$$

$$+x(1-z)(1-w)(1-l)\left(-A_D^R - A_D^P - A_D^C + I^D\right) + (1-x)z(1-w)(1-l)\left(A_D^R - A_D^P - A_D^C - T^D\right)$$

$$+(1-x)(1-z)w(1-l)\left(-A_D^R + A_D^P - A_D^C - T^D\right) + (1-x)(1-z)(1-w)l\left(-A_D^R - A_D^P + A_D^C - T^D\right)$$

$$= xzwl\begin{bmatrix} \left(A_D^R + A_D^P + A_D^C + I^D\right) + \left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(A_D^R - A_D^P - A_D^C + I^D\right) + \left(-A_D^R + A_D^P - A_D^C + I^D\right) \\ +\left(-A_D^R - A_D^P + A_D^C + I^D\right) + \left(A_D^R + A_D^P - A_D^C - T^D\right) + \left(A_D^R - A_D^P + A_D^C - T^D\right) + \left(-A_D^R + A_D^P + A_D^C - T^D\right) \\ -\left(A_D^R + A_D^P + A_D^C - T^D\right) - \left(-A_D^R + A_D^P + A_D^C + I^D\right) - \left(A_D^R - A_D^P + A_D^C + I^D\right) - \left(A_D^R + A_D^P - A_D^C + I^D\right) \\ -\left(-A_D^R - A_D^P - A_D^C + I^D\right) - \left(A_D^R - A_D^P - A_D^C - T^D\right) - \left(-A_D^R + A_D^P - A_D^C - T^D\right) - \left(-A_D^R - A_D^P + A_D^C - T^D\right) \end{bmatrix}$$

$$+xzw\begin{bmatrix} \left(A_D^R + A_D^P - A_D^C + I^D\right) + \left(-A_D^R - A_D^P - A_D^C + I^D\right) + \left(A_D^R - A_D^P - A_D^C - T^D\right) + \left(-A_D^R + A_D^P - A_D^C - T^D\right) \\ -\left(-A_D^R - A_D^P - A_D^C - T^D\right) - \left(A_D^R - A_D^P - A_D^C + I^D\right) - \left(-A_D^R + A_D^P - A_D^C + I^D\right) - \left(A_D^R + A_D^P - A_D^C - T^D\right) \end{bmatrix}$$

$$+xzl\begin{bmatrix} \left(A_D^R - A_D^P + A_D^C + I^D\right) + \left(-A_D^R - A_D^P - A_D^C + I^D\right) + \left(A_D^R - A_D^P - A_D^C - T^D\right) + \left(-A_D^R - A_D^P + A_D^C - T^D\right) \\ -\left(-A_D^R - A_D^P - A_D^C - T^D\right) - \left(A_D^R - A_D^P - A_D^C + I^D\right) - \left(-A_D^R - A_D^P + A_D^C + I^D\right) - \left(A_D^R - A_D^P + A_D^C - T^D\right) \end{bmatrix}$$

$$+xwl\begin{bmatrix} \left(-A_D^R + A_D^P + A_D^C + I^D\right) + \left(-A_D^R - A_D^P - A_D^C + I^D\right) + \left(-A_D^R + A_D^P - A_D^C - T^D\right) + \left(-A_D^R - A_D^P + A_D^C - T^D\right) \\ -\left(-A_D^R - A_D^P - A_D^C - T^D\right) - \left(-A_D^R + A_D^P - A_D^C + I^D\right) - \left(-A_D^R - A_D^P + A_D^C + I^D\right) - \left(-A_D^R + A_D^P + A_D^C - T^D\right) \end{bmatrix}$$

$$+zwl\begin{bmatrix} \left(A_D^R + A_D^P + A_D^C - T^D\right) + \left(A_D^R - A_D^P - A_D^C - T^D\right) + \left(-A_D^R + A_D^P - A_D^C - T^D\right) + \left(-A_D^R - A_D^P + A_D^C - T^D\right) \\ -\left(-A_D^R - A_D^P - A_D^C - T^D\right) - \left(A_D^R + A_D^P - A_D^C - T^D\right) - \left(A_D^R - A_D^P + A_D^C - T^D\right) - \left(-A_D^R + A_D^P + A_D^C - T^D\right) \end{bmatrix}$$

$$+xz\left[\left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(A_D^R - A_D^P - A_D^C + I^D\right) - \left(-A_D^R - A_D^P - A_D^C + I^D\right) - \left(A_D^R - A_D^P - A_D^C - T^D\right)\right]$$

$$+xw\left[\left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(-A_D^R + A_D^P - A_D^C + I^D\right) - \left(-A_D^R - A_D^P - A_D^C + I^D\right) - \left(-A_D^R + A_D^P - A_D^C - T^D\right)\right]$$

$$+xl\left[\left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(-A_D^R - A_D^P + A_D^C + I^D\right) - \left(-A_D^R - A_D^P - A_D^C + I^D\right) - \left(-A_D^R - A_D^P + A_D^C - T^D\right)\right]$$

$$+zw\left[\left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(A_D^R + A_D^P - A_D^C - T^D\right) - \left(A_D^R - A_D^P - A_D^C - T^D\right) - \left(-A_D^R + A_D^P - A_D^C - T^D\right)\right]$$

$$+zl\left[\left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(A_D^R - A_D^P + A_D^C - T^D\right) - \left(A_D^R - A_D^P - A_D^C - T^D\right) - \left(-A_D^R - A_D^P + A_D^C - T^D\right)\right]$$

$$+wl\left[\left(-A_D^R - A_D^P - A_D^C - T^D\right) + \left(-A_D^R + A_D^P + A_D^C - T^D\right) - \left(-A_D^R + A_D^P - A_D^C - T^D\right) - \left(-A_D^R - A_D^P + A_D^C - T^D\right)\right]$$

$$+x\left[\left(-A_D^R - A_D^P - A_D^C + I^D\right) - \left(-A_D^R - A_D^P - A_D^C - T^D\right)\right]$$

$$+z\left[\left(A_D^R - A_D^P - A_D^C - T^D\right) - \left(-A_D^R - A_D^P - A_D^C - T^D\right)\right]$$

$$+w\left[\left(-A_D^R + A_D^P - A_D^C - T^D\right) - \left(-A_D^R - A_D^P - A_D^C - T^D\right)\right]$$

$$+l\left[\left(-A_D^R - A_D^P + A_D^C - T^D\right) - \left(-A_D^R - A_D^P - A_D^C - T^D\right)\right]$$

$$+\left(-A_D^R - A_D^P - A_D^C - T^D\right)$$

$$= xzwl(0) + xzw(0) + xzl(0) + xwl(0) + zwl(0) + xz(0) + xw(0) + xl(0) + zw(0) + zl(0) + wl(0)$$

$$+x\left(I^D + T^D\right) + z\left(2A_D^R\right) + w\left(2A_D^P\right) + l\left(2A_D^C\right) + \left(-A_D^R - A_D^P - A_D^C - T^D\right)$$

$$= x\left(I^D + T^D\right) + z\left(2A_D^R\right) + w\left(2A_D^P\right) + l\left(2A_D^C\right) - A_D^R - A_D^P - A_D^C - T^D$$

The expected profit of the Family doctor when choosing the "FP's No Discount Offer for Family Package" strategy is:

$$E_{NS}^D = xzwl\left(-A_D^R - A_D^P - A_D^C - K^D\right) + (1-x)(1-z)(1-w)(1-l)\left(-A_D^R - A_D^P - A_D^C - T^D\right)$$

$$+xz(1-w)(1-l)\left(-A_D^R-A_D^P-A_D^C-K^D\right)+x(1-z)w(1-l)\left(-A_D^R-A_D^P-A_D^C-K^D\right)$$

$$+x(1-z)(1-w)l\left(-A_D^R-A_D^P-A_D^C-K^D\right)+(1-x)zw(1-l)\left(-A_D^R-A_D^P-A_D^C-T^D\right)$$

$$+(1-x)z(1-w)l\left(-A_D^R-A_D^P-A_D^C-T^D\right)+(1-x)(1-z)wl\left(-A_D^R-A_D^P-A_D^C-T^D\right)$$

$$+(1-x)zwl\left(-A_D^R-A_D^P-A_D^C-T^D\right)+x(1-z)wl\left(-A_D^R-A_D^P-A_D^C-K^D\right)$$

$$+xz(1-w)l\left(-A_D^R-A_D^P-A_D^C-K^D\right)+xzw(1-l)\left(-A_D^R-A_D^P-A_D^C-K^D\right)$$

$$+x(1-z)(1-w)(1-l)\left(-A_D^R-A_D^P-A_D^C-K^D\right)+(1-x)z(1-w)(1-l)\left(-A_D^R-A_D^P-A_D^C-T^D\right)$$

$$+(1-x)(1-z)w(1-l)\left(-A_D^R-A_D^P-A_D^C-T^D\right)+(1-x)(1-z)(1-w)l\left(-A_D^R-A_D^P-A_D^C-T^D\right)$$

$$=xzwl\begin{bmatrix}\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)\\+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)+\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)\\-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)\\-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{K^D}\right)-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)-\left(-\mathrm{A_D^R}-\mathrm{A_D^P}-\mathrm{A_D^C}-\mathrm{T^D}\right)\end{bmatrix}$$

$$+xzw\begin{bmatrix}\left(-A_D^R-A_D^P-A_D^C-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)\\-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\end{bmatrix}$$

$$+xzl\begin{bmatrix}\left(-A_D^R-A_D^P-A_D^C-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)\\-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\end{bmatrix}$$

$$+xwl\begin{bmatrix}\left(-A_D^R-A_D^P-A_D^C-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)\\-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\end{bmatrix}$$

$$+zwl\begin{bmatrix}\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)\\-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\end{bmatrix}$$

$$+xz\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+xw\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+xl\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+zw\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+zl\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+wl\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+x\left[\left(-A_D^R-A_D^P-A_D^C-K^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+z\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+w\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+l\left[\left(-A_D^R-A_D^P-A_D^C-T^D\right)-\left(-A_D^R-A_D^P-A_D^C-T^D\right)\right]$$

$$+\left(-A_D^R-A_D^P-A_D^C-T^D\right)$$

$$=xzwl(0)+xzw(0)+xzl(0)+xwl(0)+zwl(0)+xz(0)+xw(0)+xl(0)+zw(0)+zl(0)+wl(0)+z(0)+w(0)+l(0)$$

$$+x\left(T^D-K^D\right)+\left(-A_D^R-A_D^P-A_D^C-T^D\right)$$

$$=x\left(T^D-K^D\right)-A_D^R-A_D^P-A_D^C-T^D$$

Then, the average profit of Family doctor is:

$$E^D=yE_S^D+(1-y)E_{NS}^D$$

Therefore, the replicator dynamics equation of Family doctor is calculated as follows:

$$F(y)=\frac{dy}{dt}=y(E_S^D-E^D)=y\left(E_S^D-yE_S^D-(1-y)E_{NS}^D\right)=y(1-y)\left(E_S^D-E_{NS}^D\right)$$

$$=y(1-y)\begin{bmatrix}x\left(I^D+T^D\right)+z\left(2A_D^R\right)+w\left(2A_D^P\right)+l\left(2A_D^C\right)-A_D^R-A_D^P-A_D^C-T^D\\-x\left(T^D-K^D\right)+A_D^R+A_D^P+A_D^C+T^D\end{bmatrix}$$

$$= y(1-y)\left[x\left(I^D + K^D\right) + z\left(2A_D^R\right) + w\left(2A_D^P\right) + l\left(2A_D^C\right)\right] \quad (2)$$

c. **Grandparents (R)**

Similar to the calculation of Family doctor, the expected profit of Grandparents choosing the "Support and Cooperation" strategy is:

$$E_S^R = x\left(I^R + T^R\right) + y\left(2A_R^D\right) + w\left(2F_R^P + 2M_R^P\right) + l\left(2M_R^C\right) - A_R^D - F_R^P - M_R^P - M_R^C - T^R$$

Similar to the calculation of Family doctor, the expected profit of Grandparents choosing the "No Support and Cooperation" strategy is:

$$E_{NS}^R = x\left(T^R - K^R\right) - A_R^D - F_R^P - M_R^P - M_R^C - T^R$$

Then, the average profit of Grandparents is:

$$E^R = zE_S^R + (1-z)E_{NS}^R$$

Therefore, the replicator dynamics equation of Grandparents is calculated as follows:

$$F(z) = \frac{dz}{dt} = z\left(E_S^R - E^R\right) = z\left(E_S^R - zE_S^R - (1-z)E_{NS}^R\right) = z(1-z)\left(E_S^R - E_{NS}^R\right)$$

$$= z(1-z)\begin{bmatrix} x\left(I^R + T^R\right) + y\left(2A_R^D\right) + w\left(2F_R^P + 2M_R^P\right) + l\left(2M_R^C\right) - A_R^D - F_R^P - M_R^P - M_R^C - T^R \\ -x\left(T^R - K^R\right) + A_R^D + F_R^P + M_R^P + M_R^C + T^R \end{bmatrix}$$

$$= z(1-z)\left[x\left(I^R + K^R\right) + y\left(2A_R^D\right) + w\left(2F_R^P + 2M_R^P\right) + l\left(2M_R^C\right)\right] \quad (3)$$

d. **Parents (P)**

Similarly, the expected profit of Parents choosing the "Support and Cooperation" strategy is:

$$E_S^P = x\left(I^P + T^P\right) + y\left(2A_P^D\right) + z\left(2F_P^R + 2M_P^R\right) + l\left(2M_P^C\right) - A_P^D - F_P^R - M_P^R - M_P^C - T^P$$

Similarly, the expected profit of Parents choosing the "No Support and Cooperation" strategy is:

$$E_{NS}^P = x\left(T^P - K^P\right) - A_P^D - F_P^R - M_P^R - M_P^C - T^P$$

Then, the average profit of Parents is:

$$E^P = wE_S^P + (1-w)E_{NS}^P$$

Therefore, the replicator dynamics equation of Parents is calculated as follows:

$$F(w) = \frac{dw}{dt} = w\left(E_S^R - E^R\right) = w\left(E_S^R - wE_S^R - (1-w)E_{NS}^R\right) = w(1-w)\left(E_S^P - E_{NS}^P\right)$$

$$= w(1-w)\begin{bmatrix} x\left(I^P + T^P\right) + y\left(2A_P^D\right) + z\left(2F_P^R + 2M_P^R\right) + l\left(2M_P^C\right) - A_P^D - F_P^R - M_P^R - M_P^C - T^P \\ -x\left(T^P - K^P\right) + A_P^D + F_P^R + M_P^R + M_P^C + T^P \end{bmatrix}$$

$$= w(1-w)\left[x\left(I^P + K^P\right) + y\left(2A_P^D\right) + z\left(2F_P^R + 2M_P^R\right) + l\left(2M_P^C\right)\right] \quad (4)$$

e. **Children (C)**

Similarly, the expected profit of Children choosing the "Support and Cooperation" strategy is:

$$E_S^C = x\left(I^C + T^C\right) + y\left(2A_C^D\right) + z\left(2F_C^R + 2M_C^R\right) + w\left(2F_C^P + 2M_C^P\right) - A_C^D - F_C^R - M_C^R - F_C^P - M_C^P - T^C$$

Similarly, the expected profit of Children choosing the "No Support and Cooperation" strategy is:

$$E_{NS}^C = x\left(T^C - K^C\right) - A_C^D - F_C^R - M_C^R - F_C^P - M_C^P - T^C$$

Then, the average profit of Children is:

$$E^C = lE_S^C + (1-l)E_{NS}^C$$

Therefore, the replicator dynamics equation of Children is calculated as follows:

$$F(l) = \frac{dl}{dt} = l\left(E_S^C - E^C\right) = l\left(E_S^C - lE_S^C - (1-l)E_{NS}^C\right) = l(1-l)\left(E_S^C - E_{NS}^C\right)$$

$$= l(1-l)\begin{bmatrix} x\left(I^C + T^C\right) + y\left(2A_C^D\right) + z\left(2F_C^R + 2M_C^R\right) + w\left(2F_C^P + 2M_C^P\right) - A_C^D - F_C^R - M_C^R - F_C^P - M_C^P - T^C \\ -x\left(T^C - K^C\right) + A_C^D + F_C^R + M_C^R + F_C^P + M_C^P + T^C \end{bmatrix}$$

$$= l(1-l)\left[x\left(I^C + K^C\right) + y\left(2A_C^D\right) + z\left(2F_C^R + 2M_C^R\right) + w\left(2F_C^P + 2M_C^P\right)\right] \quad (5)$$

Stability analysis of strategy combination

According to the method proposed by Lyapunov, the evolutionary stability strategy (ESS) of a differential equation system can be obtained from the local stability analysis of the Jacobian matrix of the system.

From Eqs. (1), (2), (3), (4) and (5), a system of replicator dynamics equations is constructed as follows:

$$\begin{cases} F(x) = x(1-x)\begin{bmatrix} -y\left(I^D + K^D + S^D\right) - z\left(I^R + K^R + S^R\right) - w\left(I^P + K^P + S^P\right) - l\left(I^C + K^C + S^C\right) \\ +\left(2G - C + K^D + S^D + K^R + S^R + K^P + S^P + K^C + S^C\right) \end{bmatrix} \\ F\left(y\right) = y(1-y)\left[x\left(I^D + K^D\right) + z\left(2A_D^R\right) + w\left(2A_D^P\right) + l\left(2A_D^C\right)\right] \\ F(z) = z(1-z)\left[x\left(I^R + K^R\right) + y\left(2A_R^D\right) + w\left(2F_R^P + 2M_R^P\right) + l\left(2M_R^C\right)\right] \\ F(l) = l(1-l)\left[x\left(I^C + K^C\right) + y\left(2A_C^D\right) + z\left(2F_C^R + 2M_C^R\right) + w\left(2F_C^P + 2M_C^P\right)\right] \end{cases}$$

Let $F(x) = F\left(y\right) = F(z) = F(w) = F(l) = 0$, we obtain 32 equilibrium. However, in our model, children (aged 0–15) are assumed to be fully dependent on their parents, so we fix their strategies as $w = l = 1$. Grandparents (R) remain a strategic independent actor ($z = 0$ or 1), while the Local Government (G) and Family Doctor (D) each have two strategies. This reduces the system to 8 feasible equilibrium points. All eight are listed in Table 4. Among them, the four with $z = 1$ represent full family cooperation and are of primary policy interest. These equilibrium points may be located at fixed positions within the strategy space of the game or along its boundaries. Points situated within the interior of the strategy space may serve as centroids or saddle points rather than evolutionarily stable strategies (ESS) within the evolutionary game. Therefore, the asymptotic stability of these equilibrium points is further assessed by analyzing the local stability characteristics of the Jacobian matrix.

By computing the partial derivatives of $F(x), F\left(y\right), F(z), F(w)$ and $F(l)$ with respect to x, y, z, w and l, the Jacobian matrix of the replication dynamic system can be obtained as:

$$Det(J) = \begin{bmatrix} \frac{F(x)}{dx} & \frac{F(x)}{dy} & \frac{F(x)}{dz} & \frac{F(x)}{dw} & \frac{F(x)}{dl} \\ \frac{F(y)}{dx} & \frac{F(y)}{dy} & \frac{F(y)}{dz} & \frac{F(y)}{dw} & \frac{F(y)}{dl} \\ \frac{F(z)}{dx} & \frac{F(z)}{dy} & \frac{F(z)}{dz} & \frac{F(z)}{dw} & \frac{F(z)}{dl} \\ \frac{F(w)}{dx} & \frac{F(w)}{dy} & \frac{F(w)}{dz} & \frac{F(w)}{dw} & \frac{F(w)}{dl} \\ \frac{F(l)}{dx} & \frac{F(l)}{dy} & \frac{F(l)}{dz} & \frac{F(l)}{dw} & \frac{F(l)}{dl} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix}$$

Where:

$$a_{11} = (1-2x)\begin{bmatrix} -y\left(I^D + K^D + S^D\right) - z\left(I^R + K^R + S^R\right) \\ -w\left(I^P + K^P + S^P\right) - l\left(I^C + K^C + S^C\right) \\ +\left(2G - C + K^D + S^D + K^R + S^R + K^P + S^P + K^C + S^C\right) \end{bmatrix}$$

$$a_{22} = \left(1-2y\right)\left[x\left(I^D + K^D\right) + z\left(2A_D^R\right) + w\left(2A_D^P\right) + l\left(2A_D^C\right)\right]$$

$$a_{33} = (1-2z)\left[x\left(I^R + K^R\right) + y\left(2A_R^D\right) + w\left(2F_R^P + 2M_R^P\right) + l\left(2M_R^C\right)\right]$$

$$a_{44} = (1-2w)\left[x\left(I^P + K^P\right) + y\left(2A_P^D\right) + z\left(2F_P^R + 2M_P^R\right) + l\left(2M_P^C\right)\right]$$

$$a_{55} = (1-2l)\left[x\left(I^C + K^C\right) + y\left(2A_C^D\right) + z\left(2F_C^R + 2M_C^R\right) + w\left(2F_C^P + 2M_C^P\right)\right]$$

Substituting the equilibrium points into the Jacobian matrix, we obtain the following results

$$J = \begin{bmatrix} \lambda_1 & 0 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 & 0 \\ 0 & 0 & \lambda_3 & 0 & 0 \\ 0 & 0 & 0 & \lambda_4 & 0 \\ 0 & 0 & 0 & 0 & \lambda_5 \end{bmatrix}$$

According to the first Lyapunov theorem, a Jacobian matrix is considered asymptotically stable when all of its eigenvalues λ are negative. Conversely, the system is deemed unstable when all eigenvalues are positive. Additionally, if the Jacobian matrix contains both positive and negative eigenvalues, the equilibrium point is classified as unstable, commonly referred to as a saddle point. The subsequent analysis will methodically explore the scenarios in which the local government implements either the "Support Policies" strategy or the "No Support Policies" strategy to evaluate the stability of the five-party evolutionary game replicator dynamic system. This investigation aims to identify the equilibrium states of the system and assess the key factors influencing the strategic decisions of the local government, family doctor, grandparents, parents, and children in response to regulatory policies.

According to Table 4, there are two ESS: $(1, 1, 1, 1, 1)$ and $(0, 1, 1, 1, 1)$. However, it is evident that these two equilibrium points cannot occur simultaneously. In this section, we will focus exclusively on the analysis of the equilibrium point $(1, 1, 1, 1, 1)$, as it represents the scenario where all stakeholders actively cooperate in the system.

The condition $-G < G - C - I^D - I^R - I^P - I^C$ indicates that the reputational risks $-G$ associated with the Local Government adopting the "No Support Policies" strategy are smaller than the reputational benefits G from implementing the "Support Policies" strategy, after accounting for the costs and medical subsidies allocated to Family doctor $\left(I^D\right)$, Grandparents $\left(I^R\right)$, Parents $\left(I^P\right)$, and Children $\left(I^C\right)$. This condition highlights the crucial role that reputational considerations play in shaping the local government's strategic decisions. When the benefits of implementing supportive policies outweigh the costs, both direct and indirect, such as financial subsidies and resource allocation to stakeholders, the government is more likely to adopt the "Support Policies" strategy.

The equilibrium point $(1, 1, 1, 1, 1)$ suggests a state of full cooperation among all parties, which is expected to lead to more efficient resource utilization, lower healthcare costs, and improved overall system sustainability. From a practical standpoint, the cooperation of all parties in this equilibrium results in better alignment between policy goals and stakeholder interests. This alignment, in turn, fosters a more robust healthcare system where each actor contributes to and benefits from the collective effort, ensuring long-term viability and stability. Additionally, the government's role in providing subsidies and creating an enabling environment for collaboration strengthens the incentive for family members and family doctors to engage in cooperative behavior.

Simulation analysis

This study utilizes MATLAB to investigate the impact of key factors within the replicator dynamic system on the evolutionary process and outcomes of the five-party evolutionary game. The analysis incorporates survey data collected from several major cities in Vietnam, specifically, the 2023 Hanoi Family Health Survey ($n = 250$ households), to better understand the real-world implications and dynamics of the system. This dataset was stratified by district, income level, and family structure to ensure representativeness of urban, middle-income Vietnamese households, the core demographic under study. These data provide empirical insights into the behaviors and interactions of the stakeholders involved, including the local government, family doctor, grandparents, parents, and children. Crucially, all key parameters, including government medical subsidies, penalties for non-cooperation, and reputational benefits, were not arbitrarily assigned, but rigorously calibrated using real-world benchmarks.

Table 4 Eigenvalues of the Jacobian matrix.

Equilibrium point	Eigenvalues	Stability
(1, 0, 1, 1, 1)	$\lambda_1 = -2G + C - K^D - S^D + I^R + I^P + I^C$	Saddle
	$\lambda_2 = I^D + K^D + 2A_D^R + 2A_D^P + 2A_D^C > 0$	
	$\lambda_3 = -I^R - K^R - 2F_R^P - 2M_R^P - 2M_R^C < 0$	
	$\lambda_4 = -I^P - K^P - 2F_P^R - 2M_P^R - 2M_P^C < 0$	
	$\lambda_5 = -I^C - K^C - 2F_C^R - 2M_C^R - 2F_C^P - 2M_C^P < 0$	
(1, 1, 1, 1, 1)	$\lambda_1 = -2G + C + I^D + I^R + I^P + I^C$	ESS if $-2G+C + I^D + I^R + I^P + I^C < 0$ or $-G < G - C - I^D - I^R - I^P - I^C$
	$\lambda_2 = -I^D - K^D - 2A_D^R - 2A_D^P - 2A_D^C < 0$	
	$\lambda_3 = -I^R - K^R - 2A_R^D - 2F_R^P - 2M_R^P - 2M_R^C < 0$	
	$\lambda_4 = -I^P - K^P - 2A_P^D - 2F_P^R - 2M_P^R - 2M_P^C < 0$	
	$\lambda_5 = -I^C - K^C - 2A_C^D - 2F_C^R - 2M_C^R - 2F_C^P - 2M_C^P < 0$	
(0, 0, 1, 1, 1)	$\lambda_1 = 2G - C2F_C^P - I^R - I^P - I^C + K^D + S^D$	Saddle
	$\lambda_2 = 2A_D^R + 2A_D^P + 2A_D^C > 0$	
	$\lambda_3 = -2F_R^P - 2M_R^P - 2M_R^C < 0$	
	$\lambda_4 = -2F_P^R - 2M_P^R - 2M_P^C < 0$	
	$\lambda_5 = -2F_C^R - 2M_C^R - 2F_C^P - 2M_C^P < 0$	
(0, 1, 1, 1, 1)	$\lambda_1 = 2G - C - I^D - I^R - I^P - I^C$	ESS if $2G - C - I^D - I^R - I^P - I^C < 0$ or $G - C - I^D - I^R - I^P - I^C < -G$
	$\lambda_2 = -2A_D^R - 2A_D^P - 2A_D^C < 0$	
	$\lambda_3 = -2A_R^D - 2F_R^P - 2M_R^P - 2M_R^C < 0$	
	$\lambda_4 = -2A_P^D - 2F_P^R - 2M_P^R - 2M_P^C < 0$	
	$\lambda_5 = -2A_C^D - 2F_C^R - 2M_C^R - 2F_C^P - 2M_C^P < 0$	
(0, 1, 0, 1, 1)	$\lambda_1 = 2G - C - I^D - I^P - I^C + K^R + S^R$	Saddle
	$\lambda_2 = -2A_D^P - 2A_D^C < 0$	
	$\lambda_3 = 2A_R^D + 2F_R^P + 2M_R^P + 2M_R^C > 0$	
	$\lambda_4 = -2A_P^D - 2M_P^C < 0$	
	$\lambda_5 = -2A_C^D - 2F_C^P - 2M_C^P < 0$	
(0, 0, 0, 1, 1)	$\lambda_1 = 2G - C - I^P - I^C + K^D + S^D + K^R + S^R$	Saddle
	$\lambda_2 = 2A_D^P + 2A_D^C > 0$	
	$\lambda_3 = 2F_R^P + 2M_R^P + 2M_R^C > 0$	
	$\lambda_4 = -2M_P^C < 0$	
	$\lambda_5 = -2M_C^P - 2F_C^P > 0$	
(1, 1, 0, 1, 1)	$\lambda_1 = -2G + C + I^D + I^P + I^C - K^R - S^R$	Saddle
	$\lambda_2 = -I^D - K^D - 2A_D^P - 2A_D^C < 0$	
	$\lambda_3 = I^R + K^R + 2A_R^D + 2F_R^P + 2M_R^P + 2M_R^C > 0$	
	$\lambda_4 = -I^P - K^P - 2A_P^D - 2M_P^C < 0$	
	$\lambda_5 = -I^C - I^K - 2A_C^D - 2M_C^P < 0$	
(1, 0, 0, 1, 1)	$\lambda_1 = -2G + C - K^D - S^D - K^R - S^R + I^P + I^C$	Saddle
	$\lambda_2 = I^D + K^D + 2A_D^P + 2A_D^C > 0$	
	$\lambda_3 = I^R + K^R + 2F_R^P + 2M_R^P + 2M_R^C > 0$	
	$\lambda_4 = -I^P - K^P - 2M_P^C < 0$	
	$\lambda_5 = -I^C - K^C - 2F_C^P - 2M_C^P < 0$	

- FParameter calibration: Values for subsidies, penalties, and reputational benefits are derived from official data (Ministry of Health 2024), including caregiver stipend pilot programs in Hanoi.
- Reputational Values and Caregiver Incentives were informed by pilot programs for caregiver stipends implemented in Hanoi, which provided empirical data on

Table 5 Setting model parameters.

Local Government	Family doctor (D)	Grandparents (R)	Parents (P)	Children (C)
$x = 0$	$y = 0.5$	$z = 0.9$	$w = 0.9$	$l = 0.9$
$G = 40$	$A_D^R = 25$	$A_R^D = 25$	$A_P^D = 20$	$A_C^D = 15$
$C = 30$	$A_D^P = 20$	$F_R^P = 28$	$F_P^R = 28$	$F_C^R = 28$
$I^D, I^R, I^P, I^C = 10$	$A_D^C = 15$	$M_R^P = 32$	$M_P^R = 32$	$M_C^R = 32$
$K^D, K^R, K^P, K^C = 10$		$M_R^C = 32$	$M_P^C = 32$	$F_C^P = 28$
$S^D, S^R, S^P, S^C = 8$				$M_C^P = 32$
$T^D, T^R, T^P, T^C = 7$				

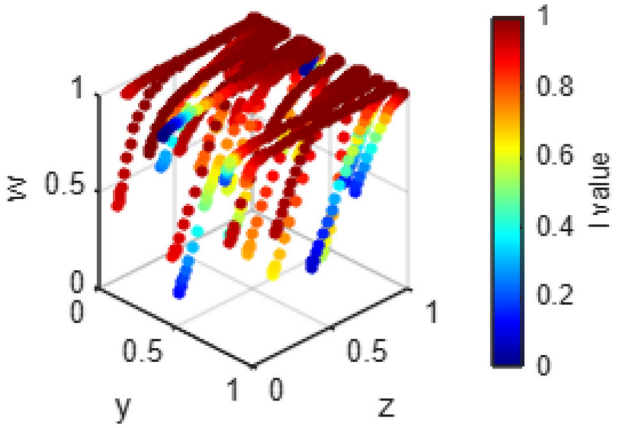

Fig. 2 Evolutionary trajectory of Local Government regulatory strategies x = 0.

perceived societal value and behavioral responses to financial incentives.

These data provide critical empirical grounding for the model, offering insights into actual behaviors and strategic interactions among stakeholders: local government, family physicians, grandparents, parents, and children. By integrating these data into the mathematical model, this section aims to validate the theoretical framework and assess how various factors influence the stability and cooperation within the family healthcare system under different policy conditions.

Analyzing the impact of Local Government regulatory mechanisms on evolutionary strategies. The assumed parameters are shown in Table 5 below.

The simulation results presented in Fig. 2 demonstrate that even when the Local Government adopts the "No Support Policies" strategy ($x = 0$), the system still converges to an evolutionary stable strategy $(1, 1, 1, 1)$. Despite the absence of direct governmental support, the system achieves a stable state of cooperation among all stakeholders (Family Doctors, Grandparents, Parents, and Children) - the system can still converge toward an evolutionarily stable strategy (ESS) at the equilibrium point (0,1,1,1,1). This outcome is clearly illustrated by the trajectory flows in the multi-dimensional phase space, where the strategic choices of Family Physicians (D), Grandparents (R), Parents (P), and Children (C) all evolve toward full cooperation ("Support and Cooperation" and "FP's Discount Offer"), despite the government's passive role ("No Support Policies"). This indicates that the interactions within the system are not entirely dependent on government interventions but rather on the internal dynamics among the involved parties.

The fact that the system reaches this stable equilibrium without the government's active involvement points to the intrinsic motivations that drive cooperation. Family Doctors, Grandparents, Parents, and Children each derive significant benefits from collaborative behavior, such as improved healthcare outcomes, efficient resource utilization, and the reduction of healthcare costs. These intrinsic rewards, rooted in the mutual understanding of shared family health needs and goals, appear to be strong enough to sustain cooperation in the absence of external pressure. As a result, all parties involved are likely to continue contributing to the system's stability even when the local government does not provide active support. This finding is further corroborated by empirical evidence from the Global South, where collectivist norms and multigenerational co-residence remain deeply embedded in social practice. In many Southeast Asian, families routinely pool resources, share caregiving duties, and maintain long-term relationships with local health providers, not as a policy-driven choice, but as a culturally reinforced norm. These lived practices demonstrate that cooperation can indeed emerge and persist organically when social structures and mutual interdependence are intact.

Furthermore, this outcome highlights the resilience of the cooperative system in fostering long-term engagement among stakeholders. Even without governmental incentives or penalties, the positive feedback loop created by mutual support and resource-sharing within multigenerational families can drive consistent cooperation. This is particularly evident in the context of family physicians, who benefit from establishing long-term relationships with patients and their families. These relationships, built on trust and continuity of care, can create an environment where stakeholders remain invested in maintaining cooperation, driven by the expectation of positive long-term outcomes, rather than short-term regulatory mandates.

However, these cultural foundations are increasingly under pressure. Global trends show a rapid rise in individualism, even in traditionally collectivist societies like, marked by shrinking household sizes, declining intergenerational co-residence, and the growing normalization of autonomy over interdependence (Ogihara 2023). As these norms weaken, the (0,1,1,1,1) equilibrium becomes socially fragile. What once emerged organically now requires deliberate reinforcement.

Without subsidies, the upfront costs of preventive care or shared support deter participation. Without enforcement, short-term defection, such as skipping screenings or withholding care, becomes more attractive. External shocks like job loss or chronic illness can easily destabilize voluntary cooperation, especially among middle-income households.

Thus, while the model demonstrates that cooperation can persist without government support in culturally cohesive

Table 6 Setting model parameters.

Local Government	Family doctor (D)	Grandparents (R)	Parents (P)	Children (C)
$x = 0.5$	$y = 0.5$	$z = 0.9$	$w = 0.9$	$l = 0.9$
$G = 25, 40, 55$	$A_D^R = 25$	$A_R^D = 25$	$A_P^D = 20$	$A_C^D = 15$
$C = 30$	$A_D^P = 20$	$F_R^P = 28$	$F_P^R = 28$	$F_C^R = 28$
$I^D, I^R, I^P, I^C = 10$	$A_D^C = 15$	$M_R^P = 32$	$M_P^R = 32$	$M_C^R = 32$
$K^D, K^R, K^P, K^C = 10$		$M_R^C = 32$	$M_P^C = 32$	$F_C^P = 28$
$S^D, S^R, S^P, S^C = 8$				$M_C^P = 32$
$T^D, T^R, T^P, T^C = 7$				

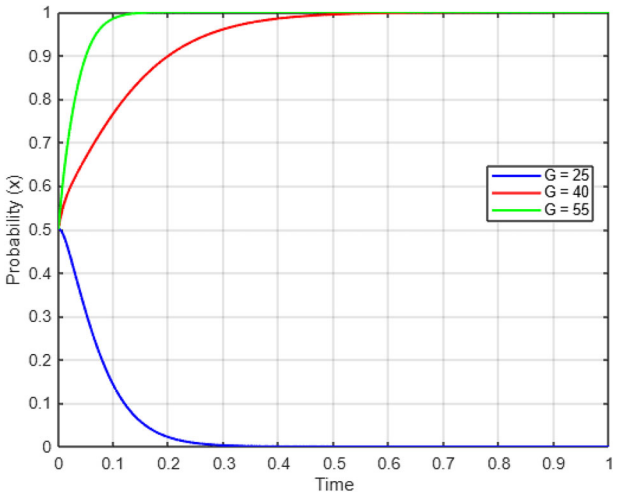

Fig. 3 The strategy evolution process of Local Government under different reputational benefits scenarios.

settings, real-world trajectories reveal a narrowing window of opportunity. In an era of accelerating individualism, strategic government intervention is no longer optional, it is essential to preserve the very conditions that make the (0,1,1,1,1) equilibrium possible. The government must act not as a director, but as a stabilizer: protecting cultural capital, reducing transaction costs, and transforming voluntary solidarity into a sustainable, systemically embedded norm.

Analyzing the impact of Local Government reputational benefits on evolutionary strategies. The assumed parameters are shown in Table 6 below.

To examine the impact of Local Government's reputational benefits on the evolutionary strategies of all stakeholders, we conduct a simulation of system dynamics under varying levels of reputational benefits. Three distinct scenarios are considered: low ($G = 25$), moderate ($G = 40$), and high reputational benefits ($G = 55$). The corresponding simulation results are presented in Fig. 3.

Figure 3 illustrates that when reputational benefits are low ($G = 25$), the probability of the Local Government adopting the "Support Policies" strategy remains low. In this scenario, the Local Government perceives the costs associated with implementing regulatory interventions, such as the financial outlay for subsidies, administrative burdens, and potential inefficiencies, as outweighing the perceived reputation gains. With limited public trust or the expectation of minimal electoral or social benefit from implementing such policies, the government is less likely to engage in the active promotion of collaborative strategies among the stakeholders.

As the reputational benefits rise to moderate levels ($G = 40$), the Local Government begins to perceive a more favorable cost-benefit ratio in adopting the "Support Policies" strategy. In this case, the government starts to recognize the potential for enhanced social capital and political support arising from the successful implementation of cooperative healthcare strategies. The reputational benefits from fostering cooperation, along with the positive long-term outcomes such as reduced healthcare costs and improved health outcomes, provide sufficient incentives for the government to initiate and sustain support policies. These policies, in turn, facilitate a more structured environment for collaboration, encouraging Family Doctors, Grandparents, Parents, and Children to align their strategies with the government's objectives. At this stage, we observe a notable shift in the evolutionary game: stakeholders begin to increase their cooperation, anticipating that the government's involvement will bring about a more predictable and secure healthcare framework. Consequently, the probability of the "Support Policies" strategy being adopted by the Local Government rises, leading to a more stable and cooperative environment.

When reputational benefits reach high levels ($G = 55$), the Local Government's strategic behavior fully shifts towards the "Support Policies" strategy. At this point, the government perceives the implementation of support policies not only as a means to enhance its reputation but also as a fundamental approach to ensuring long-term healthcare system stability. The combination of substantial public trust, political incentives, and the desire to maintain a strong image of effective governance leads the Local Government to commit significantly to supporting the family medicine system. With these high reputational benefits, the government can afford to bear the initial costs of subsidies and infrastructure investments, which are outweighed by the anticipated reputational rewards and the political capital gained from being seen as a proponent of sustainable and equitable healthcare.

The shift to "Support Policies" under high reputational benefits strengthens the system's overall stability by reinforcing the alignment of interests between the government and the other stakeholders. Family Doctors are more likely to offer discounts and provide continuous care as part of a stable, government-supported system, thereby increasing their own reputation and financial stability. Similarly, Grandparents, Parents, and Children, recognizing the increased stability and resources provided by government intervention, are incentivized to increase their level of cooperation with one another and with the family doctor. The shared understanding that government policies create an environment conducive to mutual benefit leads to the system achieving a higher level of coordination and cooperation across all parties. This, in turn, enhances the overall efficiency and

Table 7 Setting model parameters.

Local Government	Family doctor (D)	Grandparents (R)	Parents (P)	Children (C)
$x = 0.5$	$y = 0.5$	$z = 0.9$	$w = 0.9$	$l = 0.9$
$G = 40$	$A_D^R = 25$	$A_R^D = 25$	$A_P^D = 20$	$A_C^D = 15$
$C = 15, 30, 45$	$A_D^P = 20$	$F_R^P = 28$	$F_P^R = 28$	$F_C^R = 28$
$I^D, I^R, I^P, I^C = 10$	$A_D^C = 15$	$M_R^P = 32$	$M_P^R = 32$	$M_C^R = 32$
$K^D, K^R, K^P, K^C = 10$		$M_R^C = 32$	$M_P^C = 32$	$F_C^P = 28$
$S^D, S^R, S^P, S^C = 8$				$M_C^P = 32$
$T^D, T^R, T^P, T^C = 7$				

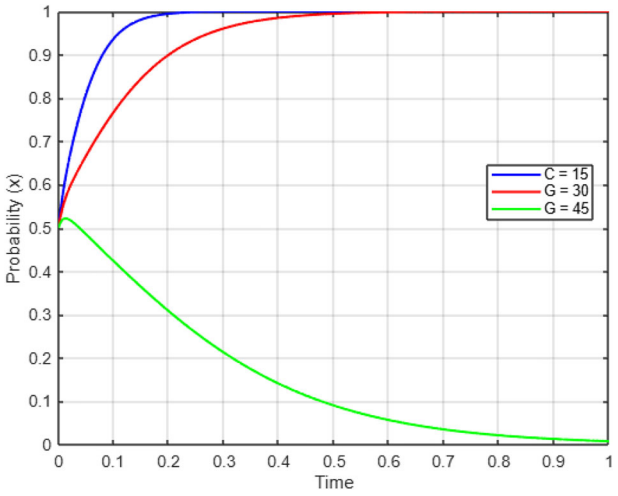

Fig. 4 The strategy evolution process of Local Government under different additional costs scenarios.

sustainability of the healthcare system, reducing costs, improving health outcomes, and fostering long-term collaboration.

Analyzing the impact of Local Government additional costs on evolutionary strategies. The assumed parameters are shown in Table 7 below.

To investigate the effect of Local Government's additional costs on the evolutionary strategies of the various stakeholders, we simulate system dynamics under three different cost scenarios: low ($C = 15$), moderate ($C = 30$), and high ($C = 45$). The corresponding results from these simulations are illustrated in Fig. 4.

In the scenario where additional costs are low ($C = 15$), the Local Government is highly inclined to adopt the "Support Policies" strategy. The minimal financial burden of implementing support measures, such as subsidies or infrastructure development, enables the government to maintain a proactive stance in encouraging cooperative behavior among Family Doctors, Grandparents, Parents, and Children. In this case, the relatively low cost of policy enforcement allows for sustained investment in cooperation, ensuring that all parties engage with one another in a mutually beneficial manner. This low-cost environment facilitates the realization of cooperative strategies across all stakeholders, fostering stability and encouraging optimal outcomes in terms of healthcare efficiency and resource utilization. The government's ability to provide consistent support enhances the effectiveness of collaborative health strategies, contributing to the overall success and equilibrium of the system.

As the additional costs increase to moderate levels ($C = 30$), the Local Government's propensity to implement "Support Policies" diminishes. At this point, the cost-benefit analysis becomes more complicated. The government must weigh the incremental costs associated with policy enforcement against the potential long-term advantages of cooperation, such as improved healthcare outcomes and reduced long-term expenditures. The moderate increase in costs introduces a level of fiscal strain, forcing the government to reconsider the breadth and depth of its support. Although still inclined to promote cooperation, the government may focus its efforts on specific stakeholders, such as Family Doctors, while offering less comprehensive support to Grandparents or Children. This selective engagement may cause some stakeholders to become less involved, decreasing the level of collaboration across the system. As a result, the system's stability begins to erode, as mixed evolutionary strategies (e.g., partial cooperation) emerge in response to reduced governmental commitment. The lack of consistent support from the government could lead to strategic fragmentation, where some parties adopt non-cooperative behaviors, further destabilizing the system.

In the case of high additional costs ($C = 45$), the government faces significant fiscal constraints that severely limit its ability to engage in the "Support Policies" strategy. At this stage, the costs of implementing support measures, such as subsidies, administrative overhead, and infrastructure investment, outweigh any perceived benefits. As the financial burden becomes increasingly unsustainable, the government is forced to scale back its involvement in fostering cooperation, which leads to a breakdown in the policy framework that previously encouraged collaboration. With the government withdrawing or significantly limiting its support, the incentives for Family Doctors, Grandparents, Parents, and Children to cooperate diminish. Stakeholders, now left with fewer external incentives, may opt for individualistic strategies, prioritizing their own interests over collective welfare. The result is a system characterized by lower levels of collaboration, increased inefficiencies, and higher individual healthcare costs. This shift to non-cooperative behavior disrupts the equilibrium, and the system may no longer converge to a stable evolutionary strategy. Instead, it could fragment into less effective, self-interested strategies, exacerbating the inefficiency and cost burden on the entire system.

The implications of these findings are clear: the balance of costs and benefits plays a pivotal role in determining the viability of government-supported healthcare models. When the additional costs are low, the government can afford to foster widespread cooperation, yielding a stable and efficient system. However, as costs rise, the government's capacity to sustain such cooperation diminishes, leading to partial or full disengagement, which weakens stakeholder cooperation. This analysis underscores the importance of carefully considering fiscal limitations in the design

Table 8 Setting model parameters.

Local Government	Family doctor (D)	Grandparents (R)	Parents (P)	Children (C)
$x = 0$	$y = 0.5$	$z = 0.9$	$w = 0.9$	$l = 0.9$
$G = 40$	$A_D^R = 25$	$A_R^D = 25$	$A_P^D = 20$	$A_C^D = 15$
$C = 30$	$A_D^P = 20$	$F_R^P = 28$	$F_P^R = 28$	$F_C^R = 28$
$I^D, I^R, I^P, I^C = 6, 10, 14$	$A_D^C = 15$	$M_R^P = 32$	$M_P^R = 32$	$M_C^R = 32$
$K^D, K^R, K^P, K^C = 10$		$M_R^C = 32$	$M_P^C = 32$	$F_C^P = 28$
$S^D, S^R, S^P, S^C = 8$				$M_C^P = 32$
$T^D, T^R, T^P, T^C = 7$				

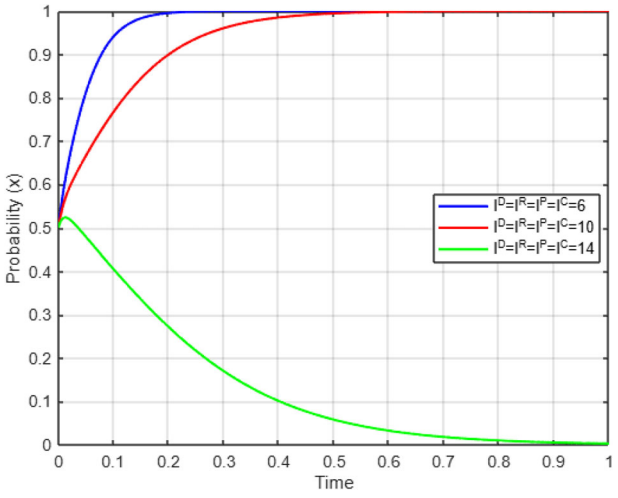

Fig. 5 The strategy evolution process of Local Government under different medical subsidies scenarios.

of support policies, as excessive costs can lead to destabilization. It also highlights the need for a robust strategy to manage the financial aspects of policy enforcement to maintain stakeholder cooperation and ensure the long-term sustainability of healthcare systems.

Analyzing the impact of Local Government medical subsidies on evolutionary strategies. The assumed parameters are shown in Table 8 below.

To investigate the influence of Local Government medical subsidies on its regulatory decisions, we simulate the system's dynamics under varying levels: low $\left(I^A = I^B = I^C = I^D = 6\right)$, moderate $\left(I^A = I^B = I^C = I^D = 10\right)$, and high $\left(I^A = I^B = I^C = I^D = 14\right)$. The resulting data from the simulation are depicted in Fig. 5.

In the low-subsidy scenario $\left(I^A = I^B = I^C = I^D = 6\right)$, the government is more inclined to adopt the "Support Policies" strategy. Here, the relatively modest financial outlay required to fund the subsidies aligns with the government's strategic interest in stimulating cooperation without exerting excessive fiscal pressure. The moderate subsidy level appears sufficient to encourage Family Doctors, Grandparents, Parents, and Children to engage in cooperative behaviors, as the government's relatively small financial commitment creates an environment in which cooperation is seen as mutually beneficial. Importantly, the low cost of supporting these stakeholders allows the government to preserve fiscal flexibility while achieving a broad-based alignment of interests. As such, the adoption of the "Support Policies" strategy in this context fosters stability, incentivizing all stakeholders to remain engaged in cooperative healthcare practices.

However, as subsidies increase to a moderate level $\left(I^A = I^B = I^C = I^D = 10\right)$, the simulation results reveal a shift in the government's decision-making process. The additional cost required to maintain this level of subsidy leads the Local Government to reassess the sustainability of its support. In this case, although the subsidies continue to offer incentives for cooperation, they begin to place a greater strain on the government's budget, which reduces the net benefits of expanding support. The moderate subsidy level exacerbates the demand for incentives from the stakeholders, leading to an increased expectation for more substantial subsidies over time. This growing demand creates an imbalance where the financial incentives required to maintain cooperation start to outweigh the perceived gains in healthcare efficiency and long-term cost savings. As a result, the government may begin to limit its support or apply the "Support Policies" strategy selectively, focusing only on certain stakeholders or specific aspects of the healthcare system. This partial reduction in support can lead to fragmented cooperation, with some groups, such as Family Doctors, potentially receiving more favorable treatment, while others may experience reduced subsidies, weakening overall system stability.

In the high-subsidy scenario $\left(I^A = I^B = I^C = I^D = 14\right)$, the simulation results indicate a sharp decline in the probability of the Local Government adopting the "Support Policies" strategy. The substantial financial burden associated with providing high subsidies across all stakeholders forces the government to reconsider its policy stance. As the subsidy demands become significantly higher, the marginal returns of these subsidies diminish, meaning that the government perceives a limited increase in overall cooperation relative to the additional fiscal outlay. Moreover, the higher the subsidies, the more dependent the stakeholders become on continued financial support, reducing their intrinsic motivation to cooperate. This dependence fosters a dynamic where the government, overwhelmed by the escalating costs, finds itself unable to sustain the level of financial commitment necessary to maintain the full support policy framework. Consequently, the Local Government may reduce or withdraw its subsidies, leading to a breakdown in cooperation and a shift towards non-cooperative behaviors among the stakeholders.

This analysis underscores the delicate balance that the Local Government must navigate in determining the appropriate level of medical subsidies. When subsidies are low, the government is able to foster widespread cooperation with minimal fiscal strain, ensuring long-term system stability. However, as subsidies increase, the government's fiscal constraints become more pronounced, and the diminishing returns from subsidies force the government to scale back its support. The findings suggest

that excessive reliance on subsidies may ultimately hinder the very cooperation they aim to promote, as stakeholders become more dependent on government support, reducing their incentive for independent collaboration. Thus, the optimal subsidy strategy lies in calibrating financial support to avoid overburdening the system while still incentivizing sustainable cooperation among all parties.

Discussion

The 3GFD model does not impose a 'one-size-fits-all' family structure, it recognizes that in collectivist contexts, biological kin provide the backbone of care; in individualistic settings, 'chosen families' must be nurtured through policy and trust-building.

Cultural and Religious Adaptability of the 3GFD Model. The 3GFD model does not impose a 'one-size-fits-all' family structure, it recognizes that in collectivist contexts, biological kin provide the backbone of care; in individualistic settings, 'chosen families' must be nurtured through policy and trust-building.

In collectivist societies, multigenerational co-residence and familial obligation are culturally embedded, turning social norms into structural advantages for primary care delivery. Policies here can leverage existing networks, for example, filial piety in East Asia (Chang 2020), to reduce implementation costs and accelerate adoption.

In individualistic societies, such as many Western countries, nuclear households dominate, and the willingness to cooperate across generations is often lower. In these contexts, community-based or "chosen family" arrangements may substitute for biological kinship in providing care. Religious institutions also play a significant role in shaping caregiving norms and moral obligations, which can directly affect both intergenerational cooperation and engagement with family physicians.

While the present model abstracts from these cultural and religious differences for analytical tractability, it is adaptive rather than prescriptive and can be tailored to different sociocultural conditions. Future research should explicitly incorporate cultural orientation and religious factors to improve cross-cultural generalizability.

Policy Implications from a Synergistic Model. The collaboration among multigenerational families, family doctors, and government support forms a robust framework for enhancing healthcare systems, particularly in aging populations and resource-limited environments. This integrated approach carries significant policy implications.

Below is a ranked list of policy priorities, organized according to a logical sequence of foundational, operational, and sustainable measures. This structure reflects the progression from enabling conditions, to effective implementation, and finally to long-term optimization.

Priority: High (Foundational & Enabling).

a. **Formal Recognition of Informal Caregiving**

- **Policy**: Establish legal frameworks that formally acknowledge and support informal caregivers, typically family members, by providing benefits such as caregiver allowances or tax incentives, as implemented in certain countries.
- **Impact**: Recognizes and promotes the contribution of multigenerational households in maintaining health, thereby helping to alleviate the burden on healthcare providers.
- **Rationale**: This policy establishes the legal and societal framework that validates the role of informal caregivers. Without such recognition, caregivers remain invisible in the healthcare system, lacking rights, benefits, and legitimacy. It is a prerequisite for all subsequent interventions, such as financial support, training, and mental health programs, because it transforms caregiving from a private expectation into a recognized and valued public health function.

b. **Financial Incentives for Multigenerational Living**

- **Policy**: Offer tax breaks, housing subsidies, or caregiver stipends to multigenerational households providing care for elderly or disabled relatives, helping to ease the financial challenges associated with caregiving.
- **Impact**: Encourages family cohabitation by providing incentives for multigenerational living, while also contributing to a reduction in state spending on institutional care, as more families take on caregiving responsibilities at home, fostering a more sustainable and cost-effective approach to long-term care.
- **Rationale**: Financial cost is the most immediate and significant barrier preventing families from adopting multigenerational living arrangements. By offering tax breaks, subsidies, or stipends, this policy provides tangible motivation for households to embrace caregiving roles. It ensures that other supportive measures can reach a broader population base, making it a direct enabler of system-wide adoption.

Priority: Medium (Operational & Capacity-Building).

c. **Caregiver Training and Health Literacy Programs**

- **Policy**: Invest in and broaden public training programs that provide family members with foundational healthcare knowledge, such as managing chronic illnesses, supporting mental well-being, and maintaining hygiene standards.
- **Impact**: Improves health outcomes by equipping family members with the necessary skills and knowledge, while also reducing the likelihood of costly errors or complications in home-based care, ultimately leading to better patient safety and well-being.
- **Rationale**: Training equips caregivers with essential skills and knowledge to manage chronic illness, promote hygiene, and support mental well-being. This reduces preventable errors, improves patient outcomes, and enhances overall safety in home-based care. It represents a critical investment in quality, ensuring that informal caregiving complements rather than undermines formal healthcare efforts.

d. **Integrated Care Teams: Families + Physicians**

- **Policy:** Develop structured community health programs that officially incorporate family caregivers into primary care frameworks, enabling physicians to delegate non-clinical responsibilities, such as providing medication reminders and monitoring dietary habits, to family members who have received appropriate training.
- **Impact:** Enhances physicians' time management by allowing them to focus on clinical tasks, while simultaneously empowering families to participate actively and meaningfully in the caregiving process, fostering a more collaborative and efficient model of patient care.
- **Rationale** : This policy operationalizes collaboration between families and physicians by formally incorporating caregivers into primary care structures. It allows physicians to focus on clinical expertise while delegating non-clinical support tasks to trained family members. Such integration reduces fragmentation, strengthens

coordination, and establishes a sustainable division of responsibilities within the healthcare system.

e. **Digital Support Platforms**

- **Policy:** Invest in government-supported telehealth platforms that provide families with the opportunity to regularly connect with physicians, share patient updates, seek medical advice, and access a wide range of educational resources. This will enhance the quality of care for individuals at home, improve communication between caregivers and healthcare professionals, and support families in effectively managing health conditions outside of traditional clinical settings.
- **Impact**: Bridges the gap between formal and informal care, particularly in rural or underserved areas, by providing families with direct access to healthcare professionals through telehealth, ensuring continuity of care, and enhancing the support available to patients in regions with limited access to in-person healthcare services.
- **Rationale:** Technology enhances the reach and effectiveness of caregiving, especially in rural or underserved areas. Digital platforms enable continuous monitoring, timely communication with physicians, and easy access to resources. However, their effectiveness depends on caregivers being health-literate, which is why they follow after training programs in the policy hierarchy.

Priority: Lower (Sustainable & Optimizing).

f. **Incentivizing Family Physicians in Community-Centered Models**

- **Policy**: Develop policies that offer incentives for physicians to participate in healthcare models that actively collaborate with families. This can be achieved through financial mechanisms such as capitation payments or performance-based bonuses tied to community-based care initiatives.
- **Impact**: This policy promotes a transition from volume-driven to community-based care, enabling physicians to build stronger, long-term relationships with patients and families. It supports more personalized and preventative healthcare, improves overall outcomes, and reduces dependence on costly institutional services, ultimately creating a more sustainable and responsive healthcare system.
- **Rationale:** Physicians must be incentivized to participate in community-based models for long-term success. Payment reforms, such as capitation or performance-based bonuses, encourage stronger physician-family collaboration. However, this becomes impactful only once a robust system of trained and recognized caregivers is in place, which is why it is ranked lower in priority.

g. **Respite and Mental Health Support for Caregivers**

- **Policy**: Offer respite services, mental health support, and access to social workers for family caregivers, helping to prevent burnout and ensuring they receive the necessary assistance to manage the emotional, physical, and mental demands of caregiving. By offering these resources, caregivers can take necessary breaks, receive professional guidance, and maintain their well-being, ultimately preventing burnout and ensuring the sustainability of their caregiving roles.
- **Impact**: Ensures the sustainability of the home-care model by providing necessary support and resources, preventing the overburdening of family members, and allowing them to continue providing care without compromising their own well-being or the quality of care they offer.
- **Rationale:** Physicians must be incentivized to participate in community-based models for long-term success. Payment reforms, such as capitation or performance-based bonuses, encourage stronger physician-family collaboration. However, this becomes impactful only once a robust system of trained and recognized caregivers is in place, which is why it is ranked lower in priority.

Strategic Vision: The envisioned model promotes a decentralized, community-focused healthcare system in which households function as the foundational units of care. Within this framework, family physicians play a pivotal role as both clinical authorities and care coordinators, directing and supporting health management at the family and community levels. This model is especially impactful in settings with limited healthcare infrastructure, such as many developing countries, and in aging populations of developed nations where institutional care is often expensive and disjointed. It also holds significant relevance in rural areas, where multigenerational living remains prevalent, offering a practical and sustainable solution to improve healthcare accessibility and effectiveness.

The Rationale And Feasibility Of Budget Allocation For The Policy. This section analyzes the Rationale and feasibility of budget allocation for the proposed policies, examining not only the financial requirements but also their cost-effectiveness, scalability.

Phase 1: Foundation Building (Years 1–2)
Objective: Establish a supportive legal and institutional framework that formally recognizes informal caregivers and builds foundational caregiving capacity.

Key Actions. Legal Recognition of Caregivers: Enact policies that formally acknowledge the role of family caregivers in health and social care systems. This includes creating national registries, defining caregiver rights, and integrating them into public health planning.

Training and Capacity Building Launch standardized training programs focused on chronic disease management, elderly and child care, mental health first aid, and basic digital health literacy. Priority is given to rural and underserved communities to reduce disparities.

Rationale: These foundational steps require minimal financial outlay but generate high leverage by transforming invisible, informal care into a visible, valued, and coordinated component of the health system, making the model adaptable to both high- and low-resource settings.

Phase 2: Operationalization and Connection (Years 3–5)
Objective: Strengthen collaboration between families, family physicians, and the health system through practical support mechanisms and digital connectivity.

Details
Key Actions: Targeted Support Mechanisms: Introduce non-monetary or context-appropriate incentives to encourage multi-generational co-residence and active caregiving.

Digital Care Coordination Platform: Deploy scalable telehealth and care coordination tools that enable real-time communication between caregivers and family doctors, support remote monitoring, and facilitate health education, drawing on successful models from diverse countries.

Pilot Integrated Care Teams: Test formalized care teams in selected regions, where trained family caregivers work alongside primary care providers under clear protocols for task sharing and mutual support.

Rationale: This phase focuses on system integration rather than large-scale funding. By leveraging existing infrastructure and adapting incentives to local contexts, the approach remains feasible across countries with varying economic capacities.

Phase 3: Sustainability and Expansion (Year 5 onward)
Objective: Consolidate system quality, expand nationwide coverage, and ensure long-term sustainability by addressing caregiver burnout and incentivizing physicians.

Key Actions. Scale Up Proven Support Mechanisms for Households: Expand support to all eligible multigenerational households based on demonstrated improvements in health outcomes and reduced reliance on institutional care. The form of support, whether through social protection linkages, service vouchers, tax benefits, or non-monetary recognition, can be adapted to each country's welfare system and fiscal capacity.

Reform Physician Incentives Toward Community-Based Care: Shift from fee-for-service toward payment models that reward preventive care, continuity, and collaboration with families, such as capitation or performance-based recognition. This realigns physician motivation with long-term health outcomes rather than short-term service volume.

Institutionalize Respite and Mental Health Support for Caregivers: Integrate accessible, routine support, such as counseling, peer networks, and temporary relief care, into primary care systems. This prevents burnout and ensures that caregiving remains a sustainable role across generations.

Strategic Vision: The envisioned model promotes a decentralized, community-focused healthcare system in which households function as the foundational units of care. Within this framework, family physicians play a pivotal role as both clinical authorities and care coordinators, directing and supporting health management at the family and community levels. This model is especially impactful in settings with limited healthcare infrastructure, such as many developing countries, and in aging populations of developed nations.

Summary

Conclusion and Future Research. The 3GFD synergy and simulation above shows us that the synergy between multigenerational families, family physicians, and government support teaches us several crucial lessons about building resilient, efficient, and inclusive healthcare systems, especially in the face of workforce shortages, faging populations, and rising healthcare costs. What we learn from the synergy:

a. Healthcare is Strongest When Shared Across Systems: Effective healthcare depends on interdependent relationships, not isolated interventions.
   - The complexity of modern healthcare challenges exceeds the capacity of any single stakeholder, whether physicians, families, or government, to manage independently. Each faces limitations when operating in isolation, particularly in the face of aging populations, rising chronic conditions, and resource constraints.
   - A more sustainable and effective approach lies in collaborative models where each actor plays a clearly defined yet interdependent role. By working in coordination, physicians providing clinical expertise, families offering day-to-day support, and governments ensuring policy and financial backing, the healthcare system can become more resilient, responsive, and equitable.

b. Informal Care Has Formal Value: Informal caregiving should be integrated into public health strategies, not treated as invisible labor.
   - Multigenerational families play a vital role in healthcare by delivering essential forms of support, including health monitoring, emotional care, and assistance with daily activities, contributions that significantly lessen the burden on formal healthcare services.
   - By formally acknowledging and supporting this informal care through targeted policies, caregiver training programs, and financial assistance, governments can alleviate pressure on the healthcare system, enhance care quality at home, and promote a more integrated and sustainable model of care.

c. Family Physicians Thrive in Community-Based Models: Family medicine is most effective when rooted in community and supported by both households and policy.
   - With the backing of both families and government support structures, family physicians are better positioned to concentrate on complex clinical cases, rather than being overextended by routine or preventable health concerns that could be managed at the community or household level.
   - Their impact is significantly amplified when they operate within a well-integrated local support network, where responsibilities are shared, communication is streamlined, and care is coordinated across both formal and informal providers.

d. Prevention and Continuity Are Cost-Efficient: Prevention and relational continuity are key levers for reducing long-term costs and improving outcomes.
   - Multigenerational households naturally encourage preventive health practices and ongoing monitoring of health over time, creating a stable environment for early intervention and consistent care.
   - This continuity and emphasis on long-term well-being closely align with the family physician's holistic care approach, ultimately contributing to improved health outcomes and more effective disease management across generations.

e. Government Support Is the Catalyst: Government intervention is essential to scale and sustain these synergies.
   - While families and physicians are essential pillars of care, their efforts remain limited without the backing of comprehensive, state-supported infrastructure, such as caregiver training programs, financial incentives, digital health tools, and respite services.
   - Public policy plays a crucial role in providing the foundational support needed to scale and sustain these private caregiving efforts, ultimately converting them into measurable public health improvements and system-wide benefits.

f. Culture and Social Norms Matter: Healthcare models must align with cultural and socioeconomic realities to be effective.

- The proposed model thrives in societies where multigenerational living is both culturally accepted and economically viable, as it allows families to naturally assume caregiving responsibilities within the household. In these environments, the integration of informal care with formal healthcare services creates a strong, supportive system that promotes continuity of care and strengthens family bonds.
- However, in regions where multigenerational living is either uncommon or not economically feasible, this model may not be as effective. In such cases, alternative community-based caregiving models must be developed and tailored to local needs. These models could involve a network of local caregivers, community support groups, or cooperative healthcare services, all designed to provide similar benefits while adapting to the unique circumstances of the community.

g. Phase-Dependent Evolutionary Games:
The current model presumes fixed incentive structures, yet real-world cooperation within multigenerational families unfolds across distinct life-cycle phases, ranging from stable co-residence and child-rearing to chronic illness onset and end-of-life care. Future research should advance toward a Phase-dependent evolutionary game framework, in which payoff structures, cooperation costs, and government policy instruments evolve dynamically in response to shifting household needs and health trajectories. By embedding temporal transitions into the strategic landscape, such a model would more faithfully reflect critical real-world disruptions, including acute health shocks, caregiver burnout, and intergenerational tensions, and support the design of adaptive, time-sensitive policies that align with the rhythms of family life.

Therefore, our proposed synergy model and simulation shows that a blended model of care, anchored in family, empowered by physicians, and scaled through government policy, offers a holistic, sustainable path forward for healthcare systems facing crises. It's not about replacing doctors with families, but about empowering each actor to do what they do best, in mutual support of healthier populations.

Data availability

All data generated or analyzed during this study are included in this published article and its supplementary information files.

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Competing interests

The authors declare no competing interests.

Ethics approval

Not applicable.

Informed consent

The authors consent to the publication of this manuscript.

Declarations

All data generated or analyzed during this study are included in this published article and its supplementary information files.

Additional information

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