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Integration of Income-Oriented Physician Behaviour in Simulation Models for Health Systems

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Ao.Univ.Prof. Dipl.-Ing. Dr.techn. Felix Breitenecker

durch

Vilma Urbonaite
Martinstraße 45/27
1180 Wien

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Abstract

This master's thesis focuses on the income-oriented physician behaviour in health markets. It presents a discrete time agent-based simulation model for extramural health care. The work takes a closer look at the physician-patient relationship and introduces the concept of perfect physician agency, which describes physician behaviour based purely on behalf of his/her patient. With reference to theoretical and empirical findings in the literature, the thesis reviews a set of factors that have the greatest impact on the physician's decisions and actions. Following the finding that the conflict between the physician's own financial interest and responsibilities to the patient could significantly affect his/her practice pattern, the thesis considers the causes of deviation from perfect agency. For this purpose, the presented simulations with the developed model compare the 'perfect' and income-oriented physician's behaviour. In particular, they incorporate self-interested physicians' behavioural responses to a reduction in their fees. The different analysed behaviour scenarios are chosen taking into account the possible ways for physicians who act only as imperfect agents for their patients to increase the income under a prospective (case-based) and a retrospective (fee-for service) reimbursement system. In this context special attention is paid to the hypothesis of supplier-induced demand, the potential reduction in time devoted to the treatment and possible intentional patient misdiagnosis. The simulation results - the health care costs - are evaluated and compared for both payment systems. These results confirmed that the imperfect physicians' agency affects the economic outcomes of the modelled health system. However, the modelling revealed that even minimal assumptions about the limitations of the income-oriented physician behaviour restrict the physicians' ability to achieve their target income.

Zusammenfassung

Die vorliegende Arbeit befasst sich mit der Dynamik des einkommensorientierten Verhaltens von Ärzten im Gesundheitssektor. Für diesen Zweck wird ein zeitdiskretes agentenbasiertes Modell für die extramurale Gesundheitsversorgung entwickelt. Die Arbeit untersucht die Beziehung zwischen Arzt und Patient und betrachtet die Ursachen der Abweichung von einer perfekten Prinzipal-Agent-Beziehung. Dabei wurden verschiedene theoretische und empirische Faktoren, die einen großen Einfluss auf das Praxisverhalten der Ärzte haben, im Zuge einer Literaturrecherche ermittelt. Unter Einbeziehung der Annahme, dass ärztliche Entscheidungen signifikant von dem Konflikt zwischen finanziellen Interessen und dem Patientenwohl beeinflusst werden, wird das Verhalten von „perfekten“ sowie eigennützigen Ärzten in Simulationen mit dem entwickelten Modell verglichen. Insbesondere werden Verhaltensreaktionen von Ärzten, die ein bestimmtes Zieleinkommen erreichen wollen, auf eine Reduktion ihrer Tarife untersucht. Die verschiedenen betrachteten Szenarien sind dabei so gewählt, dass sie die verschiedenen Möglichkeiten abbilden, mit denen ein Arzt sein Einkommen unter einem prospektiven (Fallpauschalen) beziehungsweise retrospektiven Bezahlungssystem (Einzelleistungsvergütung) erhöhen kann. Besonderes Augenmerk wird dabei auf die Hypothese der angebotsinduzierten Nachfrage, die potentielle Unterversorgung von kostengünstigen Patienten sowie mögliche vorsätzliche Fehldiagnosen gelegt. Die Simulationsergebnisse werden in Bezug auf prospektive und retrospektive Vergütungssysteme evaluiert und verglichen. Sie zeigen, dass das "imperfekte" bzw. eigennützige Verhalten der Ärzte die resultierenden Kosten im modellierten Gesundheitssystem beeinflussen kann. Allerdings reduzieren bereits minimale Annahmen zu Einschränkungen dieses Verhaltens die Möglichkeiten eines Arztes, das gewünschte Zieleinkommen zu erreichen.

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Contents

1 Introduction **1**

1.1 Presentation of the topic and goals . . . 1

1.2 Key components of health care system models and reimbursement system 4

1.3 Characteristics of medical markets and principal-agent relationship . . . 7

2 Theory of a Perfect Agency **10**

2.1 Physicians' responsibilities toward the patient . . . 10

2.1.1 Serving as the patient's clinical agent . . . 11

2.1.2 Serving as the patient's economic agent . . . 12

2.1.3 Responding to reasonable patient demand . . . 13

2.1.4 Avoiding practice defence medicine . . . 13

2.1.5 Considering a patient's medical and personal characteristics . . . 14

2.1.6 Considering a patient's convenience . . . 14

2.1.7 Treating patients with understanding and respect . . . 14

2.2 Physicians' objectives and utility function under the Perfect Agency . . . 15

2.3 Benefits from the Perfect Agency . . . 18

2.4 Conclusion . . . 22

3 Simulation of the Model with Perfect Agency **23**

3.1 Model structure . . . 23

3.2 Model assumptions and rules . . . 28

3.2.1 Main assumptions and limitations . . . 28

3.2.2 Modelling of getting ill and the treatment process . . . 34

3.3 Simulation run and results . . . 39

3.3.1 Model initialisation . . . 39

3.3.2 Simulation run . . . 40

3.3.2.1 Example No. 1 . . . 41

3.3.3 Identification and selection of most important model parameters . 49

4 Imperfect Agency and Income-Oriented Physician Behaviour: Theory and Empirical Evidence **55**
4.1 Physicians' objectives . . . 56
4.2 External factors influencing physician behaviour . . . 58
4.2.1 Clinical uncertainty and defensive medicine . . . 59
4.2.2 Patient characteristics . . . 59
4.2.3 Ownership structure of the physician practice . . . 60
4.2.4 Non-price competition and operating environment . . . 60
4.3 Physician behaviour constraints . . . 61
4.4 Income-oriented physician behaviour . . . 62
4.4.1 Prospective reimbursement system . . . 63
4.4.1.1 Undersupply of healthcare: reduction in medical input and length of stay . . . 64
4.4.1.2 Cream skimming and dumping . . . 66
4.4.1.3 Coding bias and other financial incentives . . . 67
4.4.2 Retrospective reimbursement system . . . 67
4.4.2.1 The hypothesis of Supplier-Induced Demand (SID) . . . 68
4.4.2.2 SID: first empirical support and economic interpretation 68
4.4.2.3 Potential drivers of SID: empirical studies and developed models . . . 71
4.4.2.4 The identification problems of SID . . . 73
4.4.2.5 Overview . . . 74

5 Simulation of the Model with Income-Oriented Physician Behaviour **76**
5.1 General model assumptions . . . 76
5.1.1 Income-oriented physician . . . 77
5.1.2 The target income . . . 79
5.2 Simulation of the income-oriented physician behaviour . . . 81
5.2.1 Model initialisation: the simplified health system . . . 82
5.2.2 The perfect scenario . . . 84
5.2.3 The reduction in physician fees . . . 85
5.2.4 Scenario No. 1: Affecting the provision of medical services under a fee-for-service reimbursement . . . 86
5.2.4.1 Assumptions . . . 86
5.2.4.2 Simulation run and results . . . 88
5.2.5 Scenario No. 2: Additional patient visits under a fee-for-service reimbursement system . . . 95

5.2.5.1 Assumptions 95
5.2.5.2 Simulation run and results 96
5.2.6 Scenario No. 3 and Scenario No. 4: An intentional misdiagnosis and decreasing the number of patient visits under a case-based reimbursement system 100
5.2.6.1 Assumptions 100
5.2.6.2 Simulation run and results 101
5.3 Overview 105

6 Conclusions **106**

Appendix **109**

A Appendix to Chapter 2 **110**

References **120**

List of Figures **130**

Chapter 1

Introduction

1.1 Presentation of the topic and goals

Models for health care systems often rest on the assumption that physicians serve as the perfect agents, i.e., choose exactly those quantities and types of health care that the patient would choose if he/she had the information and knowledge the physician has (Pauly, 1980). Such idealized vision of the physician-patient relationship reflects the physician as a person of simple economic desire whose behaviour and decision making are purely based on ethical values and the Hippocratic Oath.

Studies on physicians' practice patterns revealed that physicians deviate from the perfect agency and practice medicine differently (Pauly, 1980; McGuire, 2000; Eisenberg, 2002). Even if it comes to the specialists of the same medical field, their behaviour, decision-making and caused health expenditures may vary markedly. This could be partly explained by the complexity of the medical profession: there are just a few clear rules for practising medicine and many medical choices must be done under a certain degree of uncertainty (Eisenberg, 2002). Physicians have different characteristics and unevenly interpret patients' personal and health information. The physician-patient relationship also strongly depends on their ability to communicate and exchange important information as well as the patient's trust in their physician (AAOS, 2000). Physician behaviour may also be affected by certain external factors such as the fear of malpractice suits, the patient's personal characteristics, the ownership structure of the physician practice, the competition with other providers, the operating environment and others (Eisenberg, 2002; Bickerdyke et. al, 2002). As a result, the ill persons with similar health problems are prescribed different types and amount of medical care. However, there is a strong suspicion that physicians act as imperfect agents because their motives and goals do not coincide with those of the patient.

Eisenberg (2002), relying on the studies on physician practice patterns, reasons that when practising medicine physicians do take into account more factors than solely the patients' well-being. Physicians care about a work-life balance, workload, their reputation in community, carrier perspective, professional interests, etc. Moreover, numerous researches published over the last several decades have pointed out that the health care sector is an economic market where the physician is a supplier of medical services and therefore desires to gain a financial benefit. For example, Bickerdyke et al. (2002) talk about the potential conflict between the physicians' financial incentives and their duty to practice medicine purely on the patient's best interest and cite the survey conducted by The Center of Studying Health Change (Lake and St. Peter, 1997). Physicians were asked if they believed in making clinical decisions on the best patient's interests without reducing their income. While over 70 percent of the physicians affirmed that physicians' financial incentives are compatible with acting on patient's behalf, 10 percent of the physicians strongly disagreed and 15 percent expressed somewhat disagree with the hypothesis. Studies like this allow predicting that physicians may change their behaviour according to their financial interests. This suggestion has been supported by various empirical studies which established an oversupply of health care in medical systems where physicians charge each individual provided unit. Researchers also found the relatively high volume of patients because of shorted patients' visits or reduction in efforts per care in case of the physicians' reimbursement based on predetermined prices (e.g., Roemer, 1961; Rogers, 1990). This notion that, aside the concern for the patient's welfare, the physician is also an income seeker, has obscured the physician's image of 'unselfish good doer' and caused a discussion whether or not and under which circumstances physicians exploit their information advantage about the patient's real health status for selfish purposes. Since physicians act as both advisers and providers for health care and thus are responsible for efficiency of spending on health, attempts have been made to investigate their behaviour.

This master's thesis focuses on the income-oriented physician behaviour in health markets. It is motivated by four research questions:

(1) which factors influence physician behaviour in general and how can this influence be quantified based on empirical findings;

(2) what could be an appropriate model structure to integrate income-oriented physician behaviour in simulation models;

(3) which instruments could be used by physicians in order to achieve greater income under prospective and retrospective reimbursement systems; and

(4) what is the impact of actions initiated by income-oriented physicians on economic outcomes.

This work takes a closer look at the physician-patient relationship. It aims at implementing income-oriented physician behaviour in an appropriate simulation model for health care systems and in this way at measuring the possible economic impact of physician's intended actions on health system. These goals determine/define the structure of this work.

The rest of this chapter sets the stage for the theoretical reasoning and modelling presented in this work. The next section presents the key components of health care system models and shortly discusses the prospective and retrospective reimbursement systems. The introduction in this work is completed by reviewing the main characteristics of medical markets and principal-agent relationship. Chapter 2 provides a conceptual overview of the perfect physicians' agency. It discusses physicians' responsibilities toward the patient and reveals possible benefits of the physicians gained from the perfect behaviour. Chapter 3 introduces a discrete time agent-based simulation model for the extramural health care system based on the assumption that private-practice physicians act as the perfect agents for their patients. The model outcomes are evaluated in a prospective (case-based) and retrospective (fee-for service) reimbursement system. Referencing theoretical and empirical findings in literature, Chapter 4 addresses different factors, other than the patient's well-being, that may have an impact on the physicians' practice patterns. It rejects the assumption of the perfect physicians' agency and seeks to explain how and why physicians deviate from acting on the patient's best interest. Special attention is given to physicians' behavioural tendencies driven by their desire for additional income. This chapter also suggests a set of possibilities for income-oriented physicians to exploit prospective or retrospective payment systems. Selecting the most striking income-oriented physicians' strategies, Chapter 5 presents the model extension which compares the 'perfect' and 'imperfect' physicians' behaviour. Assuming that the income-oriented agent seeks to maintain a certain level of target income, the extended model simulates physicians' behavioural responses to reduction in their fees. According to physicians' incentives under prospective and retrospective payment systems, this chapter provides several income-oriented behaviour scenarios and presents the simulation outcomes. Conclusions and a proposal for future work are shortly discussed in Chapter 6.

1.2 Key components of health care system models and reimbursement system

The World Health Organization (WHO) defines a health system as “all the organizations, institutions, resources and people whose primary purpose is to improve health“ (WHO, 2014). Such system (sometimes referred to as health care system or healthcare system) is elaborated in order to meet the health care needs of target populations and has three main goals: to ensure good health; to respond to people’s expectations; and to maintain fairness of financial contribution. According to the WHO, strong policies and leadership, good information systems, essential medical products and technologies, human resources for health, financing, and qualified service delivery belong to the key components of a well-functioning health system (WHO, 2010).

In general, simulation models for health care represent simplified systems consisting of the target population, medical providers, problems, services and payers. The occurring health care cost depends on the application of existing reimbursement methods. The structure and dynamics of the simplified health care system is illustrated in the Figure 1.1. The simulation model developed and presented in this work is also based on this viewpoint.

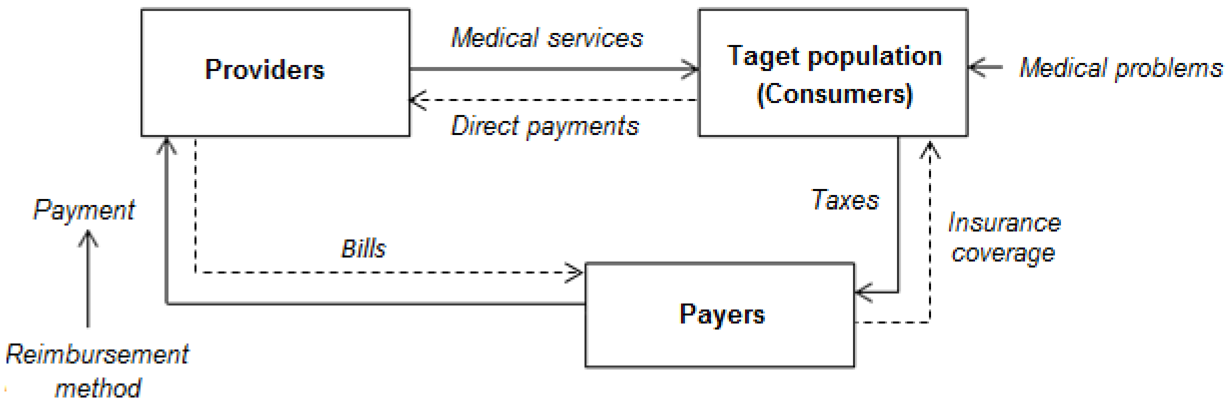


Figure 1.1: The main components of the simplified health care system (adapted from WHO, 2014)

This figure illustrates the dynamics between patients, providers (physicians) and payers in the medical system. Some individuals in the target population develop medical problems. All necessary medical services are delivered by providers who are paid by payers under the existing reimbursement system. Health care consumers pay taxes to the payers and receive insurance coverage. Some completely private physicians could also be paid by private persons.

The target population includes all people living within a certain geographic area (city, state, country, etc.). Irrespective of the existing health system, when people have medical problems they expect to receive some help from the health care providers. The individuals care about their state of health but not necessarily make the optimal choices related to the treatment process. The patient's behaviour could be significantly affected by the type of his health insurance. If, for example, all health costs are covered by a third party, an ill individual may pay less attention to the actions of the treating medical provider. If, otherwise, the patient covers all or the bigger part of the health cost on his/her own resources, he/she is most likely more aware of the recovery time, the number of physician office visits and all other factors that could have an influence on the cost of the treatment.

In the health care sector the word 'provider' refers to a trained professional who works self-employed or as an employee in an organization and provides health care services to the individuals, families or the community (Liverpool Health Authority, 2009). It also can be the organizations employing people who provide the health care. Examples for providers are physicians, nurses, psychologists, pharmacists, medical laboratory staff and hospitals. In this work the focus is settled on a specific type of health care providers, namely, the physicians. At this point it is important to emphasize that in the following parts of the thesis the terms 'doctor', 'health care provider', 'medical provider' or 'provider of medical services' refer to physicians.

Physicians are often called gatekeepers for the health care system (Zweifel et al., 2009). They are health providers who decide upon the diagnosis, prescription of drugs, treatment or refer the patients to other specialists, hospitals, pharmacists etc. This profession that combines two very important features - the capability to help other people and the opportunity to earn the above-average income and good employment prospects - is one of the most prestigious and highly respected occupations and preferred career choices in society. However, as will be shown below, the possibility 'to do a good thing' and get a benefit at the same time may become contradictory regarding the physicians' actions in the health care system. Their behaviour and decision-making is a complex process shaped by various features such as ethical standards, health state of their patients, experience and medical working field. As will be indicated later, this process also may be significantly influenced by the existing reimbursement schema.

Among other methods of funding health care systems, such as direct or out-of-pocket payments, general taxation and donations, namely health insurance is the most important financing method. Health insurance is a type of insurance that covers the medical expenses (Liverpool Health Authority, 2009). It is well known that different countries promote diverse health insurance systems. For example, the United States health care system relies more on private than on public health insurance, while 85% of Germans are covered by a basic health insurance plan. The French insurance system is characterized by solidarity: the more complicated a patient's condition, the less this patient pays (Busse et al., 2011, p. 113, p. 57–45). In Austria the most important financing source is the social health insurance system. The insurance is compulsory and based on membership of an occupational group or place of residence (Hofmarcher, 2006, p. xviii). Individuals also have an option to purchase supplementary private health insurance.

Physicians are paid for their services under the existing reimbursement method. There are two main competing types of reimbursement systems: prospective and retrospective (Jegers et al., 2002). A prospective reimbursement scheme refers to a payment method where each medical provider receives the same remuneration for each treatment of the same type. Under this system, a fixed payment rate is assigned to a specific treatment, based on predetermined factors. The determination of these payment rates can take into account the large scale economic factors, e.g., inflation, living cost in certain region etc., rather than the characteristics of individual patients. One of the best-known examples for this type of reimbursement is the Diagnosis-related groups (DRGs) payment system which classifies cases by principal and secondary diagnoses, patient's age and sex, the presence or absence of co-morbidities and complications and the procedures performed. The main advantage of the prospective reimbursement system is the better predictability of health care expenditures assured by constant payment rates.

In the retrospective payment system, fees for required medical services are reimbursed based on each medical service rendered. This schema, at least theoretically, should give high degree of freedom in terms of choices in the health services. A traditional retrospective reimbursement method is the fee-for-service (FFS) payment system. Under this schema, providers get paid for each visit, test or any other service they deliver for the patient. While prospective payment systems are criticized for motivating physicians to select more profitable patients, the main weaknesses of retrospective methods are the variability (no fixed fee) and the lack of incentives to maximize efficiency in provision of medical services and contain costs (Ogwang, 2003). For this disadvantage of the retrospective method and because of the possibility to predict the cost under the prospective payment system, the prospective payment system is preferred in many countries.

The existing reimbursement system is a very important aspect of the current health care system. The payment method can impact a physician's decisions and his behaviour related to his patient's treatment and the overall cost. Various models and empirical studies compare different reimbursement systems and show that attempts to reconcile two separate reimbursement systems or replace one system with another can lead either to a better health care or to the loss in the outcomes (e.g., Schuetz et al., 2011; Weissenberger et al., 2013; Mechanic and Altman, 2009). Several examples are shortly overviewed in

Chapter 4 of this work.

In Austria extramural care (personal health care) and intramural care (care in hospitals) have different payers and reimbursement systems. Hospital care is funded by regional health funds and its reimbursement mechanism is designed as a case-based payment system. However, in extramural care medical providers are either completely private or they have a contract with the public health insurance which covers most of the services. The majority of the insurances has a mixed-fee payment system based on a combination of fee-for-service payment and lump sums (Hofmarcher and Rack, 2006). Both these reimbursement schemes can also cause some specific problems which are inherent to the medical market. The fee-for-service payment model is often associated to the effect called 'creaming'. This concept describes an over-provision of medical services for patients who would be fully provided with fewer services. Lump-sum reimbursement can also cause a loss in the total outcome. Although the latter payment method encourages physicians to treat their patients more economically, it also may lead to possible refusal of necessary services. This is especially likely to happen in case of more costly patients ('skimping') (Ellis, 1998).

Considering the fact that demand for health care is determined based on the preferences of suppliers, rather than those of consumers, this work focuses on the fact that different payment systems also create a different range of the possible physicians' actions.

1.3 Characteristics of medical markets and principal-agent relationship

Medical markets (also known as health markets) have several attributes that distinguish them from other competitive markets. The most striking of these characteristics are the conception of health care as a commodity, demand for medical services, medical uncertainty, principal-agent relationship, information and knowledge asymmetry and physicians' market power (Bickerdyke et al., 2002).

Good health and vitality desired by patients are not commodities that could be directly acquired. A health market can provide only medical care which helps improve the health status. This care is heterogeneous and non-tradable: there are many different medical services and at least one part of them is accessible to everyone and free of charge (Reinhard, 1989). A specific type of medical care often cannot be substituted by other medical services or goods.

The demand for health care goods and services deviates from standard economic theory assumptions. In most 'real world' markets demand is rather predictable and consumers behave rationally. In medical markets the demand for some forms of medical care could be unpredictable and irregular (e.g., epidemics) (Bickerdyke et al., 2002). Damaged state of health also can lead to some irrational patient's decisions.

Medical markets suffer from a certain level of uncertainty. This is typical for both supply (providers) and demand (patients). Physicians, for instance, could have doubts with regards to the diagnosis or the best way to treat, especially when it comes to the patients with relatively complex medical conditions. Patients also face uncertainty about the right choice of treatment methods recommended by their providers (Bickerdyke et al., 2002).

In health care economics interaction between physician and patient is called 'principal-agent relationship' (see Figure 1.2). This relationship is based on physicians' dominance and patients' recognition that in most cases they are unable to make the appropriate decisions about their medical needs. Whereas health care is produced and consumed at the same time, patients have no choice but to trust physicians and expect them to practice medicine on their behalf. That means that the physician-patient relationship contains a large element of trust.

A main feature characterising the principal-agent relationship is information asymmetry (Zweifel et al., 2009, p. 295). Most people who are not satisfied with their health condition and contact the physician know only the fact that they probably need some medical care. Individuals may have some presumptions about the type of disease they have or the specialist they should go to but are never certain about their real situation. In other words, patients have incomplete information about their actual health status and required medical care. Furthermore, patients in most cases are also unable to figure out whether particular services are necessary or not and if another physician would have been more successful in the same situation.

Physicians are specialists who have more knowledge about diagnostic and treatment options than patients. They have information advantage which gives them a certain degree of power over the patients and public insurance. It is obvious that the existence of information asymmetry does not affect the efficiency of the health care system and the level of its costs as long as the physician acts as a perfect agent, taking decisions that the patient would have taken if he/she would have had the same knowledge as the physician. The situation when the physician chooses to take advantage of the 'information gap' and acts out of self-interest is one of the key questions discussed and modelled in the work.

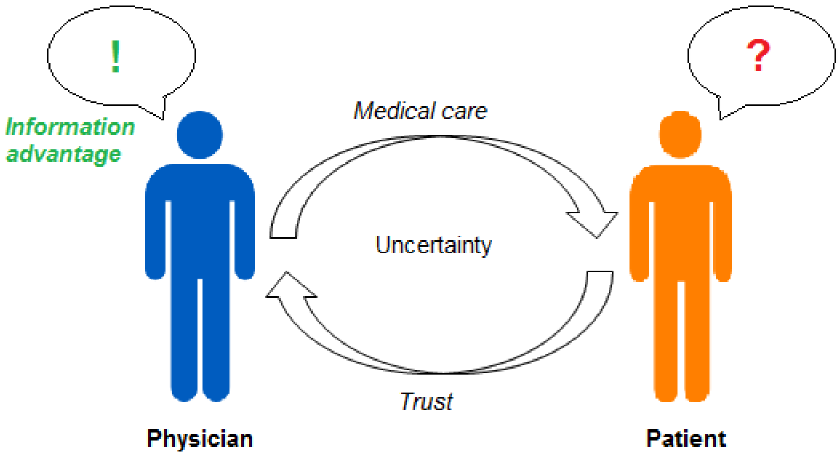


Figure 1.2: Relationship between a physician and his patient in the medical market

The physician provides medical care which is necessary to improve his/her patient's health status. He/she has an information advantage about his patient's true medical needs. The ill person in general knows only the fact that he/she has some health problem(s) and therefore must trust his/her physician. The physician-patient relationship also contains a certain degree of uncertainty.

Chapter 2

Theory of a Perfect Agency

The Hippocratic Oath obligates physicians to practice medicine honestly and on behalf of their patients (Lasagne, 1964). Although there is a lot of discussion on provider's behaviour and decision-making encouraged by financial or other personal motivations, various studies confirm that namely the patient's well-being has the greatest influence on a physician's practice patterns (see Section 2.1). This chapter takes a more detailed look at the medical provider who serves as the patient's agent. It reviews physician's responsibilities towards the patient which indicate the main factors influencing a provider's decisions and actions. The chapter aims to explain what lies behind the assumption of a perfect agency and to clarify the possible benefits of this agency for physicians.

2.1 Physicians' responsibilities toward the patient

A physician's role as the patient's agent manifests itself in six different forms (Eisenberg, 2002, p. 1019):

1. serving as the patient's clinical agent;
2. serving as the patient's economic agent;
3. responding to reasonable patient demand;
4. avoiding practice defence medicine;
5. considering the patient's medical and personal characteristics;
6. considering the patient's convenience.

A physician who accomplishes all these tasks acts on behalf of his/her patient. Such a medical provider is referred to as the patient's agent. The listed components could be considered as the physician's responsibilities toward the patient. They indicate the main factors which in diverse research studies are identified as influencing provider's behaviour and decision making when the physician is willing to act as the patient's agent (see Figure 2.1). For a better understanding of a physician's agency, these responsibilities will be discussed more exhaustively.

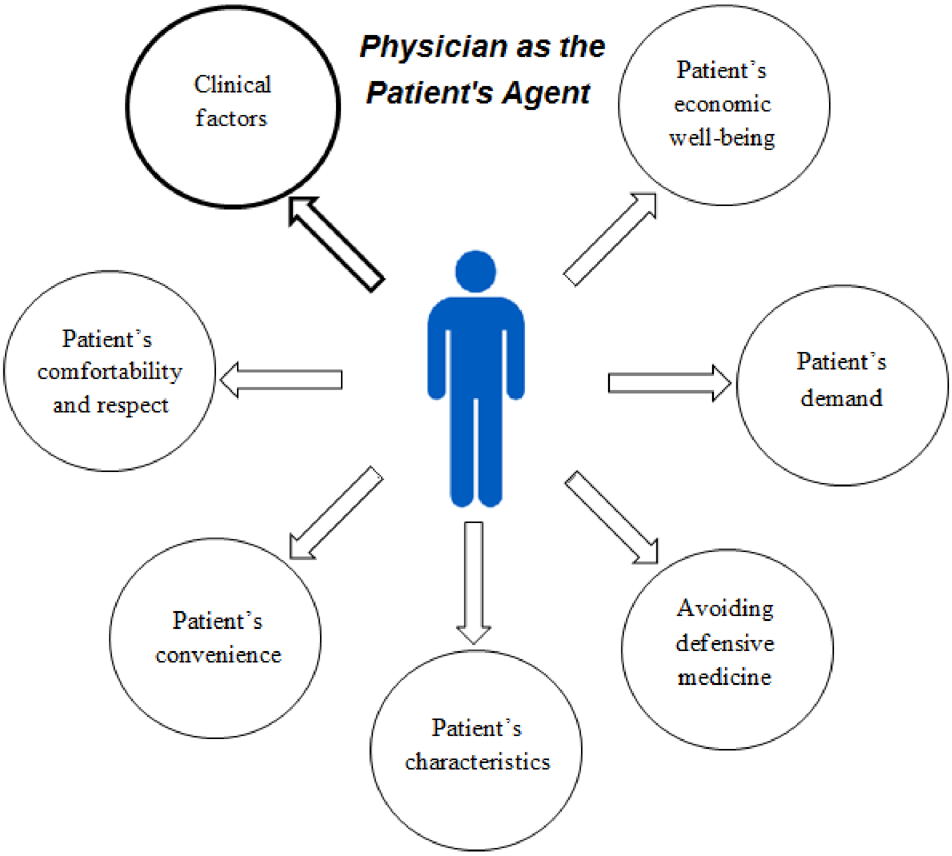


Figure 2.1: Physician serving as the Patient's Agent

The figure illustrates the main factors that influence a provider's behaviour and decision making when he/she acts on the patient's behalf. Most important are the clinical factors pointing out individual's health problems. A physician should also pay attention to the patient's economic well-being, demand and characteristics. A medical provider should demonstrate respect in all contacts with patients, ensure the patient's convenience and avoid practising defensive medicine.

2.1.1 Serving as the patient's clinical agent

The main purpose of medicine is to promote individuals' health. A practising physician seeks to deliver optimal care, i.e., to prevent, diagnose and treat medical problems effectively (Eisenberg, 2002). The quality provision of medical services for improvement of a patient's health outcomes is primarily linked to the professional ethics and morality. For instance, according to Principles of Medical Ethics adopted by the American Medical Association, "A physician shall be dedicated to providing competent medical care, with compassion and respect for human dignity and rights" (American Medical Association, 1957). On the other hand, the effectiveness of healthcare leads to the patient's satisfaction and thus could also be performed by a self-interested physician (see Section 2.3). However, irrespective of what the true physician's motivations are (i.e., ethical values, morality, professional dedication, personal interest or all these factors together), a provider who seeks to deliver optimal healthcare serves as the patient's clinical agent.

The provision of quality medical services depends not only on physician's intentions. Often a provider's efforts to help the patient are interfered with clinical ambiguity and uncertainty. The provider's doubts about the patient's diagnosis or the best treatment method induce the use of more diagnostic tests or force him/her to take decisions relying on their personal clinical experience and intuition (e.g., Hall, 2002; Hickner et al., 2014). Eisenberg (2002) draws attention to the fact that the access to better clinical information would not cause identical behaviour of physicians in similar situations. He states that even the best information provides only probabilities of the possibilities and does not eliminate the medical uncertainty of clinical decision making.

2.1.2 Serving as the patient's economic agent

The patient's agent is concerned about the ill person's financial situation and expenses for medical care that are not reimbursed by insurance. Even in countries with universal healthcare coverage (i.e., the health coverage that aims "to ensure that all people obtain the health services they need without suffering financial hardship when paying for them", (World Health Organisation, 2012)) the patient's out-of-pocket expenditures can still be relatively high (Organisation for Economic Co-operation and Development (OECD), 2013, p. 140-141). A patient may fail to follow the provider's orders because he/she can't afford the prescribed services (e.g., Essue et al., 2011). Several studies confirm that physicians acknowledge their responsibilities for a patient's out-of-pocket costs (e.g., Shrank et al., 2006). Moreover, the prices that patients must pay do seem to affect the number of ambulatory visits and the prescribing of medical services (e.g., Rossiter and Wilensky, 1983; Gonzalez Lopez-Valcarcel et al., 2011; Li and Laxminarayan, 2013). For example, Gonzalez Lopez-Valcarcel et al. 2011 investigated the sensitivity of the prescribing providers to the price afforded for the patient in the Spanish National Health

System. Results showed that patients receive cheaper medicines when they have to pay a 40% co-payment. Physicians' intentions to accomplish the provision of cost-effective services are nevertheless often restricted by the lack of knowledge about the patient's out-of-pocket costs (e.g., Alexander and Casalino, 2004).

2.1.3 Responding to reasonable patient demand

Another responsibility of a physician is to respond to patient's demands and allow him/her to participate in the decision-making process. Some individuals may require getting additional information about their health status (e.g., receiving medical services which are not necessary for their treatment) or have preferences for their mode of treatment, prescription of medical services and referrals (e.g., Little et al., 2004). However, shared patient-doctor decision making is a sensible subject in health economics. Individuals do not always understand their true situation and medical needs. They tend to overestimate small risks as well as underestimate large ones and thus challenge the provision of the optimal medical care (Say and Thomson, 2003, p. 1019). For example, some patients expect to receive antibiotics for cold symptoms, regardless of what the best way to treat their medical problem is. The other important issue is misuse and abuse of prescription drugs: individuals get addicted and try to press their provider to prescribe certain medicines (e.g., National Center on Addiction and Substance Abuse (CASA), 2005). Answering their demand keeps the patient satisfied with received services and communication. It shows the physician's care for the patient's interests and helps to build trust. If a physician refuses to fulfil certain requirements of the patient because of possible damage to the patient's health, better understanding about the patient's needs or other reasons, it could strain their relationship. However, a physician acting on behalf of the patient answers just reasonable demands.

2.1.4 Avoiding practice defence medicine

Physicians acting for their patients' interest avoid using defensive medicine. This practice occurs when providers deviate from optimal medical practice in order to minimize the possibility of malpractice liability (Adwok and Kearns, 2013, p. 29). Fear of malpractice affects physicians' behaviour and decision making in various ways by providing and recommending additional testing or treatment, referring patients to other providers and refusing to treat certain patients (Studdert et al., 2006). Defensive medicine could have grave consequences such as neglecting of high-risk patients, increase in health costs and decline in the quality of healthcare (Manner, 2007). It harms the relationship between physician and patient by fostering adversarial actions rather than collaboration.

2.1.5 Considering a patient's medical and personal characteristics

Various patient characteristics such as age, sex, ethnicity, income, social class or physical appearance have an impact on the decisions, behaviour and recommendations of a medical provider (Eisenberg, 2002). A physician should consider special needs and expectations of different types of patients (e.g., to recommend preventive health behaviour for overweight individuals, to be precisely respectful with older people, etc.). A patient's characteristics can significantly influence clinical decision making: for instance, an appropriate treatment for pregnant young women may strongly differ from the medical care delivered to an 80-year-old elderly lady having diabetes even if these two females suffer from the same medical problem.

2.1.6 Considering a patient's convenience

The approach that a physician serves as the patient's agent includes the provider's attention to the factors which ensure the convenience of the patient (Eisenberg, 2002, p. 1020). Regarding to his/her own availability, a physician should at least try to designate the best appointment date and time for the patient. When choosing the date, time and frequency of the follow-up visits, a 'good' medical provider also considers the time it takes for an individual to go to a physician, transportation costs, time he/she is missing from work, etc. There is a lot of literature and research on patient appointment scheduling and reducing waiting times in doctors' offices (e.g., Cayirli and Veral, 2003).

2.1.7 Treating patients with understanding and respect

It goes without saying that optimal results due to physician agency will be reached only if the patient understands the provider's good intentions and feels comfortable. Certain abilities of a physician such as professional courtesy and communication skills could affect the patient-physician relationship and health outcomes (e.g., Street et al., 2009). The provider should attempt to gain the patient's trust by openly supporting him/her and showing concern about the individual's health. Following these considerations, the list of a physician's responsibilities toward his/her patient should be supplemented with one more duty:

7. treating patients with understanding and respect

Each one of the discussed physician's responsibilities is important for a well-functioning physician-patient relationship. The next section emphasizes that a physician honestly acting as the patient's agent can be seen as a perfect agent.

2.2 Physicians' objectives and utility function under the Perfect Agency

Physicians and various medical organisations often represent themselves as advocates for the patient's care and well-being. For example, the American Medical Association (AMA) declares that physician's advocacy involves the responsible provision of medical care, the provision of important information to the patient, respect for the patient and the patient's decisions and individual's rights to confidentiality and continuity of healthcare (American Medical Association, 1992). Medical providers, who accomplish the introduced responsibilities towards the patient, fulfil this advocacy role. Since the patient seeks as well for his/her welfare and better health, the principle physician's aim is to help the patients to achieve their goals. A provider who besides the interest of his/her patient has some own goals but does not perform any direct actions to achieve these goals (e.g., seeks to increase his practice by providing quality healthcare and gaining good reputation in community) is still considered as the patient's agent.

Many medical goods and services, including prescription of drugs and hospital care, cannot be directly demanded by the patient (Pauly, 1980). The physician as the patient's agent is the one who requests for provision of the necessary healthcare to the individuals. A medical specialist who "would take on entirely the patient's point of view and act as if she were the patient" (Evans, 1984, p. 75) is regarded as 'perfect agent'. In other words, the physician acting as the perfect patient's agent requests and/or provides exactly those quantities and types of care that the patient would choose by himself/herself if he/she would possess the same information and knowledge as the physician. That means that under perfect agency the provider's and the patient's main goal (i.e., welfare of the patient) and utility functions correspond.

Standard agency theory starts from the assumption that physician and patient have inter-dependent utility functions and both are utility maximizing (e.g., Macdonald, 1984). In economics utility functions are used to describe consumers' preferences about consumption in different circumstances (Chakravarty, 2002, p. 199). Utility functions represent the level that a consumer can obtain from all possible consumption options. As interaction between physician and patient occurs via provision of health care and is initiated by the patient, an individual's utility in health goods and services is seen as the main component of corresponding utility functions.

The models for the physician-patient relationship (especially those for medical decision making) usually use the simplified version of the consumer's utility function presented by Grossman (1972). In these models a patient is a utility maximising decision maker which has a limited budget Y. A patient's money can be spent either on health H or on other goods C (e.g., food, clothing, cost of living, etc.). Thus a patient's utility function can be written as:

$$U^*_{pat} = U(H, C) \tag{2.1}$$

In contrast to other goods C, health cannot be purchased directly. For this reason in the models health is often described by a health production function $H = H(H_0, M)$ where H_0 is the initial health condition and M is medical care or services (see, e.g., Pauly,1980; Galama and Kapteyn, 2011). In accordance with the modelling aims, a patient's utility function and health production function can be extended by adding additional factors such as leisure time, treatment time, social relations, etc. to U_{pat} or environmental factors, genetics, occupation, education, etc. to H.

The 'classic' physician's utility function is the function of the form

$$U_{phys} = U(I_{phys}, U_{pat}) \tag{2.2}$$

Here I_{phys} represents the physician's net income and U_{pat} is the patient's utility (see e.g., Ellis and McGuire, 1986; Pauly, 1980). The provider's net income depends on the provided healthcare: $I_{phys}(M)$. A physician willing to act as a patient's agent would:

(PA1) consider the patient's total (rather than only health-related) utility: $U_{pat} = U^*_{pat}$;

(PA2) value one Euro of the patient's benefit equal to one Euro of his income.

Health economists argue whether or not a perfect agent maximizes the total patient's utility U_{pat}. For example, Felder et al. (2014) assume that the only relevant argument of a physician's utility function under perfect agency is health, i.e. $U_{pat} = U(H)$. Most economists refer to a broader concept (e.g., Evans, 1984; Pauly, 1980). They reason that the physician as the patient's agent should consider also non-medical factors. When taking into account other components of the patient's utility function U^*_{pat} (e.g., goods C that a patient wants to consume, time which a patient can spend for activities other than those related with healthcare, etc.), the provider cares for other preferences of an individual and besides delivering quality healthcare also fulfils other responsibilities. If, however, a provider values his/her income more than the patient's benefit, he/she prefers the patient's utility from health H rather than utility from other factors. Since the physician is responsible for maximization of a patient's utility function, his/her biased preferences would impede achieving optimal outcomes for the patient. Consequentially, the income component in the physician's utility function U_{phys} could be ignored. Therefore, under assumption that a physician behaves as the perfect agent and considers the total patient's utility, the physician's and the patient's utility functions correspond:

$$U_{phys} = U(I_{phys}(M), U_{pat}) = U(I_{phys}(M), U^*_{pat}) = U^*_{pat} \tag{2.3}$$

These considerations are illustrated by the constrained optimization problem introduced by Pauly (1980, p. 8). He investigated the following maximization problem:

$$\begin{aligned} \max \quad & U^*_{pat} = U(H, C) \\ \text{s.t.} \quad & (1) \quad H = H_0 + g(M; H_0) \\ & (2) \quad Y = C + P \cdot M \end{aligned} \tag{2.4}$$

This model assumes that a patient seeks to maximize the utility function U_{pat} in health H and other goods C subject to production function constraint (1) and income constraint (2). The goods C can be directly purchased at some price. Here H_0 is the initial endowment of health and $g(M; H_0)$ is a function measuring improvement of health through medical care. The components of vector $M = (M_1, M_2, \cdots, M_n)$ represent different medical services that a physician chooses to provide to the patient. The prices for medical services M are respectively given by vector $P = (P_1, P_2, \cdots, P_n)$. The income constraint (2) indicates that the patient spends the entire income on other goods C and healthcare $M \cdot P$.

A physician as the patient's agent is expected to solve the optimization problem (2.4), i.e., to choose a vector of medical services M^* which maximizes the patient's utility in health goods H under minimal costs and thus also maximizes the rest of patient's budget spent on C. Optimisation theory suggests that the perfect patient's agent would choose M^* which satisfies two conditions:

(O1) Whatever level of health H is produced, production costs are minimized:

$$\frac{\partial H/\partial M_1}{P_1} = \frac{\partial H/\partial M_2}{P_2} = \cdots = \frac{\partial H/\partial M_n}{P_n} = \frac{1}{\Pi}$$

Where Π is the shadow price (i.e., the maximum price that a patient is willing to pay) of an increment in health.

(O2) There are no preferences between the utility from health H and the utility from other goods C:

$$\frac{U_H}{U_C} = \Pi$$

The fact that the physician is maximizing the patient's utility function U^*_{pat} rather than U_{phys} as well as condition (O1) guarantees that the provider acts as the perfect agent. For more detailed explanation of this model see Pauly (1980).

There are several reasons to expect that the physician-patient relationship will not be perfect (see Chapter 4). This approach though is helpful for modelling the physician behaviour and investigating the deviation of physician actions from the perfect scenario.

2.3 Benefits from the Perfect Agency

The patient-physician relationship based on the perfect agency is advantageous not only for individuals seeking for medical help. For example, acting as patient's economic agent under the system where patients are not completely reimbursed by insurance could have a beneficial effect also on physicians: individuals' money saved by using less expensive but still effective goods or services can be used to pay physicians' fees (Eisenberg, 2002).

From a physician's point of view the most important beneficial consequences obtained from the perfect agency are the following:

- increase in professional satisfaction;
- sustainment of self-respect and loyalty to medical profession;
- reduced malpractice claims;
- patients' satisfaction and loyalty;
- good reputation among the community and possibility to expand the practice;

- respect from other specialists and better career prospective.

As will be discussed further, the last two characteristics can cause an increase in a physician's income and thus are important for the modelling of income-oriented behaviour of a physician. A medical provider's professional satisfaction may affect the physician's practice pattern and quality of care (e.g., Grol et al., 1985; Linn et al., 1985). Furthermore, the patients of physicians who have higher professional satisfaction may themselves be more satisfied with received care (e.g., Haas et al., 2000). A survey conducted in the U.S. showed that physicians' perceptions about quality of care as well as the potential to improve some aspects of patient care are the two most important determinants of providers' professional satisfaction (Friedberg et al., 2013). The other factors such as work quantity and pace, income stability and fairness and greater autonomy play only a secondary role. Thus, when acting as the patient's agent and providing quality care, a physician increases his/her professional satisfaction.

The perfect agency rests on the ethical principles and moral standards assigned to the medical profession. Conscientious delivery of quality medical services is the essential idea codified in the Hippocratic Oath. A physician acting for the patient's benefit retains good conscience, self-respect, respect for his/her profession as well as loyalty to the patient.

The fulfilment of the physician's responsibilities toward the patient very likely induces the patient's satisfaction. The latter is a commonly used indicator to measure quality in healthcare. A system where the patients are satisfied with received medical services and attention to their health could be described as a well-functioning health system. Aside of this positive effect on the health system as a whole, physicians have some professional and personal motives to keep patients satisfied.

Satisfied patients are more likely to follow prescribed treatment plans and realize subsequent benefits relating to health outcomes (e.g., O'Brien et al., 1992). It facilitates the timely and efficient provision of quality healthcare and reduces the risk of malpractice suits (i.e., Poulas et al., 2008). Patient satisfaction also reflects how well patients do: there is a relation between patient outcomes and the patient satisfaction level. Several researches confirm the correlation between higher patient satisfaction and improvements in outcomes such as lower blood sugar, fewer complications in surgical patients and lower mortality (e.g., Kaplan et al., 1989; Kane et al., 1997; Glickman et al., 2010). Nevertheless, satisfied patients may not receive satisfactory care. A recent study of Archives of Internal Medicine revealed some controversial results: a higher patient satisfaction could be also associated with higher healthcare expenses and mortality (Fenton et al., 2012). The work expressed the suspicion that physicians may agree to patients' requests for services in order to increase their satisfaction.

Since the physician serving as the patient's agent answers just reasonable demands, the perfect agency and delivery of quality care not necessarily causes the patient's satisfaction. Patient satisfaction has the roots in consumer marketing and is a measure of how services and products from the supply side meet or exceed the expectations of the consumer (Kupfer and Bond, 2012, p. 139). Not responding to certain consumer's requests (e.g., by refusing to prescribe specific drugs, ignoring a patient's fear of pain by choosing the best treatment method, etc.) or lacking the communication skills and thus not meeting a patient's expectations could cause the patient's dissatisfaction and the decision to end his/her relationship with the medical provider (i.e., Afkhamebrahimi and Nasr Esfehani, 2013). However, if the patient understands the good intentions of his medical provider (i.e., trusts the physician) and has only reasonable demands, the perfect physician's agency and improved health leads to the patient's satisfaction, loyalty and retention (i.e., Wendy and Scott, 1994).

Patient satisfaction has a big impact on a physician's reputation and even income (e.g., Hall, 2008). A physician who provides quality services is very likely recommended by his/her patients to their family and friends. Such medical provider becomes known as a 'good specialist'. The gained good image and reputation among the community as well as respect from other medical specialists helps to build physician's practices (and, consequently, to increase the income) and could open up new career opportunities. That means that even an income-oriented physician may choose perfect agency as the instrument to increase his/her income.

All described physician's benefits from the perfect agency are illustrated in Figure 2.2.

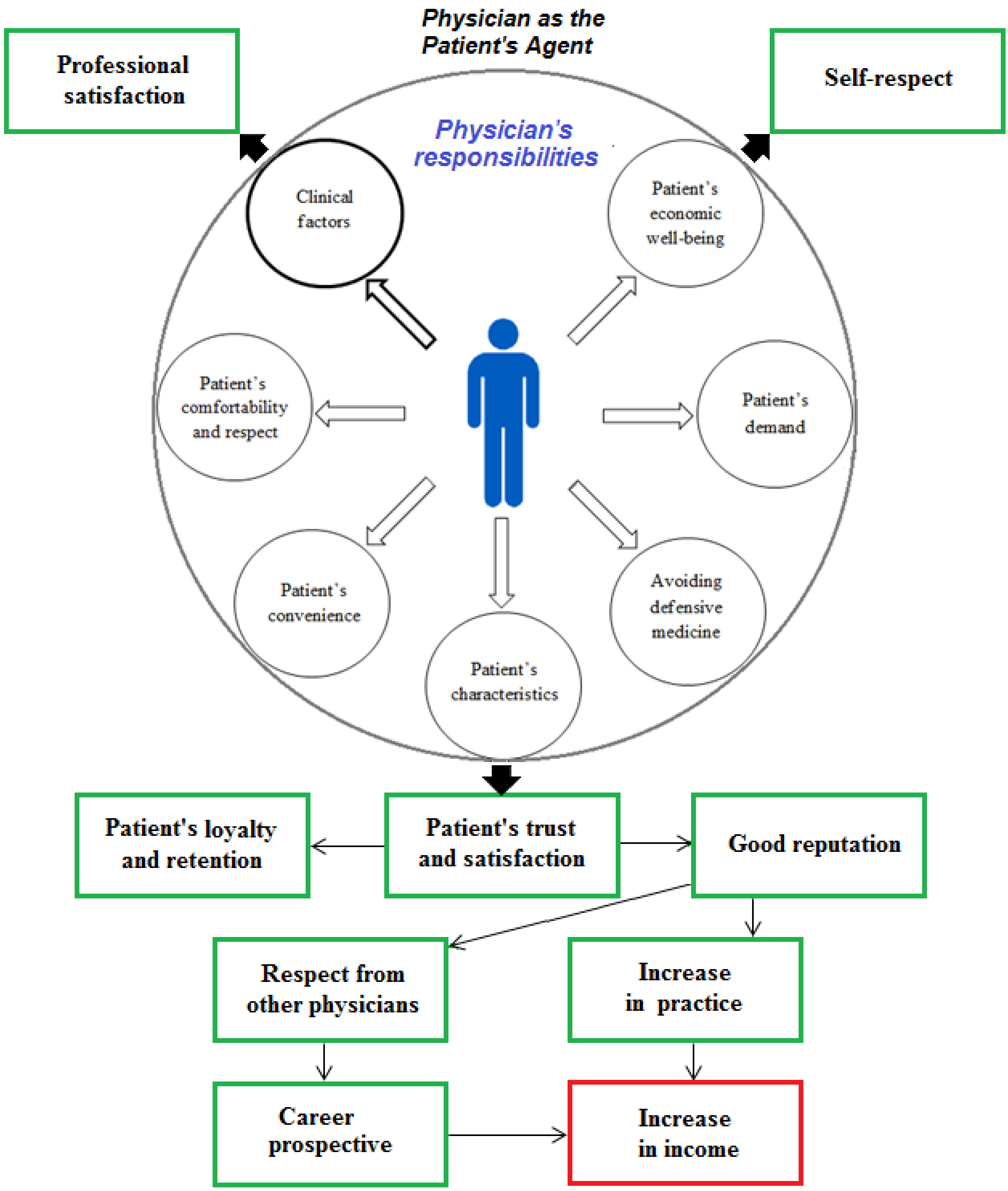


Figure 2.2: Physician's benefits achieved from the Perfect Agency

A medical provider acting as the (perfect) patient's agent increases professional satisfaction and retains self-respect. Usually patient-centred provider's actions help to gain the patient's trust and satisfaction. Satisfied patients have no motives to change their physician and could possibly recommend his/her provider to other individuals. Therefore a physician's good reputation attracts new patients and improves his/her image among other medical specialists. An increase in the physician's income is the possible result of the discussed scenario. In health systems where patients are direct or indirect (i.e. taxes) payers, a physician serving as a patient's economic agent also protects the patient's ability to pay the provider's fees.

2.4 Conclusion

A physician serving as the patient's agent must do much more than deliver quality medical services. Individuals expect the treating specialist to pay attention to their out-of-pocket costs, answer to their demands and ensure their convenience. Patients also wants to receive the optimal medical care and do not tolerate physician's malpractice. When making decisions, a physician must consider the clinical factors, personal opinion and experience as well as the characteristics, preferences and expectations of the patient while dealing with a certain degree of medical uncertainty. It can thus be concluded that a medical provider's behaviour decision making is a complex process influenced by physician's and patient's characteristics and preferences.

The perfect agency describes a physician's behaviour when his/her choices duplicate the choices the patient would make if the patient had the same knowledge and information as the physician. This approach is the main assumption of the model developed in the next chapter. The model presents the health system where each medical provider is assumed to fulfil his responsibilities toward the patients and maximize patients' utility functions. The perfect agency in this work will be used to measure the impact on economic outcomes caused by actions of an income-oriented physician.

This chapter revealed that the medical provider benefits from the (perfect) agency. The physician's benefits include: increase in professional satisfaction, strengthening of self-respect and reduced malpractice claims. It is highly probable that the physician's behaviour will be 'recompensed' by the patient's loyalty and retention, the gained respect from other physicians, better career opportunities, improved practice volume related to gained good reputation in the community and even increase in income.

Chapter 3

Simulation of the Model with Perfect Agency

This chapter presents a discrete time agent-based simulation model for the extramural sector of a health care system. Limited to uncomplicated and curable theoretical diseases, the model depicts a perfect agency relationship between physicians and patients. That means that a physician always acts on the patient's best interests and does not attempt to affect the demand in medical services. Based on the existing system in Austria, it is assumed that the cost of treatment is completely covered by the public insurance system and thus does not affect individuals' behaviour and decision making. Model outcomes are evaluated in case-based and fee-for-service reimbursement systems. The modelled health care system will be used as a framework for the simulation of different physicians' behaviour scenarios which is submitted in Chapter 5.

3.1 Model structure

Agent-based simulation is a relatively new analytical method mainly used in the social sciences, engineering and mathematics. This technique has become increasingly popular as a modelling approach. It provides a facility to design the complex systems where individual entities (so-called 'agents') and their interactions with one another and the environment are explicitly represented (Nigel, 2008). Agent-based simulation enables implementation of individual heterogeneity into a model by assigning individuals different attributes, setting various decision rules and putting agents in a geographical or some other environment. It also allows 'to see into the future' and thus anticipate the likely effects of various changes on the system as a whole. For these reasons, agent-based simulation method was chosen for implementation of the model introduced below.

The Model with a Perfect Agency depicts an extramural health care sector, specifically outpatient care from medical providers having a contract with public health insurance. There are two types of operating agents: medical providers and ordinary individuals. All together they represent a total population of the size n. All agents have a fixed place in the two-dimensional space. It could be considered as physicians' private medical offices and working or living places of ordinary individuals. The position of this fixed place for each agent is uniquely described by ordered pair (x, y) where x is the x-coordinate and y is the y-coordinate of the agent. In order to consistently follow the simulation process, agents are assigned to unique IDs (i.e., for medical providers and ordinary individuals separately labelled positive integers 1, 2, 3, etc.). They also have other diverse attributes that allows these individual entities to be distinguished.

Medical provider agents exemplify physicians who have a certain speciality. A health care system presented in the model contains p physicians and this number remains constant during the simulation run. A set of all physicians is given by $\mathbf{P} = \{\mathbf{P_1}, \ldots, \mathbf{P_p}\}$. Each element P_i, $i \in \{1, \ldots, p\}$ has a unique ID $P\_ID_i = i$ and is unambiguously reflected by one agent with certain attributes. Along with his coordinates $Pcoord_i = (x_{pi}, y_{pi})$, medical speciality $Pcg_i \in \{1, \ldots, c\}$, a constant number of patient visits supplied per working day *Pcapacity* and a constant cost per patient visit *Cvisit*, each medical provider also has two sets of attributes: a set of all medical problems he can treat $\mathbf{Pi\_D} = \{D_{ij} \mid j = 1, \ldots, d\}$ (i.e., diseases and disorders that are directly related with his speciality Pcg_i) and a set of all current patients $\mathbf{Pi\_M2} = \{\mathbf{M_{il}} \mid \mathbf{l} \in \mathbf{M2}\}$. As will be shown later, the individuals can get ill in every simulation step and therefore the cardinality of $\mathbf{Pi\_M2}$ is variable. Parameter values of $PCapacity$ and $Cvisit$ are chosen the same for all physicians and medical diseases. All information related to every single treatment and its cost is reported to the reimbursement system.

In this health care system all persons except of the medical providers are referred to as ordinary individuals. With respect to physicians, they constitute the target population. In every time step a single ordinary individual agent has one of two possible states: he is either healthy or ill. A healthy agent is also seen as a potential patient agent. It is an individual which currently has no health problems. The state 'ill' is ascribed to the patient agent, i.e., a person with a certain disease or disorder who gets help from medical provider.

All ordinary individuals are listed in the set $\mathbf{M} = \{\mathbf{M_1}, \ldots, \mathbf{M_m}\}$. This set has a fixed size of m and consists of $m1$ potential patients and $m2$ patients. Due to constant changes in the agent's health state, the numbers $m1$ and $m2$ as well as the cardinalities of the corresponding subsets of **M** may vary with each simulation step. For this reason, in the description of this model patients and potential patients are distinguished with the help of index sets **M1** and **M2** which collects respective indexes $l \in \{1, \ldots, m\}$ also known as unique M_IDs. The location of an ordinary individual M_l, $l \in \{1, \ldots, m\}$ in the two-dimensional model environment is defined by parameter $Mcoord_l = (x_{ml}, y_{ml})$.

With every change in the person's health status there are corresponding changes in his characteristics. The primary attributes of healthy individuals M_l, $l \in \mathbf{M1}$ are constant critical probabilities u_{lj} and variable deciding random numbers w_{lj}. These values predetermine the process of getting a certain medical problem D_j, $j \in \{1, \ldots, d\}$. After becoming a patient along with the new health status, the information about a treating physician and the main features of his medical problem and several help variables are also attached to the agent. The modelling of getting ill and the subsequent treatment is further explained in the Subsection 2.2.2.

A set $\mathbf{D} = \{\mathbf{D_1}, \ldots, \mathbf{D_d}\}$ of all medical problems is a particularly important component of this model. The elements of the set represent different diseases and disorders. All medical problems are assigned to a positive integer j between 1 and d which is seen as their unique $D\_ID_j = j$. Diseases and disorders are categorised into some theoretical groups, i.e. each D_j has a medical category $Dcg_j \in \{1, \ldots, c\}$, $c \leq d$. These groups $\mathbf{D\_cg_1}, \ldots, \mathbf{D\_cg_c}$ are separate and consist of at least one element. All diseases and disorders which belong to the same group $k \in \{1, 2, \ldots, c\}$ and thus satisfy $Dcg_j = k$ are related and can by handled by any medical provider having speciality $Pcg_i = k$. Therefore, these attributes are an essential link bounding medical providers and physicians. At the same time this parameter indicates the index set $\mathbf{P\_Dj}$ of all medical specialists who are qualified to treat D_j, $j \in \{1, \ldots, d\}$. As will be shown later, the patient selects from this set his treating physician MP_l.

Each medical problem D_j, $j \in \{1, \ldots, d\}$ has the following attributes related to the treatment cost: an average number of all necessary patient visits av_j, an average cost for all medical services provided during the treatment $aCms_j$, a fixed fee for this medical problem $CFix_j$ and a number of the days between two patient visits $days_j$. In each particular medical case (i.e., when a potential patient M_l, $l \in \mathbf{M1}$ gets a certain disease or disorder D_j, $j \in \{1, \ldots, d\}$ and thus the parameters D_ID_j, Dcg_j are also assigned to M_l as D_ID_j and Dcg_{lj}), occurs the determination of patient's M_l, $l \in \mathbf{M2}$ main attributes $CFix_j$, $days_j$, v_{lj} and Cms_{lj} where the last two variables are understood as a number of necessary visits caused by D_j and a cost for all medical services provided during the treatment of D_j. The values of v_{lj} and Cms_{lj} are obtained from random

Reimbursement method	**Type of reimbursement method**	**Cost determination for a single treatment of the medical problem D_j**
Cost-based payment	Prospective	$Cost_j = CFix_j$
Fee-for-service payment	Retrospective	$Cost_{lj} = Cms_{lj} + Cvisit \cdot v_{lj}$

Table 3.1: Differences between a case-based and a fee-for-service payment systems for a single medical case

In CB reimbursement the cost is equal to a fix predetermined fee $CFix_j$ while in FFS payment system it is calculated as the sum of the costs for all medical services provided during the treatment Cms_{lj} and the costs for all patient visits caused by D_j $Cvisit \cdot v_{lj}$. The indices used in the given formulas indicate that contrary to CB method where the cost is equal for all patients with the same medical problem, the cost based on FFS payment system depends also on a concrete patient M_l.

generation of respectively Poisson and Gamma distributed numbers with means av_j and $aCms_j$ while the parameters $CFix_j$ and v_{lj} are taken over together with a disease D_j. These attributes related to the treatment cost are necessary for the evaluation of the health care expenditures.

The outcomes of the Perfect Agency Model are calculated in two different reimbursement systems. For this purpose chosen case-based (CB) and fee-for-service (FFS) payment systems are considered as good examples representing prospective and retrospective reimbursement methods. In CB payment system the cost of the single patient's treatment purely depends on his medical problem and is equal to a fixed predetermined fee. FFS method charges every patient visit to a physician and all medical services provided during the treatment. The differences between these reimbursement systems are clearly visible in the cost determination for a single treatment (see Table 3.1).

In order to better envisage this model and understand relations between its separate segments, the structure is schematically pictured in the Figure 3.1.

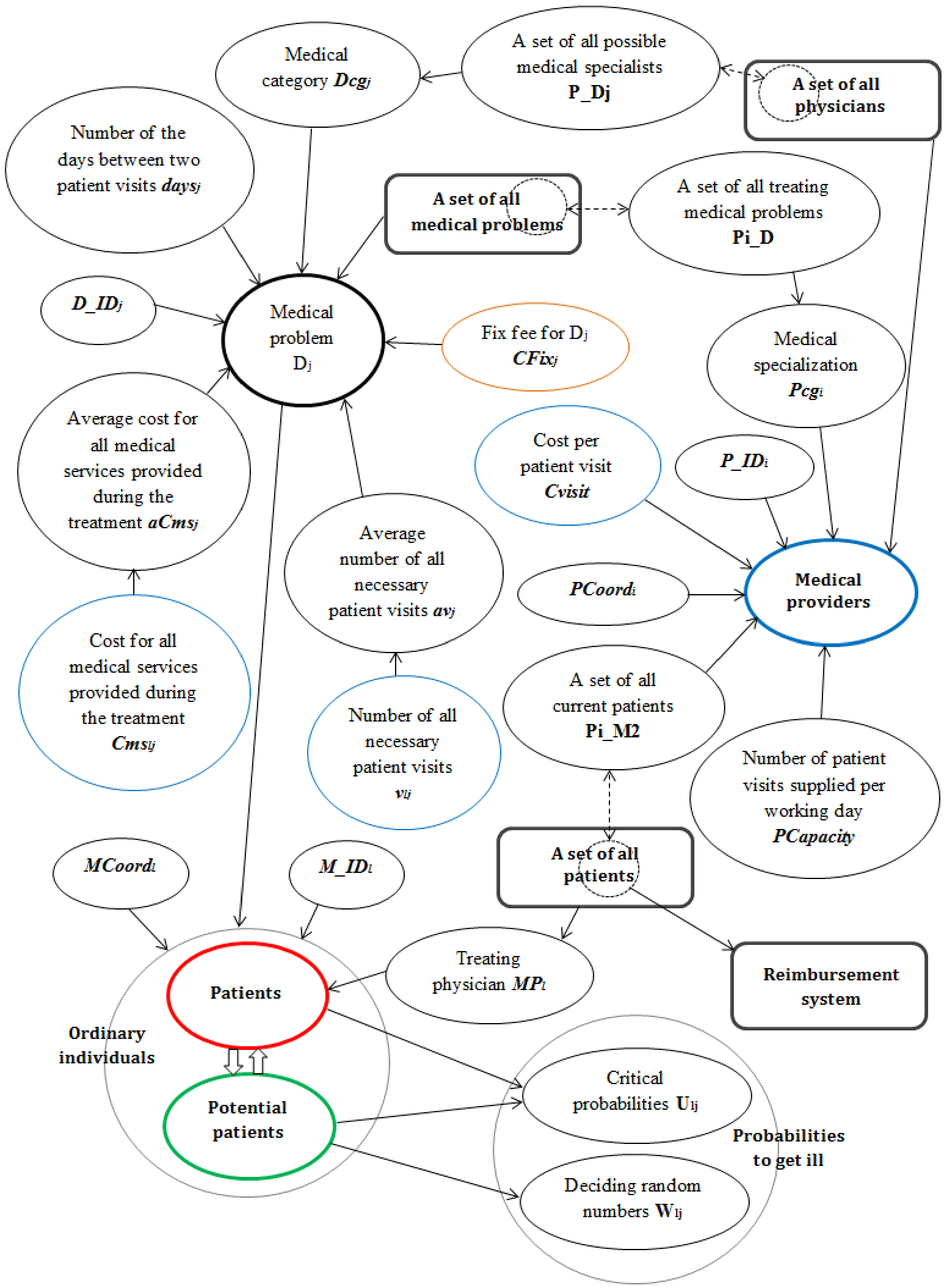


Figure 3.1: The structure of the Model with a Perfect Agency

This figure depicts all agents, their main attributes, relations and other model components. Medical providers and ordinary individuals have variables and parameters which play the main role with regard to their actions and interactions. The diagram also reflects that physicians and patients are 'connected' via a certain medical problem. The attributes displayed as brown and blue outlined ellipses are important for CB and FFS based cost evaluation.

3.2 Model assumptions and rules

3.2.1 Main assumptions and limitations

'Real world' health systems usually are characterized by great complexity. Simulation models in health care almost always are simplifications of these systems obtained by making implicit and explicit assumptions on their components. It is also evident that health care models often are not able to reflect a whole health system and thus are limited to some certain sector and disease groups. The main assumptions and limitations of the Model with a Perfect Agency are extensively discussed and explained in the following paragraphs. They are summarised and listed in Table 3.3, which is submitted in the end of the subsection. This compact overview will be particularly useful in Chapter 5.

Before the realisation of a certain model idea, some fundamental choices have to be made. One of these is the question of discrete versus continuous time modelling. Although in context of the health care modelling continuous time framework is more realistic, discrete-time approach makes it easier to follow the significant changes in variables. Moreover, data are released at discrete intervals. Therefore, the model with Perfect Agency uses a finite discrete time set. That simply means that all values of variables occur at distinct, separate points in time $t_0, t_1, \ldots, t_{max}$.

In this model each discrete time step depicts a casual working day. It is presumed that physicians are not working at weekends and holidays. Instead of a straightforward representation as time steps without any agent actions and interactions, these days are completely excluded from the time scale. Such an unusual timeline is chosen in order to avoid possible misinterpretation of results in the further simulation of physicians' behaviour (see section 2.3). Starting from a specific date, which is selected as a beginning of the simulation, all working days are thoroughly counted and subdivided in the quarters of the year $Q1$, $Q2$, $Q3$, $Q4$.

Presented model rests on several assumptions and limitations on the target population, physicians, set of considered diseases, public insurance system and existing reimbursement methods. Firstly, it should be noted that this model deals only with theoretical non-severe, nonfatal, non-chronic and relatively quickly curable diseases or disorders. Examples for it could be a common cold, a flu without any complications, not harmful infections, allergy, etc. Considered diseases are not contagious (i.e., are not passed from person to person). There are no complications, urgent or death cases caused by inappropriate treatment or self-neglect from the patient's side. That implies that a patient always recovers. The medical symptoms of diseases are not mutual (e.g., suffer from a headache could be related to various diseases). They refer directly to a concrete medical problem and thus to the set of physicians who focus on the corresponding specific medical field.

With regard to population dynamics it is assumed that the size of the total and target populations as well as the number of physicians does not change. The number of all individuals in the population being constant over time indicates that there are no births, deaths or migration. For reasons of simplicity, there is also no migration between physicians and patients. A possibility for a certain physician to get ill and become one of the patients, would lead to an appointment cancellation and thus forces his patients to wait or look for other available physicians. Such scenario would unnecessarily complicate the model and cause haziness in interpretation of model results. The model also does not take into account individual's sex, age and medical history that could have an impact on the way and duration of the treatment.

Patients are considered to be intelligent: by experienced health problems they are able to choose an appropriate medical specialist. A person can get the same disease several times. Since in this simplified health system all health care expenditures are fully borne by public health insurance, the individual's financial situation has no influence on his behaviour and choices in offered medical services. Patients also have no personal preferences (e.g., a recommendation from friends, a physician located next to the former residence, etc.) for the treating physician.

Patients take care of their health when it comes to contacting the physician immediately after feeling sick, acceptance of the first offered appointment time and following the doctor's instructions associated with the use of prescribed drugs and the treatment. Rarely occurring cases where some patients try to get some benefits which are not directly related to their medical problem (e.g., by pressing the physician to prescript a certain drug, etc.) are excluded from the model. In other words, in this health system patients behave perfectly.

Physicians are given as specialists of a certain not particularly complex medical field. For example, this could be applied to otolaryngologists or dermatologists. The medical decisions and physicians' actions are always correct; there are no mistaken diagnoses or wrong treatment choices that could lead to extension of treatment time. Health providers do not try to exploit the lacks of existing reimbursement systems to achieve the additional financial benefit. Therefore, physicians can also be seen as the perfect agents for their patients.

Modelling of health care systems requires clearly setting the objectives for all interacting agents. Since the represents the 'ideal' behaviour of both medical providers and patients, it should also be reflected in the agents' main goals (see Table 3.2). In this simplified health care system, the physicians attempt to provide qualified medical services in order to improve their patients' well-being and thus welfare of the considered society as a whole. On the supply side, each ill person concentrates just on one single aim: to become healthy as soon as possible. As will be exhaustively explained in Chapter 4, the main goals of the interacting agents have a big influence on the modelling of their decision making, behaviour and therefore on the simulation run and expected model outcomes.

Agent	**Objective**
Medical provider	To improve the patients' and social well-being
Patient	To become healthy as soon as possible

Table 3.2: The agent's objectives

Physicians and ill persons are interested in the patient's well-being and have no intentions to get some additional personal benefit. The agent's actions encouraged by these main goals have a positive influence on the well-being of the entire society.

Since each medical provider $P_i, i \in \{1, \ldots, p\}$ has a certain medical speciality $P\_cg_i \in \{1, \ldots, c\}$, a set $\mathbf{P}$ can be expressed as the union of non-overlapping subsets $\mathbf{P\_cg_1} \ldots, \mathbf{P\_cg_c}$. Every $\mathbf{P\_cg_k}$, $k \in \{1, \ldots, c\}$ consists of all physicians having a medical speciality Pcg_i $= k$. The same applies to the set all medical problems $\mathbf{D}$ and the categories Dcg_j of D_j, $j \in \{1, \ldots, d\}$. Therefore, every subgroup $\mathbf{P\_cg_k}$ of the co-domain $\mathbf{P}$ is mapped to by exactly one $\mathbf{D\_cg_k}$ of the domain $\mathbf{D}$ for some fix $k \in \{1, \ldots, c\}$ (see Figure 3.2). Such one-to-one correspondence in mathematics is called bijection. As regards to the elements of $\mathbf{P\_cg_k} \subseteq \mathbf{P}$ and $\mathbf{D\_cg_k} \subseteq \mathbf{D}$, each P_i with $P\_cg_i = k$ is qualified to handle all D_j with $D\_cg_j = k$. The model also assumes that a single ill person can have just one disease at once. This restriction helps to prevent a possible coincidence of two or more appointments on the same day.

Each medical provider $P_i, i \in \{1, \ldots, p\}$ can treat a fixed maximum number *PCapacity* of patients per working day. This number is the same for all physicians and does not vary during the simulation. Most likely more than one individual (i.e., 'new' ill persons and the patients who already are in the treatment) is visiting a concrete physician on the certain day $t \in \{0, \ldots, t_{max}\}$. All patients who come to the same physician are ranked in one line. In some cases it may raise a waiting queue problem, which in this model is organised by the FIFO ('First-In-First-Out') algorithm. This method simply queues processes in the order that they arrive in the ready queue. Although the FIFO way of organising access to a limited resource or service is often called as 'the most fair', in context of health care system models it excludes the priority of the urgent medical cases

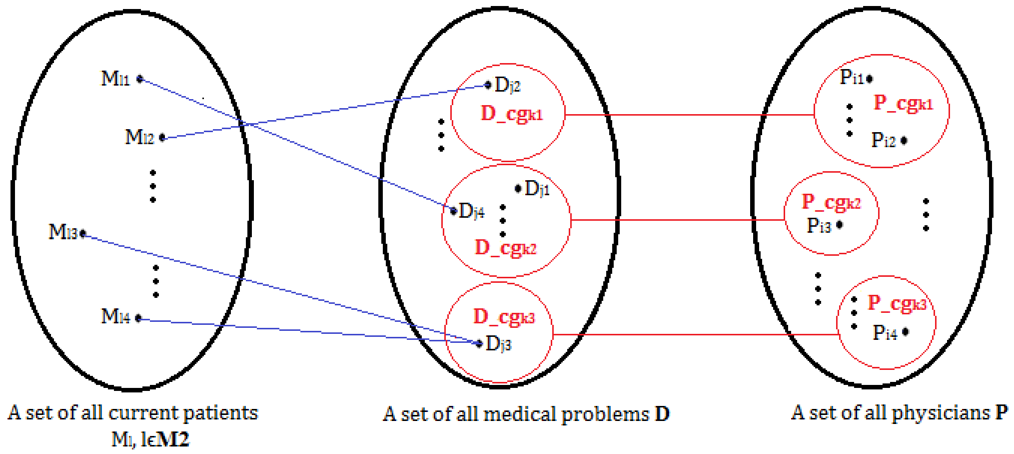


Figure 3.2: Relations between the sets **M**, **D** and **P**

At some time step $t_m, m \in \{0, \ldots, t_{max}\}$ each ill person M_l, $l \in \mathbf{M2}$ has exactly one assigned medical problem D_j, $j \in \{1, \ldots, d\}$. The correspondence between the subsets $\mathbf{D\_cgk_1}, \mathbf{D\_cgk_2}, \mathbf{D\_cgk_3} \subseteq \mathbf{D}$ and $\mathbf{P\_cgk_1}, \mathbf{P\_cgk_2}, \mathbf{P\_cgk_3} \subseteq \mathbf{P}$ illustrates the fact that all diseases and disorders and all medical providers are 'connected' via the categories of D_j and physicians' medical specialities.

(see A17 in the Table 3.3). The patients who have higher as the value of *PCapacity* position on the waiting queue are transferred to the next day. At the time step $t_{(m+1)}$ they are served first.

The length of the treatment depends for the most part on the type of the patient's medical problem. However, for several patients with the same medical problem the time spent being ill may slightly differ. This can be seen in the following formula which calculates the expected duration of the treatment required for a patient M_l, $l \in \mathbf{M2}$ suffering from a certain disease or disorder $D_j, j \in \{1, \ldots, d\}$:

$$T_{explj} = 1 + days_j \cdot (v_{lj} - 1) \tag{3.1}$$

(Expected duration of the treatment)

Patients visit their treating physicians at the regular intervals of the length $days_j$. This parameter has the same value for all patients undergoing the treatment for D_j and remains constant during the simulation run. The model also assumes that at the beginning of the treatment a physician is able to predetermine how many visits a patient M_l, $l \in \mathbf{M2}$ needs until his medical problem D_j, $j \in \{1, \ldots, d\}$ will be completely cured. As already mentioned in the previous section, the variable number of necessary visits v_{lj} for each single patient M_l, $l \in \mathbf{M2}$ is obtained by random generation of Poisson distributed numbers with the mean av_j. Such selection of v_{lj} leads to the possible differences in T_{explj} between all ordinary individuals who are or were suffering from the same medical problem.

This assumption is in line with reality where the effectiveness of the treatment and the recovery time depends on various factors. In the perfect scenario T_{explj} corresponds to the actual duration of the treatment T_{lj} for some fixed l and j. In some rare cases, when the patient's appointment is moved to the next day, the regularity of visits is disturbed and T_{lj} exceeds T_{explj} (see Figure 3.3).

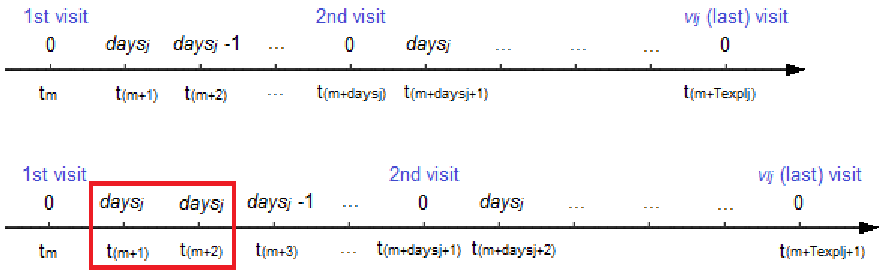


Figure 3.3: Representation of the treatment process

A timeline given above illustrates a 'perfect scenario' treatment for a patient M_l, $l \in \mathbf{M2}$ who at the time step $t_m, m \in \{0, \ldots, t_{max}\}$ became a certain medical problem D_j, $j \in \{1, \ldots, d\}$. The patient visits his physician at regular intervals of length $days_j$ and after v_{lj} visits, becomes healthy. Since his appointments are never rescheduled, the expected and the actual duration of the treatment coincides ($T_{explj} = T_{lj}$). The other timeline depicts one of the possible situations when in the time step $t_{(m+1)}$ a physician postpones patient's visit to the next day. It leads to a longer than expected treatment time ($T_{explj} < T_{lj} = T_{explj} + 1$).

In order to maintain the equity in this model, both reimbursement systems should bring the same or similar outcomes. This is achieved by setting the cost under the FFS reimbursement method equal to the cost of CB reimbursement for each medical case. On the basis of Table 3.1 submitted cost evaluation formulas, it simply means the satisfaction of the following cost condition:

$$CFixj = \mathbb{E}(Cms_{lj}) + \mathbb{E}(v_{lj}) \cdot Cvisit$$

Since Cms_{lj} and v_{lj} follow the given probability distributions and therefore are randomly generated for each single patient M_l, $l \in \mathbf{M2}$ with a certain D_j, $j \in \{1, \ldots, d\}$, this equality is moderated to:

$$CFix_j \approx \mathbb{E}(Cms_{lj}) + \mathbb{E}(v_{lj}) \cdot Cvisit \tag{3.2}$$

(Cost condition)

The determination of the health cost for each quarter of the year $Q1, Q2, Q3, Q4$ occurs at the beginning of the next quarter. This calculation is performed in FFS and CB payment systems by aggregating the values obtained by using the formulas given in Table 3.1. For the patients who are in the middle of their treatment, health costs will be equally divided for both quarters.

Assumption ID	**Subject**	**Description**
A1	Population	Closed population of fixed size n (a sum of p physicians and m ordinary individuals; the numbers p and m remain constant during the simulation run)
A2		No dynamics between the set of all medical providers $\mathbf{P}$ and the set of all ordinary individuals $\mathbf{M}$
A3	Patient	No specification of individual's sex, age and medical history
A4		Intelligence: a patient is able to choose the 'right' medical specialist
A5		No personal preferences in the treating physician
A6		No resistance to the same type of disease or disorder after the recovery
A7		Perfect behaviour with regard to immediately contacting physician and designated treatment
A8		No intentions to get the additional personal benefit from the medical provider
A9		Regular intervals between the visits to physician. Interval length depends on the medical problem
A10	Medical provider (physician)	Speciality in a certain medical field
A11		Diagnosis is always correct; the way of treatment is considered as optimal and causes no delays in the expected duration of the treatment
A12		Perfect behaviour with regard to the medical decisions and the actions related to each single patient
A13		No intentions to get the additional personal benefit from the existing reimbursement system
A14		Waiting lines are organized by FIFO method
A15	Medical problem	Theoretical non-severe, nonfatal, non-chronic, not contagious and relatively quickly curable
A16		No complications or deaths: a patient always recovers
A17		No urgent cases which would require to be prioritised in waiting queues
A18		Medical symptoms are not mutual and refers to a concrete disease or disorder
A19		Existence of one or more appropriate physician
A20	Insurance system	All health costs are covered by the public health insurance
A21	Reimbursement system	CB and FFS payment systems bring the same expenditures for each single treatment; the payers costs are equal to the physicians' benefit

Table 3.3: The main assumptions and limitations of the Model with a Perfect Agency

This table contains the major foundations for the presented health care system regarding the population, patients, medical providers, diseases and disorders, existing insurance system and reimbursement methods. All model assumptions and limitations are categorised and numbered.

3.2.2 Modelling of getting ill and the treatment process

Various health care models set different rules regarding to modelling of getting ill, the method to choose an appropriate physician and the treatment process. In the Model with a Perfect Agency the relevant decisions were made taking into account the type of model (i.e., discrete time agent-based modelling) and simulation goals.

In every simulation step t_m, $m \in \{0, \ldots, t_{max}\}$ a potential patient can get ill and thus change his health status and become a patient. This process is accomplished in the following way:

- At the beginning of simulation for every ordinary individual in the target population M_l, $l \in \{1, \ldots, m\}$ is assigned the list $\mathbf{U_l} = [u_{l1}, \ldots, u_{ld}]$. It contains the random probabilities to get the medical problems $D_1, \ldots, D_d$:

  $P(D_j \mid M_l) = u_{lj}$ is the probability for an ordinary individual M_l, $l \in \{1, \ldots, m\}$ to get a medical problem D_j, $j \in \{1, \ldots, d\}$.

  In the model u_{lj} are considered as 'the critical probabilities'. They are Beta-distributed with the shape parameters $\alpha, \beta > 0$ and remain constant during the simulation run. The changes in ratio between patient agents and potential patient agents over time are related to the initial choice of α and β.

- The other type of values defined in this model is so called 'deciding random numbers'. They follow standard uniform distribution and are regenerated in every time step. For each healthy person M_l, $l \in \mathbf{M1}$ deciding random numbers are collected in the list $\mathbf{W_{lj}} = [\mathbf{w_{l1}}, \ldots, \mathbf{w_{ld}}]$. The elements of $\mathbf{W_l}$ represent in a certain way the chances to become the medical problem $D_1, \ldots, D_d$ at the current day $t_m, m \in \{1, \ldots, t_{max}\}$:

  $w_{lj} \ldots$ the random number indicating how high the possibility for an ordinary individual M_l is, $l \in \mathbf{M1}$ to get a medical problem D_j, $j \in \{1, \ldots, d\}$ at the current day $t_m, m \in \{1, \ldots, t_{max}\}$.

Deciding random numbers play a key role in the transition from potential patient to patient.

- In each simulation step the critical probabilities are compared with the deciding random numbers. If the condition

$$u_{lj} \leq w_{lj} \tag{3.3}$$

(Probabilities Comparison Condition)

is satisfied (i.e., the critical probability u_{lj} is less than or equal to the deciding random number w_{lj}) for some fix $l \in \mathbf{M1}, \mathbf{j} \in \{\mathbf{1}, \ldots, \mathbf{d}\}$then an individual M_l becomes this disease or disorder D_j. In case the *(3.3) Probabilities Comparison Condition* is satisfied for several medical problems at the same time, the disease or disorder for the individual is selected in a random way.

As in Figure 3.2 presented, one-to-one correspondence between the set of all medical providers with a certain speciality $k \in \{1, \ldots, c\}$ $\mathbf{P\_cgk} \subseteq \mathbf{P}$ and the set of all diseases and disorders belonging to the category k $\mathbf{D\_cgk} \subseteq \mathbf{D}$ implies that for a patient M_l, $l \in \mathbf{M2}$ suffering from D_j, $j \in \{1, \ldots, d\}$ there always exists at least one appropriate doctor. The assumption that all ill persons have no preferences regarding their medical specialists, allows for using the same selection method to ascribe the unique treating physician for the patients. Since the modelling environment does not involve a geographical framework and the agent's location in the environment is expressed in coordinates, the unique treating medical specialist can be chosen by the minimum distance principle MDP (see Figure 3.4. This approach calculates Euclidian distances between a certain patient M_l, $l \in \mathbf{M2}$ and all for his disease or disorder D_j appropriate physicians and selects minimum:

$$\min_{i \in \mathbf{P\_D_j}} \{\sqrt{(x_{ml} - x_{pi})^2 + (y_{ml} - y_{pi})^2}\} \tag{3.4}$$

(Minimum distance principle)

Here $\mathbf{P\_D_j}$ is the index set of all physicians who are seen as the specialists of D_j and the ordered pairs (x_{ml}, y_{ml}) and (x_{pi}, y_{pi}) describe respectively patient's and physician's coordinates in a two-dimensional environment.

In addition to the main parameters $D\_ID_{lj}, Dcg_{lj}, days_j, M\_ID_l, T_{explj}, T_{lj}, \mathbf{U_l}$ and variables Cms_j, v_{lj} described in the previous two sections, a patient has three more help variables related to his treatment. Let $vleft_{lj}$ be a number of all visits to the physician that are left until the end of the treatment for a patient $M_l, l \in \mathbf{M2}$ with a medical problem

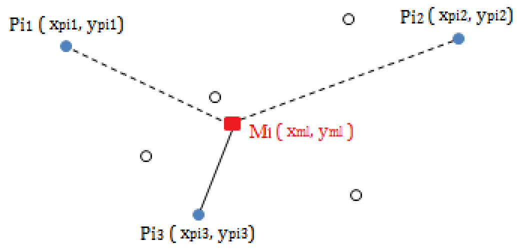


Figure 3.4: Minimum distance principle

Minimum distance principle. This figure represents an example where a patient M_l with a medical problem D_j, $j \in \{1, \ldots, d\}$ must choose one of three appropriate medical specialists P_{1j}, P_{2j}, P_{3j}. Using minimum distance principle M_l chooses P_{3j}.

$D_j, j \in \{1, \ldots, d\}$. The initial value of this variable at the beginning of the treatment is equal to the v_{lj} and is being reduced by one with each visit. The other variable $daysleft_{lj}$ starting from $days_j$ in descending order, counts the number of days until the next visit. The binary variable WQ_l is associated to the patient's waiting in treating the physician's office and his position in the line. It has a value 1 if an ill person should visit his medical specialist today and because of higher as the value of *PCapacity* position in the queue must wait until the next day. The patient's attributes and relations between them are illustrated in Figure 3.5.

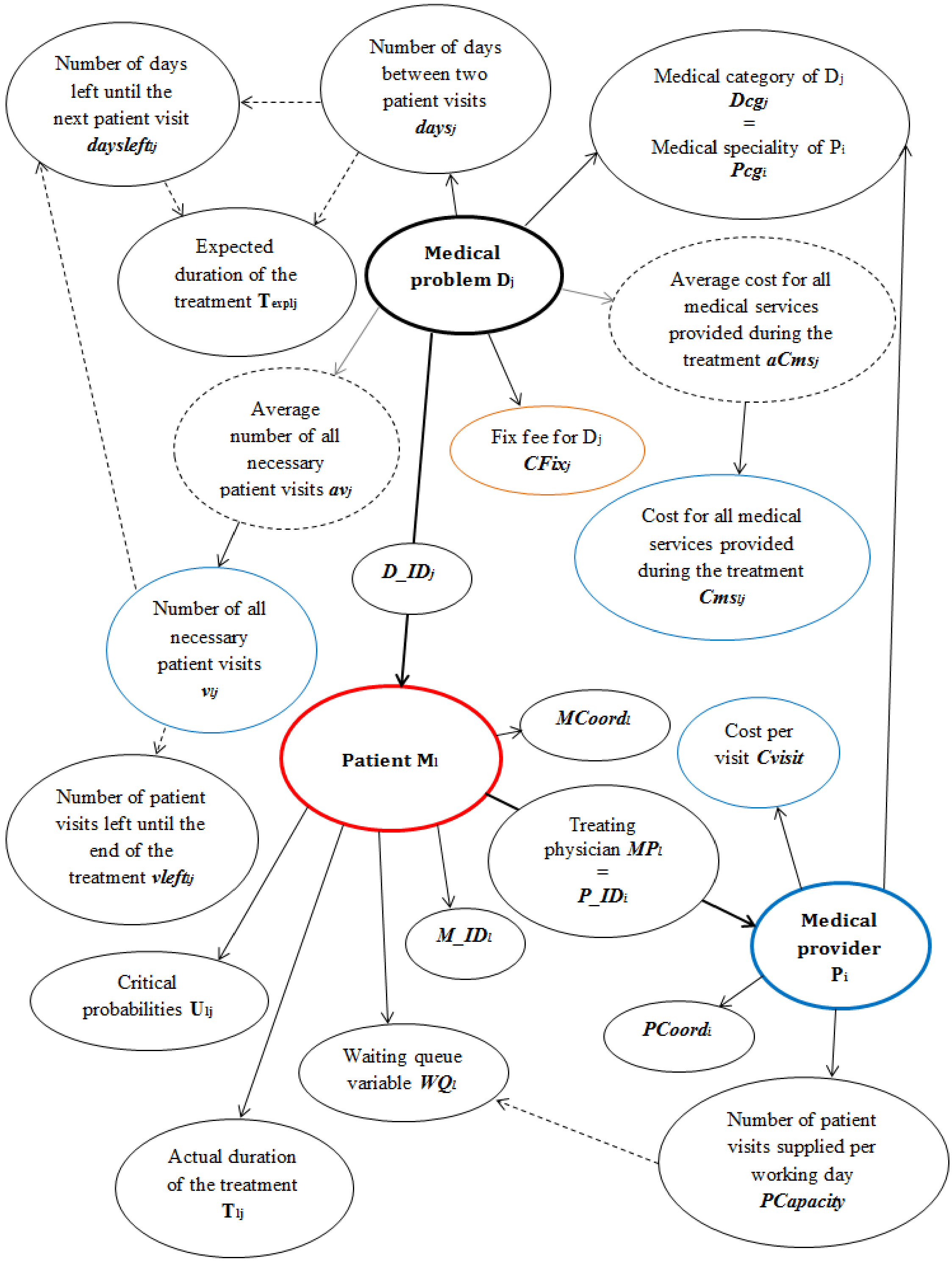


Figure 3.5: Patient's attributes and relations between them

The given figure represents the main attributes and help variables which describe the patient's treatment process and are used to model the patient's actions.

During the treatment, all ill agents are acting according to the certain rules which are explicitly stated in Table 3.4. If the patient got ill at the current time step (i.e., the condition (3.3) is satisfied), his first visit to the physician occurs still at the same time (see MC1, Table 3.4. If it is necessary, he is seeing his medical provider in a minimum of $(days_{lj} + 1)$ days again (see MC2, MC3, Table 3.4). Between physician visits a patient takes the medical instructions at home and simply waits until the next appointment (see MC4, Table 3.4). This is repeated until the last visit to his medical provider, which is considered as the end of the treatment (see MC5, Table 3.4). In other words, at some fixed time moment $t \in \{0, \ldots, t_{max}\}$ a patient $M_l, l \in \mathbf{M2}$ is visiting his physician, waiting for the next visit or having the last visit and thus becoming healthy. Which one of these three possible 'actions' should be performed is indicated by patient's and potential patient's attributes. One of the standard medical cases starting from the process of getting ill and ending with the last patient visit is illustrated in Figure 3.6. It narrowly describes the dynamics of the Model with the Perfect Agency.

Condition	**Patients' action**	**Changes in attributes**
MC1: $u_{lj} \leq w_{lj}$	Go to a physician for the first time at the current time step	$w_{lj} = 0$ $daysleft_{lj} = days_j$ $vleft_{lj} = v_{lj} - 1$
MC2: $daysleft_{lj} = 0$ and $vleft_{lj} > 1$ and $WQ_l = 1$	Go to a physician at the next time step again	$daysleft_{lj} = days_j$ $vleft_{lj} = v_{lj} - 1$
MC3: $daysleft_{lj} = 0$ and $vleft_{lj} > 1$ and $WQ_l = 0$	Go to a physician at the current time step	—
MC4: $daysleft_{lj} > 0$	Wait	$daysleft_{lj} = daysleft_{lj} - 1$
MC5: $daysleft_{lj} = 0$ and $vleft_{lj} = 1$	Go to a physician and become healthy	$daysleft_{lj} = 0$ $days_j = 0$ $vleft_{lj} = 0$ $v_{lj} = 0$

Table 3.4: Patient's behaviour during the treatment

This table provides all conditions on the ordinary individual's attributes, patient's responding actions and respective changes in the variables at a certain time step $t_m, m \in \{0, \ldots, t_{max}\}$. These patient's behaviour rules are established in view of the introduced assumptions that a patient is responsibly following physicians' instructions with regard to designated treatment and the treatment is going without complications, death or urgent cases (see A7, A16 and A17 in the Table 3.3)

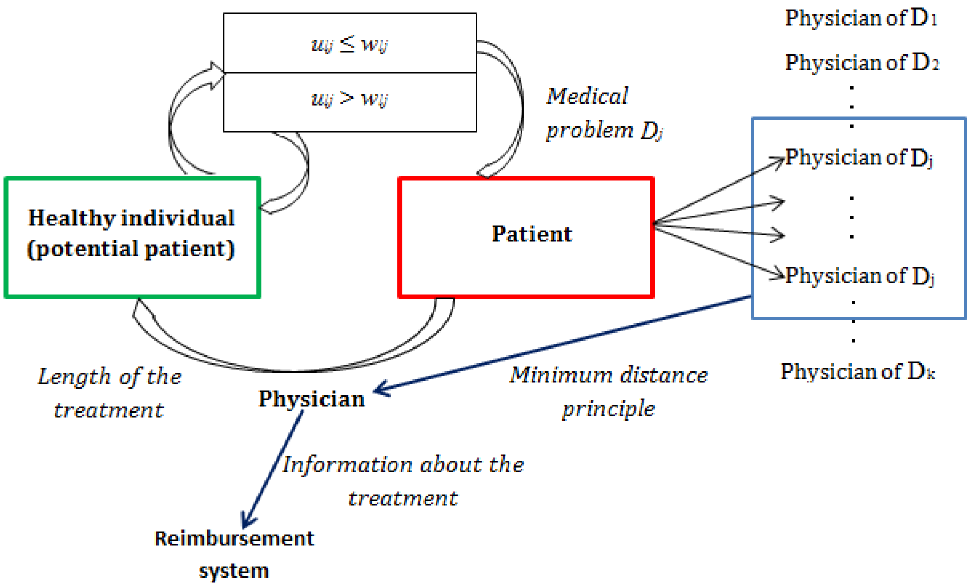


Figure 3.6: The dynamics of the Model with a Perfect Agency

This figure illustrates a single medical case occurring in the model. After getting ill and the following choice of the appropriate physician occurring by minimum distance principle, a patient starts the treatment and after a certain amount of time becomes a potential patient again. All information about patient visits and provided medical services and their cost is reported to the reimbursement system.

3.3 Simulation run and results

3.3.1 Model initialisation

At the beginning of the simulation the total population consisting of p medical providers, $m1$ potential patients and $m2$ patients is randomly and uniformly distributed in a two-dimensional rectangular space of size $k1$ x $k2$. In this environment all n agents have a fixed place which is described by the coordinates and could be considered as their working (for physicians) or living (for ordinary individuals) place. The parameters $k1$, $k2$, n and p as well as the initial value of variable $m2$ are settled before the simulation run. The initial number $m1$ of potential patients depends on the chosen values of n, p and $m2$ ($m1$ = n - p - $m2$).

The Model with the Perfect Agency requires an accurate definition of all d medical problems. For these diseases or disorders $D_1, \ldots, D_d$ their attributes D_ID_j, Dcg_j, $days_j$, $CFix_j$, $aCms_j$ and aCv_j must be submitted manually. The three last parameters are related to the health cost evaluation and should be initialised bearing in mind the *(3.2) Cost condition*. In view of the assumptions that the presented model deals with relatively easily treatable medical problems (see A15-A16, Table 3.3), the initial values of aCv_j and $days_j$ should not lead to the excessively long duration of the treatment (see *(3.1) Expected duration of the treatment*).

Before the simulation run each medical provider is randomly assigned to his P_ID_i as well as the medical speciality Pcg_i and thus the set of all treating medical problems $\mathbf{Pi\_D}$, $i \in \{1, \ldots, p\}$. The cost per patient visit *Cvisit* and the fixed number of patient visits supplied per working day $t \in \{1, \ldots, t_{max}\}$ *PCapacity* are defined manually. These parameters have the same values for all physicians. The ordinary individuals in the random way become their unique $M\_ID_l, l \in \{1, \ldots, m\}$ and the critical probabilities to get the diseases or disorders $D_j, j \in \{1, \ldots, d\}$. The shape parameters $\alpha, \beta > 0$ of the corresponding Beta distribution are given by the model user.

At the time step t_0 each patient $M_l, l \in \mathbf{M2}$ should have a randomly selected medical problem D_ID_{lj} with its attributes Dcg_{lj}, $days_j$, $CFix_j$, Cms_{lj}, v_{lj} and the nearest located appropriate physician MP_l. These agents are already in the treatment, i.e., their attributes $vleft_{lj}, daysleft_{lj}$ are adjusted by using the uniform random integer generator within the specified intervals $(1, v_{lj})$ and $(0, days_j)$. Two additional tables with the parameters, variables and the other elements (i.e., lists, sets, abbreviations etc.) used in the Model with a Perfect Agency together with their definition, information about the initialisation process and the changes during the simulation run are submitted in the Appendix to the Chapter 3 (see Table A.2, Table A.1).

With no loss of generality the agent-based simulation of the Model with a Perfect Agency always starts on the first day of January. Along with the parameter t_{max} which define the simulation length in days, it is necessary to initialise a vector $\mathbf{tq}$ containing several values $t \in \{1, \ldots, t_{max}\}$. Each of these time steps coincides with the first day of the corresponding quarter of the year $Q1$, $Q2$, $Q3$ or $Q4$. Tables A.3 and A.4 (see Appendix to the Chapter 3) submit the full information about the number of working days per each quarter of the year 2010 – 2014 and the time steps in which the cost evaluation occurs. Depending on the desired simulation length t_{max} and the chosen year for the simulation start, the values $t \in \{1, \ldots, t_{max}\}$ are chosen based precisely on these help tables.

3.3.2 Simulation run

After the model initialisation following simulation run reflects the dynamics of the health system described in the Subsection 2.2.2: in the time interval $[1, t_{max}]$ the individuals get ill, chose appropriate physician and after a certain measurable period of time spent in the treatment become healthy. This subsection presents a simple example of the Model with a Perfect Agency and its results. Since the simulation is applied to the population of a small size, the changes in the system appearing at the separate simulation steps can be well illustrated graphically.

3.3.2.1 Example No. 1

Consider the health care system with $n = 50$ agents. The actions and interactions of $p = 5$ medical providers and $m = 45$ ordinary individuals are processed in the model environment of the size 10 x 10. These values are not proportional (5 physicians are too high number for population consisting only of 45 individuals) but they allow to follow simulation process graphically. At the time step t_0 $m2 = 3$ people are already ill and $m1 = 42$ agents are counted as the potential patients.

During the simulation run the ordinary individuals $M_1, \ldots, M_{45}$ are suffering from $d = 4$ different theoretical diseases and disorders. The information about these medical problems $D_1, \ldots, D_4$ is presented in Table 3.5. The cost attributes are selected taking in mind that each medical provider charges every patient visit by $C_{visit} = 10$ Euro. Table 3.5 contains the main attributes of all 5 medical providers, i.e., their ID, medical speciality and the set of all medical problems they are qualified to treat. Since the size of population is small, each medical provider treats a maximum of 3 patients per working day, i.e., *PCapacity*= 3. The critical probabilities to get diseases and disorders are Beta(5, 0.15) distributed (see Figure 3.7). This variation of Model with a Perfect Agency is further referred in Example No. 1.

D_ID_j	$CFix_j$	$aCms_j$	av_j	$days_j$	Dcg_j
1	55	15	4	2	1
2	35	5	3	3	2
3	40	10	3	4	2
4	70	30	4	4	3

Table 3.5: The attributes of $d = 4$ medical problems defined in the Example No.1

As can be seen from the last column, the diseases and disorders D_ID_2 and D_ID_3 both represent the medical category $D_{cg2} = D_{cg3} = 2$ and therefore can be treated by the same appropriate medical provider. All attributes are parameterized manually.

P_ID_i	Pcg_i	**Pi_D**
1	3	4
2	1	1
3	2	2 and 3
4	1	1
5	3	4

Table 3.6: The main information about the medical providers operating in the Example No.1

This table submits the list of $p = 5$ physicians, their specialities and the corresponding sets of all treating medical problems.

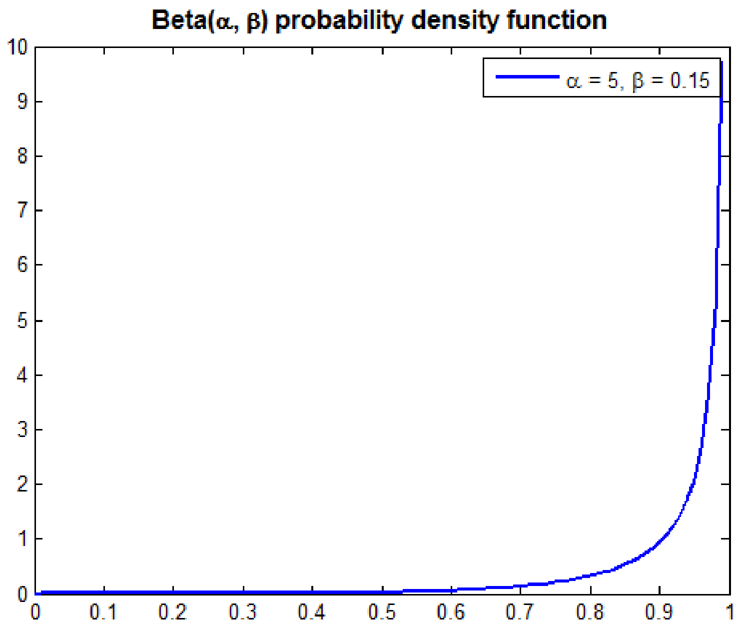


Figure 3.7: The probability density function of the Beta distribution with shape parameters $\alpha = 5$ and $\beta = 0.1$

In Example No. 1 B(5, 0.15) is chosen as the basis for random generation of the critical probabilities. The shape of the plotted density function shows that such parameter selection helps to avoid too steep increase in the number of patients over the time.

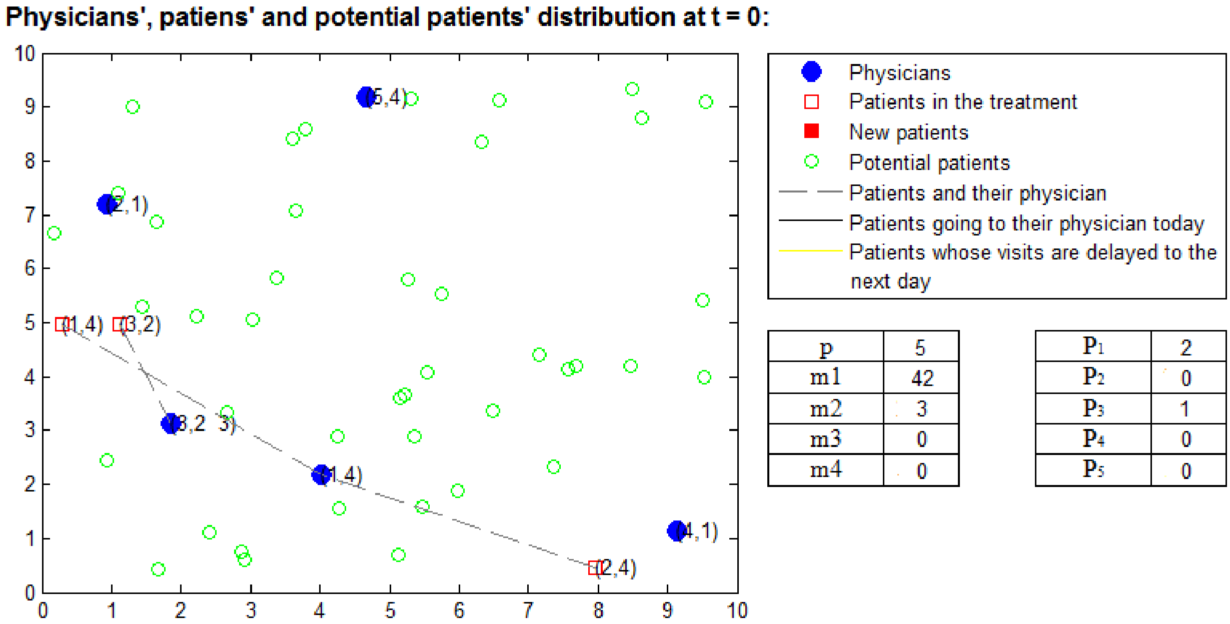
The chosen simulation duration is 2 years starting with 1^{st} of January 2013. According to the Table A.4 (see Appendix to Chapter 3), the last simulation step is equal to 502: $t_{max} = 502$. The determination of the health cost occurs at the $n\_Q = 8$ time steps. The situation at t_0 and the first four simulation steps are plotted in figures 3.8 – 3.12. In these graphical model representations the physician and patient agents are respectively displayed by blue filled circles and red outlined (for persons who are in the middle of their treatment) and filled (for new patients) squares. Healthy ordinary individuals are reflected by green outlined circles. In order to follow up the simulation run more closely, these plots include some additional information (i.e., two natural numbers (M_ID_l, D_ID_{lj}) for the patient M_l, $l \in \mathbf{M2}$ and two or more integers (P_ID_i, Pi_Dj) for the medical provider $P_i, i \in \{1, \ldots, p\}$) which is given in the brackets placed next to the agents. The relation between the ill person and his physician is displayed by the plotted grey dashed lines connecting the respective points in the model environment. If some ill person is visiting his medical provider at the current time step, the dashes turn to thick black lines. In case of a delayed physician appointment caused by the situation in the waiting line, the patient-physician relation is displayed by a yellow line. All significant changes in the system over time are commented at the bottom of the given figures 3.8 – 3.12. The summarised information submitted at the right to the plots is presented in the following form:

p	**Number of physicians in the system**
m1	Number of potential patients in the system
m2	Number of patients in the system
m3	Number of ordinary individuals who become patients at the current time step
m4	Number of ordinary individuals who become healthy at the current time step

Table 3.7: The information about all changes in the number of agents over the time

Physician	**The number of current patients**
P1	$\|\mathbf{P1\_D}\|$
P2	$\|\mathbf{P2\_D}\|$
P3	$\|\mathbf{P3\_D}\|$
P4	$\|\mathbf{P4\_D}\|$
P5	$\|\mathbf{P5\_D}\|$

Table 3.8: Numbers of current patients being treated by the medical providers $P_1, \ldots P_5$

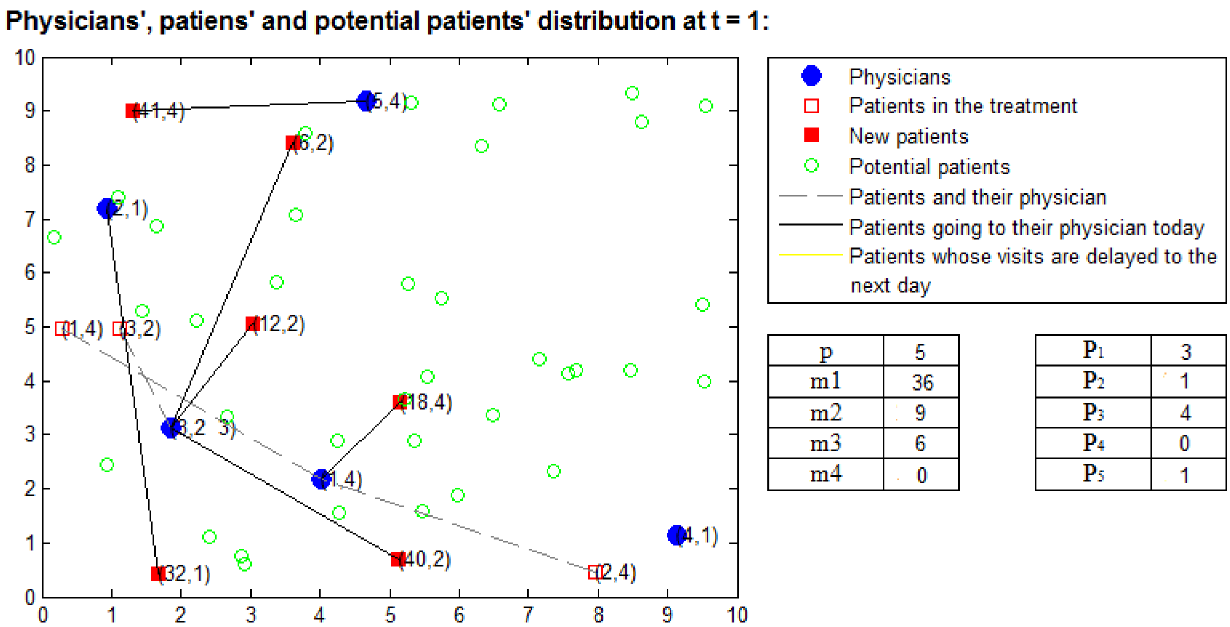


p	5
m1	42
m2	3
m3	0
m4	0

P_1	2
P_2	0
P_3	1
P_4	0
P_5	0

Figure 3.8: The health care system presented in Example No. 1 at t_0

This figure depicts the situation before the simulation run. The system consists of p = 5 physicians, $m1 = 42$ potential patients and $m2 = 3$ ill persons. In this example the medical provider P_3 (see the first number in the brackets given next to the blue circles) is the only medical provider who is qualified to treat more than one disease or disorder. To be more specific, P_3 is the specialist of the medical problems D_2 and D_3 which according to the Table 3.5 have the same category $Dcg_2 = Dcg_3 = 2$. All $m2 = 3$ patients have their medical providers (follow the dashed lines and the corresponding information at right) and are already in the treatment.

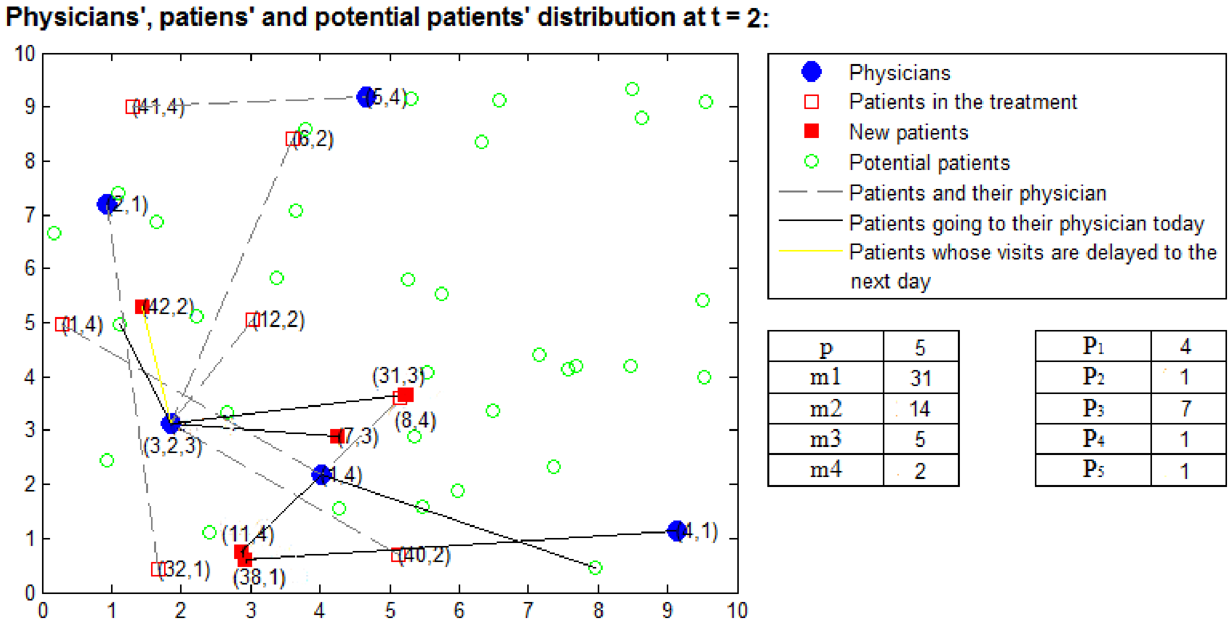


p	5
m1	36
m2	9
m3	6
m4	0

P_1	3
P_2	1
P_3	4
P_4	0
P_5	1

Figure 3.9: The health care system in the Example No. 1 at t_1

At this time step $m3 = 6$ persons got ill, found the physician and began their treatment process. Compared to the situation at the time step t_0, the number of healthy individuals decreased to $m1 = 36$. The physician P_4 still has no current patients.

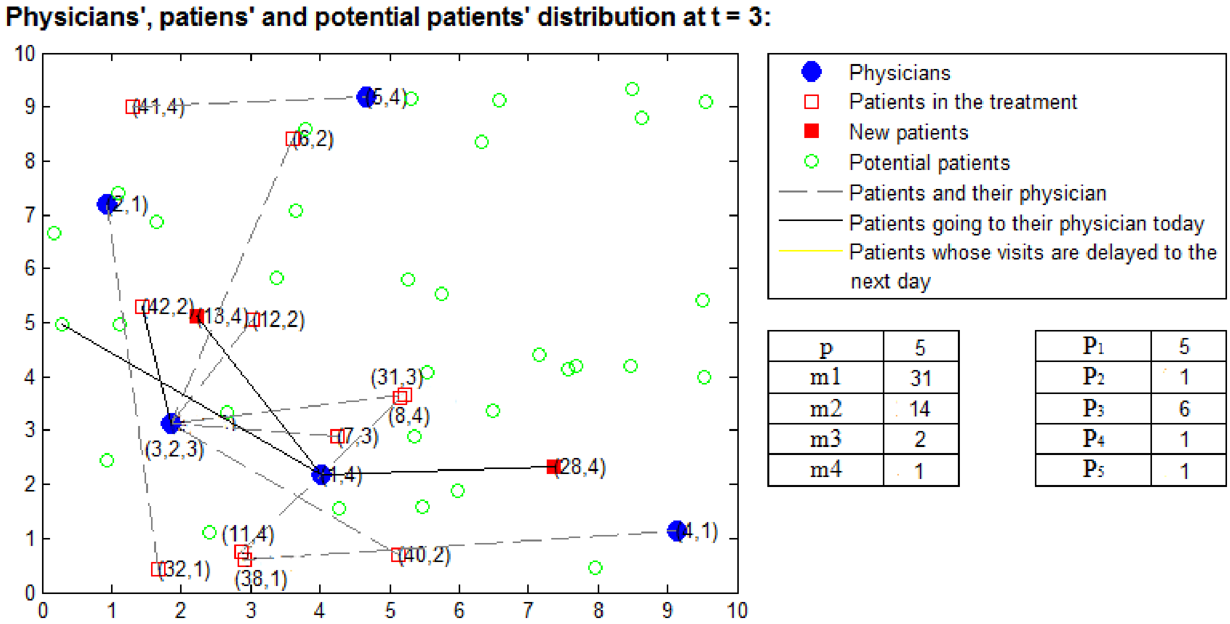


p	5
m1	31
m2	14
m3	5
m4	2

P_1	4
P_2	1
P_3	7
P_4	1
P_5	1

Figure 3.10: The health care system presented in the Example No. 1 at t_2

There are several significant changes in the system. The agent M_{30} got the medical problem D_1 and now all physicians have non-empty sets of their current patients. At this time step the patient M_3 (see Figure 3.9) has the last visit to his medical provider P_3. This patient is already displayed as a green outlined circle and is expected at t_3 to have no relation with P_3. This also applies to the agent M_2 and his physician P_1. The third important observation is the yellow line which connects the ill person M_{42} with the medical provider P_3. It simply means that at the current time step M_{42} should visit P_3 but his appointment is delayed because of the limited number of physician visits per working day. The physician P_3 already serves $PCapacity = 3$ patients (see thick black lines what connect the medical provider P_3 with the agents M_7, M_{31} and M_{32}). For this reason at time step t_4 the patient M_{42} will be served first. The set of all currently ill persons was supplemented by $m3 = 5$ new patients.

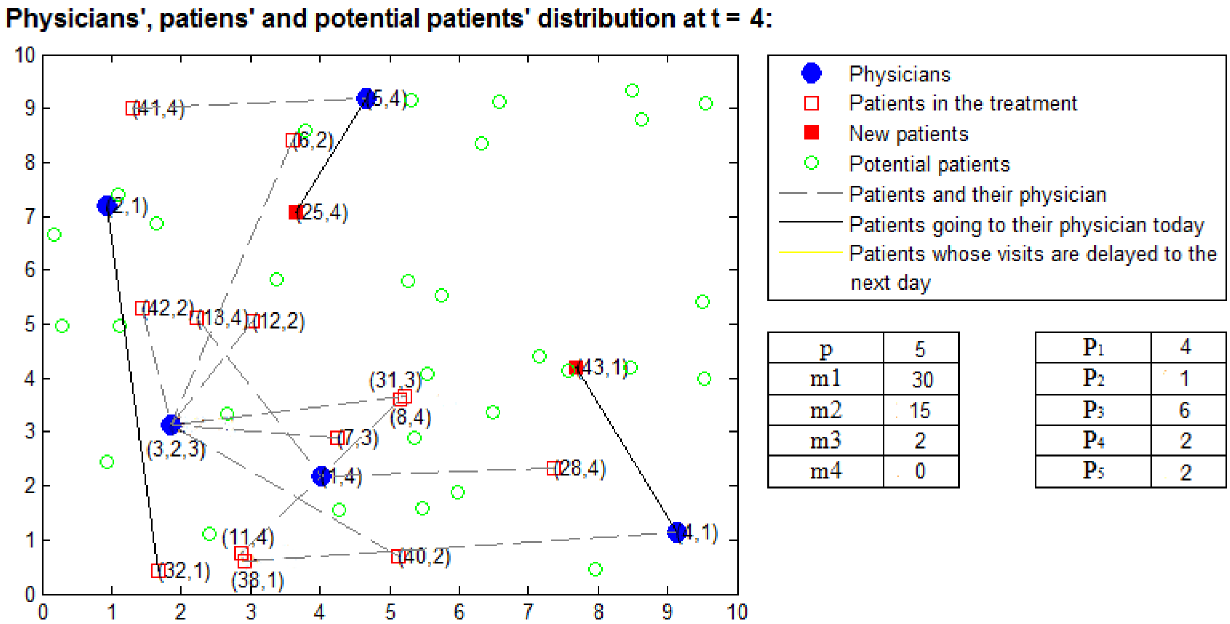


p	5
m1	31
m2	14
m3	2
m4	1

P_1	5
P_2	1
P_3	6
P_4	1
P_5	1

Figure 3.11: The health care system presented in the Example No. 1 at t_3

The agents M_2 and M_3 became healthy and are now considered as potential patients. The patient M_1 is ending his treatment process. Although there are $m3 = 2$ new patients, the number of all currently ill persons $m2$ remain unchanged because of the 'loss' of M_2 and M_3. The physicians P_1 and P_3 have the greatest numbers of patients.



p	5
m1	30
m2	15
m3	2
m4	0

P_1	4
P_2	1
P_3	6
P_4	2
P_5	2

Figure 3.12: The health care system presented in the Example No. 1 at t_4

After 4 simulation steps, the target population consists of $m1 = 30$ potential patients and $m2 = 15$ patients. The ill agents M_{25}, M_{32} and M_{43} are visiting their medical providers. At this time step the physician P_3 has the highest occupation level while P_2 has only one patient.

As mentioned above, one simulation run has a length of $t_{max} = 502$ time steps. Starting from the same initial values and considering the agents with the constant main attributes (i.e., in every simulation run the unique physician's P_ID_i, the set of all treating medical problems **Pi_D** , the physician's and patient's location in the environment $PCoord_i$, $MCoordl$ as well as the critical probabilities u_{lj} remain unchanged for all $P_i, M_l, D_j, i \in \{1, \ldots, 5\}, l \in \{1, \ldots, 45\}, j \in \{1, \ldots, 4\}$). The simulation was repeated $s = 100$ times. All respective outcomes and statistics are presented in Table 3.9, Table 3.9 and Figure 3.13. Table 3.9 submits the average health care costs $aCBQ_{100}, aFFSQ_{100}$ caused by the treatment provided by physicians $P_1, \ldots, P_5$ per one simulation run. The costs in the presented model are interpreted as physicians' net benefits. These values depend on the cost attributes of the medical problems defined in this example (see Table 3.5). They are used only an example and thus does not meet the costs which occur in real health systems. The calculations are performed in CB and FFS payment systems. The average costs are separately determined for each of $n\_Q = 8$ quarters of 2013 – 2014. The last column of Table 3.9 gives the average number of all patients who ended their treatment by the physician $P_i, i \in \{1, \ldots, 5\}$ in a certain quarter of the year (see $\mathbf{aM2Q_{100}}$, Table 3.9). This information exhibits the medical providers' 'popularity' and thus the incidence of their treating medical problems. Table 3.10 represents the summarised results of Table 3.9 where the statistical evaluations are made regardless to the year and its separate quarters. Here $\mathbf{aCB_s}$ and $\mathbf{aFFS_s}$ represent the average physicians' benefits per quarter of the year received after $s = 100$ simulation runs. The values for each medical provider are calculated under the CB and FFS reimbursement methods by aggregating all health costs which occurs in every single simulation run and dividing the sum by $s \cdot n\_Q$. The differences between average physicians' benefits can be clearly visible in the column diagram plotted in Figure 3.13. This figure simply illustrates the results presented in Table 3.10. The average outcomes shows that as the cost received from the CB and FFS reimbursement systems are almost the same. This result was requested by introducing *(3.2) Cost condition.* More detailed interpretation and explanation of the obtained outcomes are presented in the next subsection.

Y	**Q**	$\mathbf{P\_ID_i}$	$\mathbf{aCBQ_{100}}$	$\mathbf{aFFSQ_{100}}$	$\mathbf{aM2Q_{100}}$
2013	Q1	1	1345.05	1334.53	17.14
2013	Q2	1	1350.3	1340.44	19.29
2013	Q3	1	1437.45	1425.06	20.48
2013	Q4	1	1421	1409.69	20.34
2014	Q1	1	1390.55	1378.55	19.74
2014	Q2	1	1347.5	1335.35	19.34

2014	Q3	1	1448.65	1436.04	20.69
2014	Q4	1	1411.55	1400.81	20.3
2013	Q1	2	487.03	482.72	8.47
2013	Q2	2	474.38	470.48	8.57
2013	Q3	2	507.1	506.1	9.15
2013	Q4	2	504.08	495.87	9.29
2014	Q1	2	462.28	455.13	8.48
2014	Q2	2	455.4	452.34	8.16
2014	Q3	2	526.9	522.97	9.58
2014	Q4	2	468.88	462.77	8.64
2013	Q1	3	1959.73	1912.97	49.92
2013	Q2	3	1794.43	1772.44	48.39
2013	Q3	3	1967.6	1944.69	52.84
2013	Q4	3	1911.23	1877.99	51.35
2014	Q1	3	1842.45	1825.45	49.78
2014	Q2	3	1817.6	1783.39	49.12
2014	Q3	3	1930.15	1904.07	51.84
2014	Q4	3	1888.18	1857.93	50.61
2013	Q1	4	696.85	693.21	11.79
2013	Q2	4	669.08	662.32	12.29
2013	Q3	4	696.3	687.66	12.55
2013	Q4	4	687.78	680.59	12.58
2014	Q1	4	688.6	677.69	12.52
2014	Q2	4	662.75	655.48	12.07
2014	Q3	4	756.53	744.5	13.66
2014	Q4	4	709.78	703.4	12.94
2013	Q1	5	690.55	685.65	8.67
2013	Q2	5	687.05	683.7	9.82
2013	Q3	5	719.25	715.38	10.27
2013	Q4	5	692.65	684.22	9.93
2014	Q1	5	714.35	709.9	10.24
2014	Q2	5	662.9	655.14	9.42
2014	Q3	5	740.25	730.73	10.44
2014	Q4	5	726.95	720.97	10.44

Table 3.9: The average outcomes of the Example No. 1 per simulation run related to specific quarter $Q1, \ldots, Q4$ and the specific year

This table submits the information about the average cost and the number of patients in each $Q1, \ldots, Q4$ of 2013 – 2014. The statistical evaluations are made after performing $s = 100$ simulation runs based on the model initialisation described above. Here $\mathbf{aCBQ_{100}}$ and $\mathbf{aFFSQ_{100}}$ are the average physicians' benefits per simulation run received in a certain Q of the year Y (in Euro) under the CB and FFS payment systems. The column $\mathbf{aM2Q_{100}}$ represents the average number of patients who finished their treatment by $P_i, i \in \{1, \ldots, 5\}$ in the certain Q of the year Y obtained after 100 simulation runs.

$\mathbf{P\_ID_i}$	$\mathbf{aCB_{100}}$	$\mathbf{aFFS_{100}}$	$\mathbf{aM2_{100}}$
1	1394.01	1382.56	19.67
2	485.75	481.04	8.79
3	1888.92	1859.86	50.48
4	695.96	688.1	12.55
5	704.24	698.21	9.9

Table 3.10: The average outcomes of the Example No. 1 per one simulation run obtained per a quarter of the year

This table gives the information about the average financial benefits $\mathbf{aCB_{100}}$ and $\mathbf{aFFS_{100}}$ which $P_1, \ldots, P_5$ receive in one quarter of the year. The calculations are made in both CB and FFS reimbursement systems based on the results of $s = 100$ simulation runs the model initialisation described above. The last column gives the average number of patients healed by medical provider $P_1, \ldots, P_5$ in a quarter of the year.

3.3.3 Identification and selection of most important model parameters

An integral part of simulation modelling is the identification of the most important parameters and selection of their proper values. In general, it is achieved by performing the different variations of the model based on the logical considerations. Various choices in the attributes show that the outcomes of the Model with a Perfect Agency for the biggest part depend on the parametrisation and random generation of α, β, $PCoord_i$, $MCoord_l$ and the attribution and cardinality of the set **P_Dj**. Some particular selections or non-optimal distribution of these values could lead to undesired results. Therefore, special

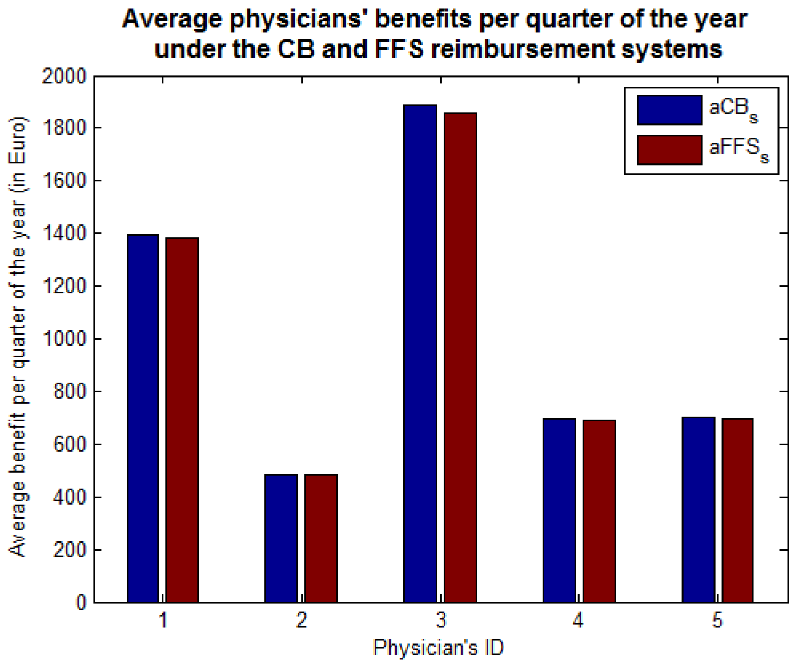


Figure 3.13: The average physicians' benefits per simulation run obtained per a quarter of the year after performing $s = 100$ simulation runs

This column diagram illustrates the results submitted in Table 3.10. The physician' benefits are given in both FFS and CB reimbursement systems.

attention should be paid to the following model initialization steps:

1) *Choice of the shape parameters of the Beta distribution $B(\alpha, \beta)$*

As presented in the Subsection 2.2.2., Beta distribution with the shape parameters α and β is used for the random generation of the critical probabilities u_{lj} (for each $l \in \mathbf{M2}$, $j \in \{1, \dots, d\}$). A 'blind' selection of α and β could lead to the satisfaction of *(3.3) Probabilities Comparison Condition* for the great number of patients and medical problems. It would cause the steep increase in the number of patients in the first simulation steps. To be more precisely, the left shaped probability density function of the Beta distribution indicates a rapid rise in the number of ill persons over the time. Since the Model of the Perfect Agency is limited to the simple medical problems and excludes the possibility of the epidemics (see Table 3.3, A15), it 'requires' to generate the critical probabilities from the right shaped Beta distribution. The relation between the different values of the parameters α, β and the changes in the average number of patients over the first simulation steps is illustrated in the Figure 3.14. This graphical representation is based on the repeated simulation of the Example No. 1. The agents have the characteristics used in the previous simulation run.

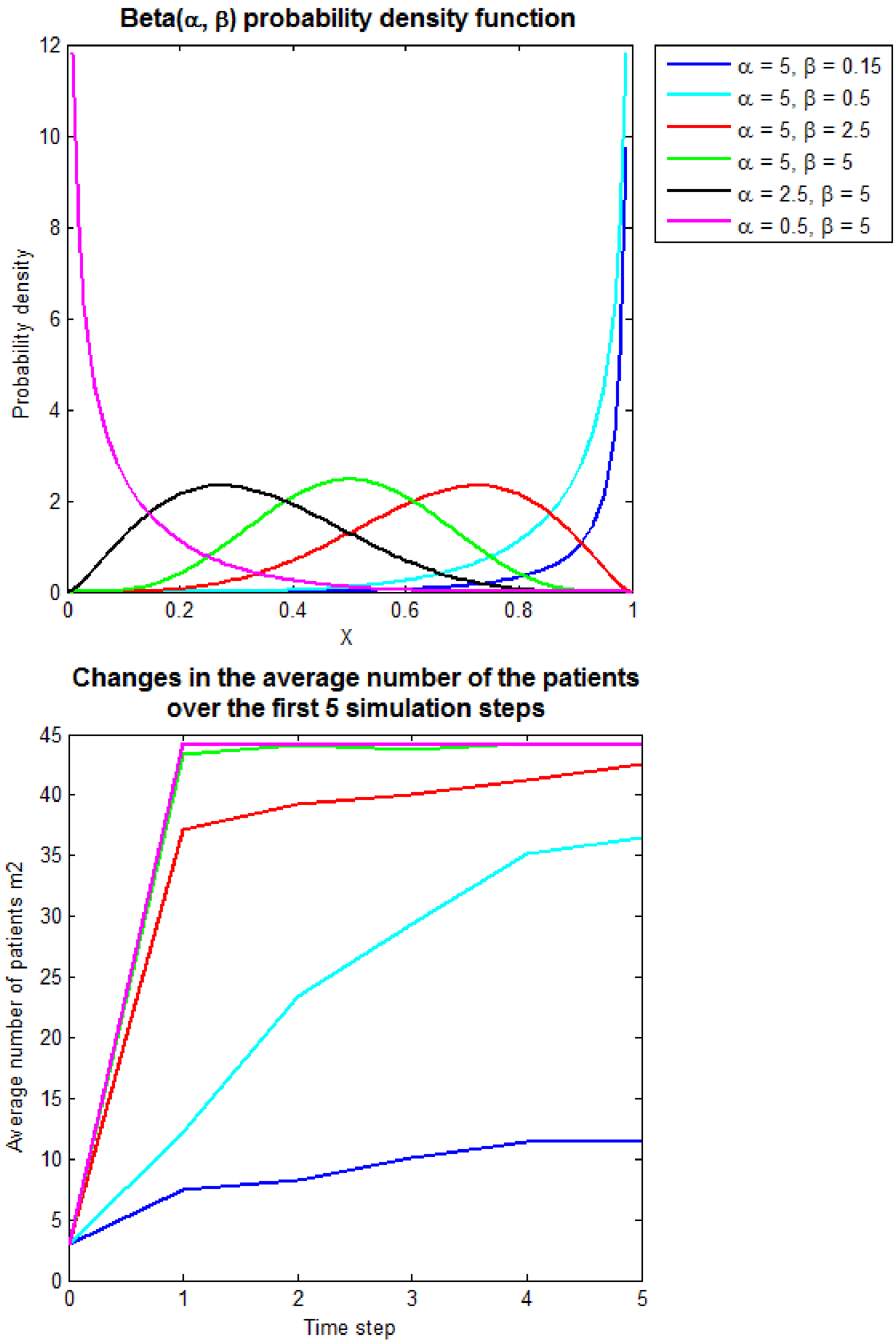


Figure 3.14: Beta probability density function B (α, β) and the corresponding changes in average number of patients based on the average results of 100 simulation runs of the Example No. 1

The figure on the right illustrates the increase in the average number in patients over the first 5 time steps. The given plots show that the left shaped probability density function of the Beta distribution leads to relatively small increase in the patients over time. This information is helpful for the parametrisation of α and β.

2) *Patients' and physicians' location in the model environment*

The simulation run and its results are strongly affected by the agents' distribution in the given two-dimensional space. Some areas characterised by fairly low or high patients' density has a big impact on the physicians' occupation level: the medical providers located in these areas usually have a relatively large or small number of patients. This feature can be noticed in the outcomes of the Example No 1. In this model the physicians P_1 and P_5 both are qualified to treat the medical problem D_4 (see Table 3.6). As can be seen in figures 3.8 – 3.12, the medical provider P_1 has the better placement when it comes to the distribution of the nearly located ordinary individuals. The model outcomes illustrated confirm that P_1 have the evidently greater average number of the patients and thus more financial benefit than P_5 (see Table 3.10, Figure 3.13).

Consider the health care system presented in the Example No. 1 at the time step t_0 once again. The population size, initial number of patients, agents' location, patients' critical probabilities, physicians IDs and medical specialities, etc., have the same values used in the previous simulation runs. Relocate all ordinary individual agents by randomly changing their coordinates and observe how this one alteration in the system affects the model results. The new agent distribution and model outcomes received after repeating the simulation run $s = 100$ times are presented in the figures 3.15 – 3.16 and Table 3.11. In this scenario the physicians P_4 and P_5 obviously have the 'worst' location in the environment and compared to other medical specialists cause the lowest cost. The rankings of physicians from the highest to the lowest earnings based on the outcomes received before and after agents' relocation clearly differ (see Figure 3.13 and Figure 3.16). This model variation approves that only one change in the attributes can be very significant and strongly influence the results.

P_ID$_\mathbf{i}$	**aCBQ**	**aFFSQ**	**aM2Q**
1	1776.82	1763.53	25.04
2	703.97	696.28	12.72
3	1878.28	1852.46	50.17
4	474.07	468.5	8.56
5	319.2	317.39	4.51

Table 3.11: The average outcomes of the Example No. 1 per one simulation run obtained per quarter of the year after changing the ordinary individuals' distribution in the model environment.

3) *Number of medical providers who represent the same medical speciality in the model*

The medical providers who are specialised to treat the same medical problems, at the time step $t_m, m \in \{1, \ldots, t_{max}\}$ are sharing all patients suffering from these diseases and

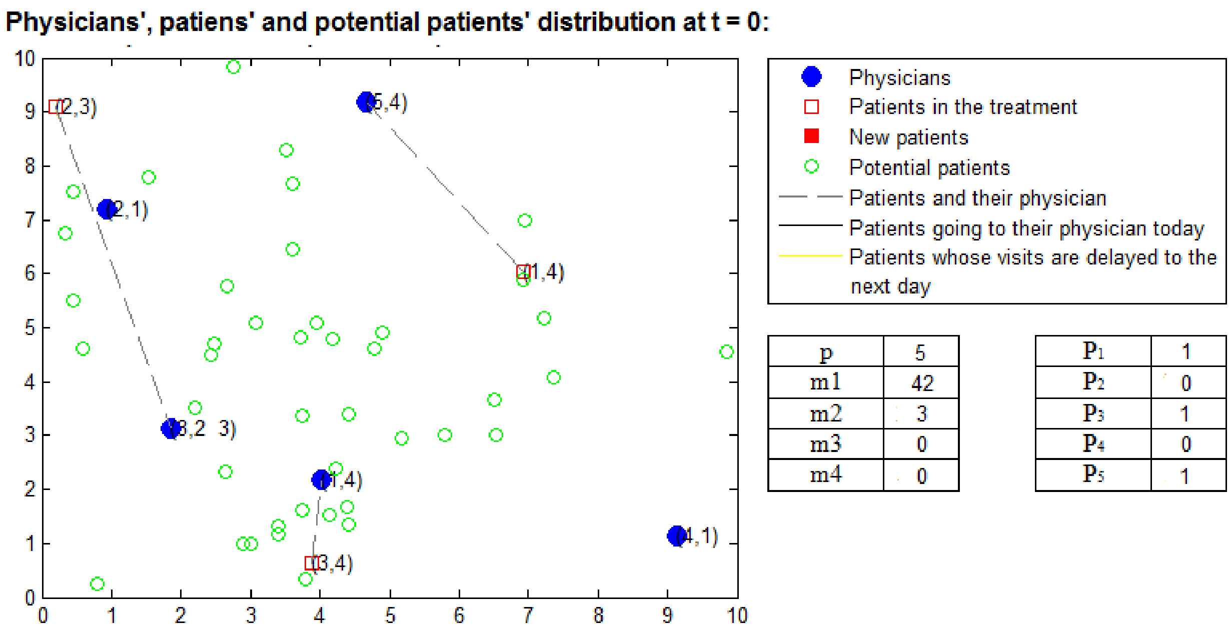


Figure 3.15: The health care system presented in the Example No. 1 at t_0 after changing the ordinary individuals' distribution in the model environment

Compared with the figures 3.8 – 3.12, the patients and potential patients have the other placement in the two-dimensional space. The location of the considered medical providers as well as the other agents' attributes and model parameters remain unchanged.

disorders. The physicians are also consequentially forced to share the overall benefit. It could be particularly relevant for the medical providers who are seen as the specialists of some less frequently-occurring not too 'expensive' medical problems. In such cases, a great number of physicians working in the same medical field go hand in hand with relatively low earnings per physician.

Example No. 1 illustrates the scenario when one medical provider has a certain monopoly in the health market. In presented model variation physician P_3 is the only one specialist qualified to treat the medical problems D_2 and D_3. Although according the information given in Table 3.5 these diseases and disorders are the least 'expensive' (i.e., the treatment of D_2 and D_3 causes much lower cost than the treatment of D_1 and D_2), namely P_3 is the agent with the highest earnings in the system. His financial benefit could be reduced, for example, by setting lower cost attributes for D_2 and D_3, choosing higher values for the corresponding critical probabilities or considering the same number of physicians representing the different medical specialities. In general the health care markets are not characterised by the monopoly: in real world terms there is always more than one appropriate medical specialist. This will be realised in the adaption of the Model with a Perfect Agency for the greater population presented in the Chapter 5.

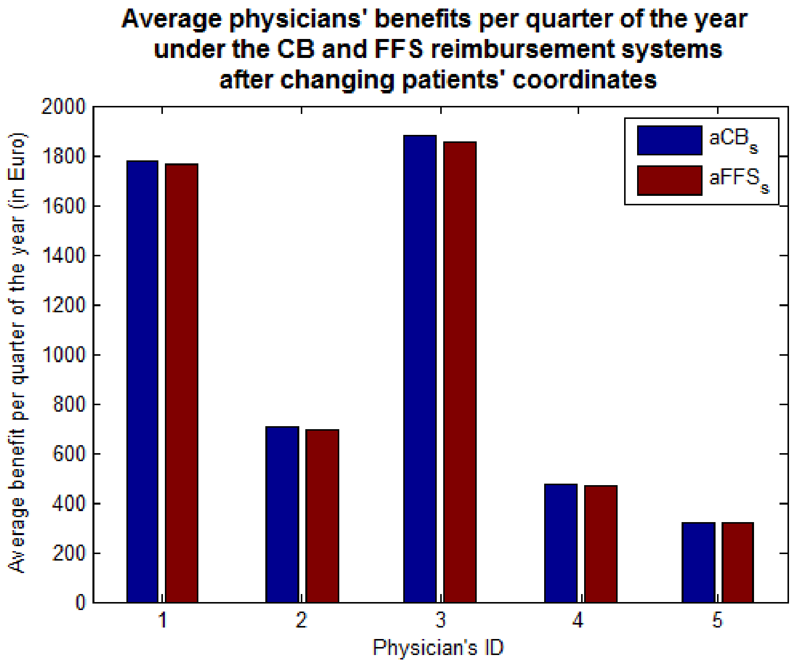


Figure 3.16: The average physicians' benefits per simulation run obtained per quarter of the year after changing patients' location in the two-dimensional space and performing the simulation $s = 100$ times

This column diagram is based on the values submitted in the Table 3.11. The physician P_3 gets the most benefit while the health care cost for the services of the physician P_5 is the lowest.

The introduced Model of the Perfect Agency is the example of the simplified well-functioning health care system where all agents behave encouraged by unselfish purposes. The fact that this model is created as a framework for the following simulation of the different physicians' behaviour scenarios strongly shaped its structure. For example, an unusual timeline used in this model (i.e., the points in time reflect just the working days) is chosen in order to avoid the possible misinterpretation of the results which will be received after the model extension. If the weekends and holidays would be presented as the time steps without any medical action, it may lead to some additional delay in the expected duration of the treatment. As will be shown later, a similar time lag could be caused also by the selfish behaviour of the medical provider. The assumption that the presented model deals only with non-complicated theoretical problems (see A15, Table 3.3) is induced by the intricacy of the considering subject. The assertion that some physicians behave selfish (i.e., give priority to their own benefit rather than the patient's well-being) could be a very sensitive subject in several specific medical fields. The goal of the work is though to measure the influence of physician behaviour of the patient's health.

Chapter 4

Imperfect Agency and Income-Oriented Physician Behaviour: Theory and Empirical Evidence

Health economics have long recognised that perfect agency does not exist. First, there is no assurance that a physician will have all information he/she needs to act on the patient's behalf. Pauly 1980 notes that physicians may have more information about the provision of healthcare but the patient alone knows how much health he/she desires and what he/she prefers. Thus patients may be better informed about their health needs as physicians. Second, even if a physician and a patient were able to exchange all relevant information through perfect communication, the physician's professional knowledge would not always be sufficient to act on the patient's best interest. The provider's information about the patient's demand for healthcare and preferences do not repeal the medical uncertainty. Third, the physician's utility function may not coincide with the one of the patient. A physician could be not motivated to behave only on the patients' best interests and care for his own benefits. Moreover, the physician's superior information about the patients' health problems and dual role of providers and advisers of medical goods and services gives favourable conditions for a medical specialist to act as imperfect agent on his/her own behalf. And fourth, apart from the clinical uncertainty there are some other external drivers affecting physician practice patterns in various ways.

This chapter gives a closer examination of internal and external factors acknowledged as significant influences on the physician's behaviour in practice. It seeks to explain the physician's departure from the perfect agency more accurately. Following the goals of this work, the last two sections discuss the physician's behaviour when he/she acts as imperfect agent for the financial interest. A special attention is given to income-oriented physician's behavioural tendencies under prospective and retrospective payment systems.

4.1 Physicians' objectives

Physicians play an essential role in determining healthcare expenditures (Neuman and Shoshana, 2009). By acting as both provider and adviser for medical services and goods, a physician controls the quantity of the care delivered to a single patient and thus is responsible for the efficient use of each monetary unit invested in healthcare. Perfect agency leads to optimal health and economic outcomes and thus is the aimed feature of the medical system. Thus attempts have been made to find possibilities to diminish the deviation from the perfect scenario. For example, the effect of clinical uncertainty may be reduced by developing advanced equipment and medical theory. The communication issues of the physician-patient relationship are widely studied by psychologists: There is a lot of literature advising physicians about ways to build the patients' trust (e.g., Belzer, 1999). When it comes to the physician's imperfect behaviour caused by his/her own interests, a more detailed look should be taken at their objectives, i.e. what a physician seeks to achieve by practising medicine.

Various researches and physicians' surveys show that besides the patient's well-being, delivery of quality healthcare and desire to help others, physicians concern about their own income, leisure, professional reputation, professional interest, workload, controlling information and involvement in patient decision making as well as other factors (McGuire, 2000; Eisenberg, 2002). The two first physician's objectives are clearly compatible with perfect agency. The other mentioned aims, however, confirm that when practising medicine, physician have certain self-interests. In this way, the physician's objectives reflect on whose behalf (i.e., physician's or patient's) a medical provider is practising medicine (see Table 4.1).

The traces of influences on the physician's behaviour related to their own interests have been found by several researches investigating physician's practice pattern. For example, medical providers seem to have preferences in certain kinds of patients, medical problems, diagnostic tests and treatment methods (Eisenberg, 2002). There is a strong suggestion that the physicians' desire for income has impact on their provision of healthcare. The latter factor is particularly important for this thesis and will be extensively discussed in

Patient-oriented	Patient- and self-oriented	Self-oriented
• Patient's well-being	• Reputation • Desire to help people • Desire to provide quality healthcare	• Income • Leisure/Free time • Professional interest • Workload • Controlling information • Involvement in patient's decision making

Table 4.1: The main objectives of physicians

The main objectives of physicians. Besides concerning about the patient's welfare, a physician weights his/her income, leisure, professional interest, workload, ability to control information and seeks to be involved in the patient's decision making. These factors can be considered as self-oriented physician objectives. A provider's desire to help others and deliver quality healthcare as well as his aim to gain good reputation are serving on both physician's and patient's behalf.

Section 4.4.

Individual physicians attach different importance to their objectives. This prioritization depends on physician's personal characteristics such as age, financial situation, place of education, location and type of practice, ethical values as well as other (Bickerdyke et al., 2002). Although economists agree upon that a physician's objective function is mostly influenced by these attributes, there is very little empirical evidence to confirm this notion. There are several statistics representing certain behavioural tendencies related to specific physician characteristics but the physicians' objectives which caused these tendencies remain unclear. For example, young physicians are usually work more hours than physicians closer to retirement. This result could indicate that a fresh graduated physician has a strong desire to help others as well as high motivation to gain experience. On the other hand, an increase in working hours could also be associated with pressure from older colleagues, the efforts to ensure good career perspectives or, in case of fee-for-service reimbursement, with the physicians' desire for income. Thus, data researches usually are able to find certain correlations between specific factors, but cannot explain the reasons that cause the relations.

The fact that there are other factors than the patient's welfare which may be important for a medical provider is not surprising. It does not harm as long as the personal providers' goals harmonize with overall goals of the health system. The scenario presented in Chapter 3 showed that the physicians' interest in their income could give them additional motivation to deliver quality healthcare, satisfy the patient, gain good reputation and thus increase his/her practice and earnings. However, among the factors that define the physician's overall objectives, there is potential for conflict between the physicians' self-interests and, more importantly, between interests of physicians and those of the patient. For example, the physicians' preferences in leisure can come in expense of their income. In the extreme case, the physicians' desire for greater income may affect the patient's well-being in a negative way. As soon as certain physicians' decisions or/and actions have adverse impact on health and overall economic outcomes, the health system suffers from imperfect agency.

Under imperfect agency, physicians' and patients' utility functions differ but still have a common argument, i.e., patient's health. A medical provider acting as the imperfect agent maximizes his/her own utility U_{phys}. Physician objectives listed above are other possible arguments of this function.

4.2 External factors influencing physician behaviour

Perfect agency expresses the view that the patient (i.e. patient's clinical factors, demands, personal characteristics, economic situation, convenience and comfortability) should be the only internal and external influence on the physician's behaviour and decision making. The previous section revealed that the physician's behaviour could be also affected by his/her own objectives. The closer investigation of the physician's responsibilities to the patient presented in Chapter 2 exposed that perfect agency is also burdened by clinical uncertainty and defensive medicine as well as physician-patient communication problems (see Section 2.1). This section provides a detailed overview of these and other external factors that have impact on the physicians' behaviour and decision making in practice.

Health economists established a number of external drivers of physicians' behaviour and decision making (e.g., Bickerdyke et al., 2002). The most frequently discussed influences are:

- clinical uncertainty;
- defensive medicine;
- the patient (patient's personal characteristics, familiarity, medical condition, etc.);
- ownership structure of the physician practice;
- non-price competition;
- operating environment;
- physician-remuneration;

The level of their impact on the physician's practice pattern depends on the physicians' objectives and behaviour constraints. Correlations between the physicians' actions and the way they are reimbursed will be discussed in the next sections.

4.2.1 Clinical uncertainty and defensive medicine

Tolerance of uncertainty is an important physician skill. Clinical uncertainty (i.e. not knowing how to deal with patient-related problems) increases the physician's demand for more information about the patient's clinical situation. As result, medical providers prescribe and order additional medical services and thus boost the treatment costs (e.g., Allison et al. 1998). Anderson et al. (1995) showed that stress that providers experience in dealing with clinical uncertainty could affect the physicians' clinical performances in a negative way. Uncertain medical cases also force medical providers to make decisions relying on their professional experience, practice style, habit or even intuition (e.g., Hall, 2004). Unnecessary healthcare utilization could also be linked with positive defensive medicine. It occurs when a physician delivers or orders additional healthcare primarily to avoid malpractice liability (McClellan, 1996). A study in the United States showed that 37 percent of malpractice cases do not involve a medical error (see Studdert et al., 2006). Self-interested physicians would take into account the fact that the ordered additional medical service could defend them in malpractice lawsuit. Negative defensive medicine describes the practising style when physician avoids certain patients or medical problems chiefly out of concern for malpractice liability (McClellan, 1996). While additional medical care in most cases affects the costs and the physicians' income, reduction in healthcare utilization have a negative impact on patient safety and physician reputation.

4.2.2 Patient characteristics

Perfect agency assumes that knowing the patient's characteristics may help to understand and satisfy the patient's needs. In practice, however, certain information related to the patient could have a negative effect on the physician's behaviour. For instance, Williams et al. (2005) have found that patients from lower social classes seem to receive less information, directions and socio-emotional building utterances from their medical provider. Studies like this often suggest that patients are stereotyped by physicians as to their ability to understand the information and take a part in healthcare process (Ryan, 1994). In medical systems where the patients pay the physicians' fees themselves the disadvantageous behaviour with 'poorer' patients could also be related to their economic status and ability to pay. There is though no clear evidence confirming this interpretation.

Researches also established a correlation between certain patient's attributes and the patient's likelihood of being prescribed and having ordered medical services. For example, a study in Spain indicates that painkillers are more often prescribed to female than male patients (Chilet-Rosella et al., 2013). This work also showed that women in less gender-sensitive regions are less likely to be treated by a specialist, whereas men are more often referred to specific physicians. Some other studies found out that the physician-patient familiarity has an effect on the physicians' information giving and communication style (e.g., Bertakis, 1999).

Relying on logical considerations it can be presumed that the patient's medical condition indisputably plays a role in the conflict between physician's and patient's best interests. Bickerdyke et al. (2002) are pointing out that patients with minor medical problems have similar information level about the possible treatment as the physician has. In these cases, the physician has less scope to prescribe unnecessary healthcare in an attempt to receive additional income (see Section 4.4.2). Minor health problems are in general less costly and under prospective payment systems could possibly lead to an undersupply of provided care (Ellis and McGuire, 1986). A complex patient's medical problem should motivate a physician to concentrate solely on the patient's needs and ignore his/her self-interests. At the same time, serious conditions often are related with higher risks and a greater probability of practising negative defensive medicine.

4.2.3 Ownership structure of the physician practice

The physicians' behaviour and decision making can be shaped by the ownership structure of their practice (Bickerdyke et al., 2002). If the medical provider is a sole practitioner, he/she considers just his/her own objectives. In case of a group practice, the physician should take into account the objectives of his/her partners and the practice as a whole. Eisenberg (2002) notes that a physician as the member of a certain practice organisation could be also affected by the clinical leaders (i.e. other medical specialists who are particularity influential in determining the norms of practice style) or peer pressure.

4.2.4 Non-price competition and operating environment

In over-supplied medical markets physicians may face non-price competition. The suspicion that medical specialists compete for the patient's custom was detected by several research studies (e.g., Kassirer, 1995; Robinson, 1991). The results revealed that non-price competition has impact on the quality of healthcare, the overall costs as well as the amount and quality of information physicians provide to their patients.

The differences between the physicians' behaviour sometimes could be associated with the characteristics of their operating environment. The distribution of health infrastructure determines whether or not patients have access to other medical providers and thus possibly affects the provision of healthcare (Bickerdyke et al., 2002). For instance, physicians in rural areas are more integrated in community. Rural providers have a closer relationship with the patients but a community's and a provider's need often become intertwined (Warren and Smalley, 2014).

4.3 Physician behaviour constraints

When acting and taking decisions, a physician has only a certain degree of freedom. A medical provider's behaviour is controlled and restricted by medical ethics and the institutional as well as regulatory environment.

Medical associations in different countries define and apply certain codes of ethics which act as a professionally-based check on physician behaviour (Bickerdyke et al., 2002). For example, medical ethics in the United States is defined as 'the moral conduct and principles that govern members of the medical profession' (Dictionary for the Health Professions and Nursing, 2012). It is a system of moral principles which involve a wide range of issues from confidentiality, responsibility to inform the patient, end-of-life treatment as well as concern about the ethics in medical decision making (Anderson and Glesnes-Anderson, 1987). In terms of physician behaviour, medical ethics command physicians to do no harm and act in the patient's best interest and thus provide a constraint against exploiting the health and reimbursement system (Bickerdyke et al., 2002).

In many countries there are limitations on the physician's time spent for one medical case as well as the amount of medical services delivered or reimbursed to a patient per a certain interval of time (see, e.g., Richards and Rathbun, 1999; Solomon, 2008). That means that the physician's provision of healthcare is often restricted. Such constraints on the physicians' behaviour are necessary in order to control overall health expenditures. At the same time it limits the physician's ability to respond to the patients' demands and their actions based on self-interest. The deficiencies of an existing reimbursement system often are readjusted by certain laws. For example, the Physician Self-Referral Law in United States is designed to prevent an abuse in a fee-for-service payment system

(ASHA, 1989). The design of public or private insurance seeks to provide patients with little incentive to restrain their demand for medical services (Bickerdyke et al., 2002).

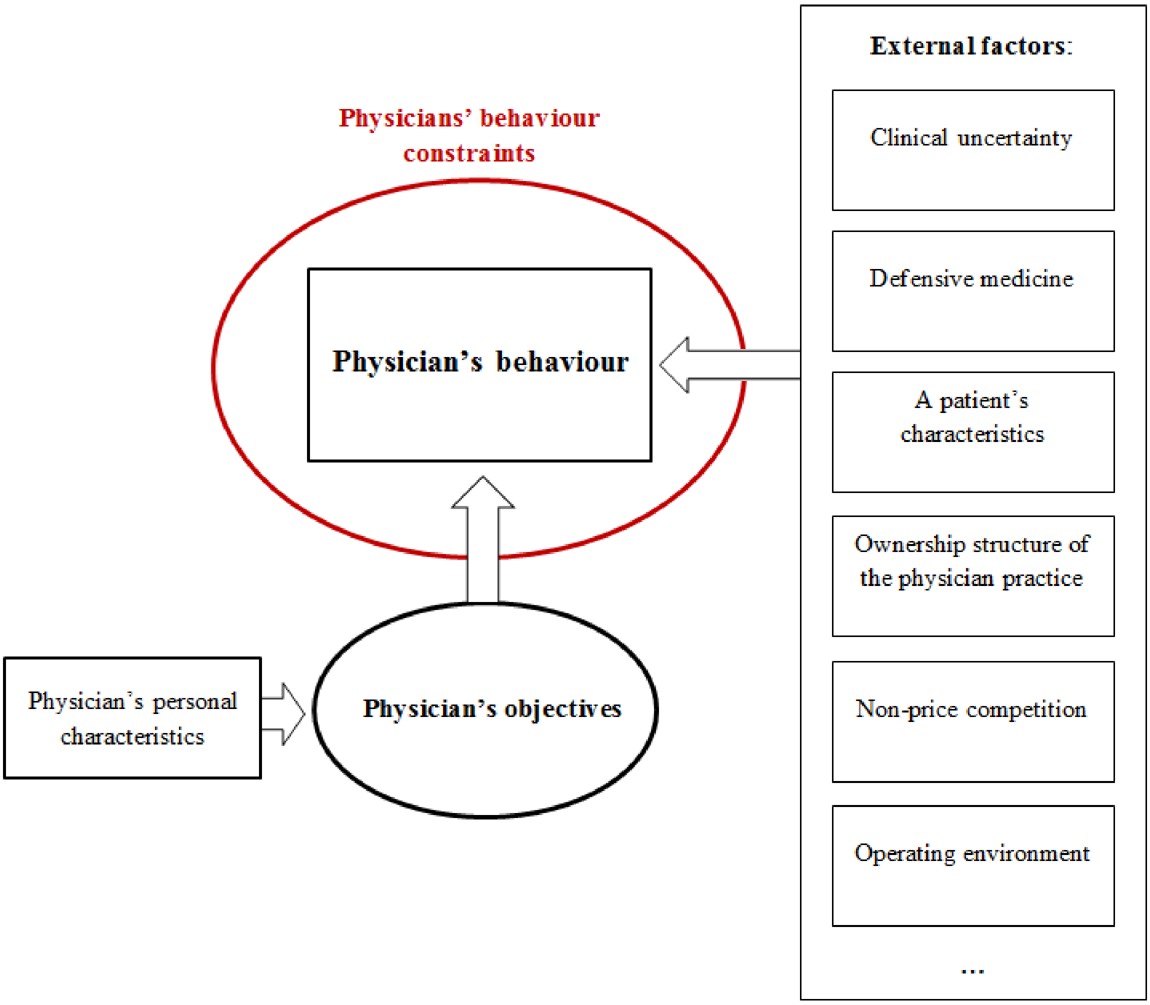


Figure 4.1: Main influences on physician behaviour

The way a physician acts strongly depends on his/her objectives defined by his/her personal characteristics. The provider's behaviour also is affected by various external factors such as clinical uncertainty, fear of malpractice claims, patient's characteristics, etc., and restricted by behavioural constraints (i.e., codes of medical ethics, ethics and institutional regulations).

4.4 Income-oriented physician behaviour

The notion that physicians' desire for money affects their practice pattern attracted particularly much attention among health economists. Income is the most 'selfish' physician objective. Other physician aims, such as desire to help others, good reputation or career prospective, are compatible or at least partly compatible with acting for the patient's behalf. Excluding the scenario presented in Chapter 2 when increase in income is achieved through perfect agency, the physician's seeking for greater earnings goes hand-in-hand with conflicts between physicians and the patients' best interest. Depending on the existing reimbursement system, the physician's desire for income could lead either to oversupply or undersupply of medical care and have impact on health costs. Based on existing literature and theories, the next two sections overview the possible physician behaviour encouraged by his/her desire for income under prospective and retrospective payment systems. The most striking - and most comparable with the model structure - behavioural tendencies will be integrated in the Model with income-oriented physician behaviour, presented in Chapter 5.

4.4.1 Prospective reimbursement system

Diverse works and articles presenting prospective reimbursement emphasize that this payment method is intended to motivate providers to deliver patient care effectively, efficiently and without over-provision of medical goods and services (ASHA, 2014). Under a prospective payment system physicians are reimbursed based on predetermined prices (Casto and Layman, 2006). For instance, in case-based payment, a physician gets a fixed fee for a certain medical case no matter of the type and amount of healthcare provided to the patient. Another prospective method, capitation payment, reimburses the physician for each assigned person: A provider gets paid a set amount for an individual per certain period of time, whether or not that person seeks care. Payment plans like these give an incentive for imperfect agents to treat the patients as briefly as possible and in the least costly way (Morris et. al., 2007).

This section aims to overview the possible behavioural tendencies of an income-oriented provider under the prospective reimbursement method. It particularly concentrates on financial incentives relevant in case-based payment. These include (Barnum et. al, 1995; Cashin et al. 2005):

- reduction in inputs per care;
- reduction in the length of the visit;
- increase of the number of cases;
- case selection (prefer the low-cost cases and avoid the costly patients);
- coding bias ('misdiagnosed' low severity patients with higher and more profitable

problems.

All listed profit maximizing strategies lead or could lead to undersupply of medical goods and services for certain patients or patient groups. Under-provision of healthcare is often mentioned as undesirable side effect of prospective reimbursement.

4.4.1.1 Undersupply of healthcare: reduction in medical input and length of stay

The suggestion that prospective payment may encourage the undersupply of healthcare is examined by several empirical studies. For example, Melichar (2009) investigated physicians' marginal responses to financial incentives by applying fixed effects regression on data from the survey of physician visits. She found that physicians spend less time with their capitated patients than with their non-capitated patients. The other work, presented by Hennig-Schmidt et al. (2011), introduced a controlled laboratory experiment to analyse the impact of incentives from fee-for-service and capitation payments on physicians' chosen quantities of medical services for patients with different states of health. The study revealed that the patients under prospective payment are underserved.

Ellis and McGuire (1986) presented a theoretical framework to understand the occurrence of under-provision of healthcare under prospective reimbursement. They developed a simple economic model in which physicians choose the level of services to be provided to their patients. The model investigates physician's behaviour when he/she either prefers his/her patient's best interest, or acts on behalf of the other provider (i.e., hospital).

In this model the revenue for patient care is described by a constant a, which is independent of the quantity of delivered services q:

$$R(q) = a.$$

The net revenue (i.e., profit) for one medical case is given by the revenue less cost:

$$\pi(q) = R(q) - C(q) = a - C(q). \tag{4.1}$$

Here C is the total cost which depends on the quantity q of the treatments.

The model assumes that the physician's utility function is seen as a function of hospitals profit $\pi(q)$ and the patient's total benefits from the treatment during the single episode

$B(q)$:

$$U_{phys} = U(\pi(q), B(q)).$$

That means that this model is restricted only to the patient's utility from health. Patients are assumed to passively accept the physicians' prescriptions. Ellis and McGuire use the profit optimization theory to maximize the physicians' utility function and derive the following condition (see Ellis and McGuire, 1986):

$$a \cdot b(q) = c(q).$$

Here $b(q)$ is a patient's marginal benefits and $c(q)$ stands for marginal costs. This condition should be interpreted in the following way: one additional medical service or good q provided by the physician would enlarge the patient's total benefits $B(q)$ by $a \cdot b(q)$ unit(s) and also cause the increase in hospital cost $C(q)$ by $c(q)$ unit(s). Accordance to the value of a, the health system faces the following scenarios:

- $a > 1$: the physician prefers patients' interests among the hospital's benefit;
- $a = 1$: the physician acts as the perfect agent (i.e., an increase in hospital's profit gives the same value as increase in the patient's benefits);
- $0 < a < 1$: the physician considers the patient's benefit from treatment, but the hospital's profit weights more;
- $a = 0$: the physician would prescribe the minimum acceptable level of treatment to maximize the hospital's net revenue $\pi(q)$.

The case when a lies between 0 and 1 could, e.g., encourage the physician to improve efficiency of the input mix. The behavioural tendency illustrated by case $a = 0$ may lead to skimping on necessary medical goods and services and, consequently, to under-provision of healthcare.

Although the presented model depicts a physician who may act on the hospital's best interests, a similar approach could be applied to private-practice physicians maximizing their own benefits. Under prospective reimbursement, the income-oriented physician would provide the minimum acceptable level of healthcare (i.e., reduce the medical input) and this minimizes the costs as well as the time invested per one medical case. The less time the physician spends on a single patient, the more patients he/she is able to treat and the greater the income. The possible side effect of this behavioural tendency is under-provision of necessary healthcare.

4.4.1.2 Cream skimming and dumping

As already mentioned above, under a prospective payment system, physicians seek to increase the volume of patients while keeping the minimal costs. This aim could be achieved in a direct way by reducing input, time and costs per care. In other words, physicians may increase their income by changing their practice pattern in caring for the current patients. Another approach suggests that physicians may enlarge their earnings by selecting more profitable patients.

Socha-Dietrich and Zweifel (2014) rely on works of Ma (1994), Newhouse (1996) and Ellis (1998) and state that, when selecting the patients, the medical provider may use two behavioural tendencies:

1) Cream skimming: preferring the patients with expected payment greater than expected cost;
2) Dumping: avoiding the patients with expected payment less than expected cost.

These strategies are encouraged by the physicians' desire for greater income and avoidance from excessive costs.

Cream skimming:

Restricting to prospective payment and assuming that more severe patients are more costly to treat, the cream skimming tendency manifests itself by over-provision of healthcare to low severity patients and under-provision of healthcare to patients with more complex medical problems (Ellis, 1998). For example, under case based reimbursement there is always a risk that a patient's treatment may be much costlier than the fixed predetermined fee for his/her medical problem (Ma, 1994; Newhouse, 1996). This risk gives physicians the incentive to prefer profitable, low severity patients over relatively severe medical cases (Newhouse, 1996). The treatment of low severity patients also often requires less of the physician's time and effort. Thus in prospective payment, income-oriented physicians have an incentive to 'cream' (i.e., over-provide) the patients for whom benefits of treatment may not exceed the cost, and 'skimp' (i.e., under-provide) the patients related to the risk of high costs (Ellis, 1998). As it will be discussed later, retrospective payment results in over-provision ('creaming') of healthcare to all types of patients payment system.

Dumping:

Ellis (1998, p. 538) describes 'dumping' as an "explicit avoidance of high cost patients". A physician who seeks to maximize the profit would clearly 'dump' the medical problems for which he/she lacks a cost advantage. Although this physician's behavioural tendency discriminates the high severity patients and is illegal in many countries, dumping may still occur in some less obvious forms. For example, a physician can reject the patient by claiming that he/she does not possess the necessary facilities (Ma, 1994), refer a costly patient to other providers or convince the severe ill individual to seek medical help somewhere else (Newhouse, 1996).

In the literature, both cream skimming and dumping are presented rather as theoretical possible profit maximizing strategies and not as the actual practising style. However, there are some empirical findings of these behavioural tendencies (see, e.g., Newhouse and Byrne, 1988; Newhouse, 1989; Ellis and McGuire, 1996).

4.4.1.3 Coding bias and other financial incentives

Under case-based reimbursement an income-oriented physician has an incentive to diagnose highly paid medical cases for the patients and code medical records to increase payments (Barnum et. al, 1995). This behavioural tendency is called bias coding (also known as the up-coding strategy). This problem is frequently found in the health systems based on diagnosis related group (DRG) payment (Silverman and Skinner, 2004). This case based method assigns different rates to the patients classified in certain groups according to their clinical profiles and requisite resources (Casto and Layman, 2006). For example, Coulam and Gaumer (1992) investigated the changes in coding induced by the change to DRG payment. The resulted increase in the severity of the reported mix of patients was greater than expected. Coulam and Gaumer established that the errors in coding were not random and always led to higher DRG rates. Depending on various factors (e.g., type of care, country, characteristics of health system, etc.) there exist different prospective reimbursement methods, such as line-item budget, global budget, per diem, etc. According to prospective method, income-oriented physician incentives can differ.

4.4.2 Retrospective reimbursement system

While there are relatively few studies on income-oriented physician behaviour under prospective payment system, physicians' opportunistic behaviour under retrospective reimbursement, especially under a fee-for services model, attracts wide attention from health economists. The retrospective method describes a physician reimbursement model where units of medical goods and services are individually priced. Consequently, the more units a healthcare provider delivers, the higher is his/her income. Under a retrospective payment system, physicians have financial incentives to provide as many medical goods and services as possible. The over-provision of healthcare caused by providers' financial interests is also known as supplier-induced-demand.

4.4.2.1 The hypothesis of Supplier-Induced Demand (SID)

In health economics, supplier-induced demand (SID), also known as physician-induced demand (PID), is assumed to exist "when the physician influences a patient's demand for care against the physician's interpretation of the best interest of the patient" (McGuire, 2000). The hypothesis of SID, formulated first by Evans (1974), reflects the suspicion that physicians are able to affect the patients' demand for health care services and goods according to their self-interests. The more precise definition of SID refers to the fact that medical markets are characterised by information asymmetry: the physician is assumed to have more knowledge about the kind and amount of health care necessary for treatment than the patient. For example, Donaldson and Gerard (1993, p. 107) define SID as "the amount of demand that exists beyond what would have occurred in a market in which patients are fully informed". Similarly, Pauly (1994, p. 370) describes the demand inducement as one with "alterations in the quantity and quality of services consumers demand as physicians change the accuracy of the information provided in response to economic incentives". Thus SID is essentially that medical specialists have and use their superior information to influence their patients' demand for medical care in order to create some additional demand for health services and goods. This behavioural tendency contradicts the concept of perfect agency and is a possible income-oriented physician strategy to increase his/her earnings under a retrospective reimbursement system.

4.4.2.2 SID: first empirical support and economic interpretation

One of the first recognitions that physicians are able to increase the utilization of medical services can be traced to the famous Roemer's Law which states that "a built bed is a filled bed" (Roemer, 1961). Roemer and his colleagues revealed a positive correlation between the number of hospital beds per person and the rate of days spent in hospital per person. This principle was thought to apply to physician services as well. A large number of subsequent researches in various medical fields have confirmed that a greater supply of physicians is concomitant with an increased utilisation of medical services such as hospitalization, surgery, office visits or diagnostic tests (Roos, 1984; Eisenberg and

Kicklin, 1981; Connel et al. 1981; Office of Technology Assessment, 1983). Such studies, based on simple or multiple regression analysis, are early empirical supports for the SID proposition.

Operationally, testing for the existence of SID implies investigation whether or not, as the supply curve shifts, there are corresponding shifts in the demand curve. The first who posed the 'Demand-Shifting Hypothesis' was Fuchs, who stated that SID deviates from standard economic analysis where supply and demand in any market are determined independently (Fuchs, 1978). Fuchs demonstrated the distinction between both theories graphically (Fuchs, 1978, p. 32). Graphic *A* (see Figure 30) illustrates the standard theory: An exogenous increase in supply (from S1 to S2) induces determination of the new equilibrium by moving down the constant demand curve D. On the contrary, SID theory asserts that given an analogous shift in supply, the physicians induce a shift in demand from D1 to D2 (see Graphic *B* in Figure 4.2).

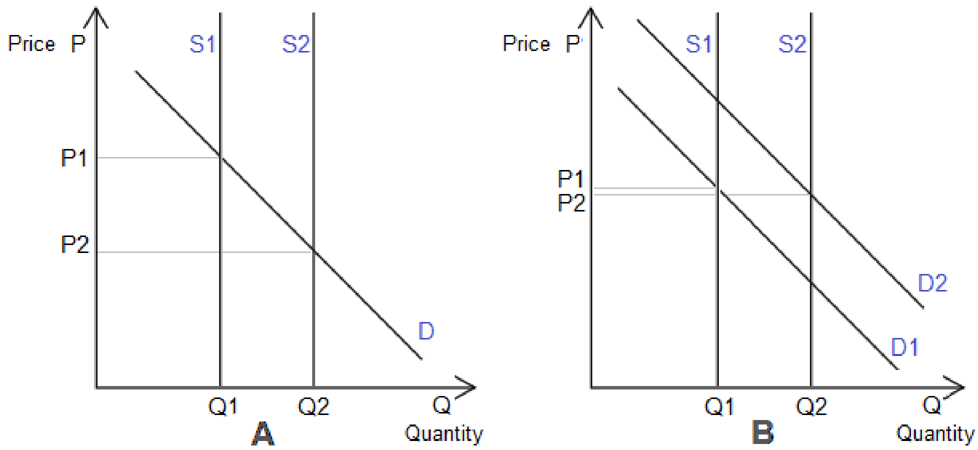


Figure 4.2: The standard theory vs. SID theory (adapted from Fuchs, 1978)

Graphic *A* illustrates the standard theory: An increase in supply from S1 to S2 leads to a lower equilibrium price P2 and higher equilibrium quantity Q2. Graphic *B* represents the phenomenon of SID: After changes in supply from S1 to S2 there are corresponding changes in demand from D1 to D2. This shifting of demand increases the quantity from Q1 to Q2 and thus smoothing the decrease in price from P1 to P2.

Health economists' approaches to the SID preposition differ greatly. They split into two groups called "narrows" and "broads"(Folland et al., 2004). "Narrows" represent economists who rely on standard economic analysis and challenge the phenomenon of SID. They argue that consumers in the health care market are sovereign as well as that supply and demand are independent (Feldman and Sloan, 1988; Green, 1986; Logan et al., 1989). The opponents of "narrows", "broads", are those who believe that SID is an important topic and could have significant consequences to government budget and society as a whole. For example, Reinhardt (1989) supports the 'Demand-Shifting Hypothesis' of Fuchs. He notes that in standard theory consumers are sovereign and production (volume and kind of goods) adapts to independent demand. If, however, demand is not independent and can be influenced by providers, it often leads to non-optimal allocation of resources. Evans (1974), Klarman (1965), Rice (1983) and Richardson (1981) also have a similar viewpoint that the consumer's sovereignty does break down and this creates the favourable conditions for supply inducement.

The difference between the "narrows" and "broads" approach to health care market could be explained graphically using the SID representation of Fuchs with sloped supply curves (see Figure 4.3). After an increase in supply of physicians from S1 to S2 'narrows' would expect a fall in prices from P1 to P2 and an increase in quantity demanded from Q1 to Q2. The demand D1 remains independent and does not change. Medical care is a type of service with inelastic demand and it induces a decrease in total spending. That means loss in patients and lower income for a physician.

"Broads" would interpret the same situation differently. They would use SID theory and predict that changes in the supply of physicians from S1 to S2 lead directly to an increase in demand from D1 to D2. In this case demand would not remain independent because of the physicians' decision to use their power and shift it out. Compared with the previous scenario, the fall in equilibrium price would be lower (P3) and the increase in the equilibrium quantity demanded greater (Q3).

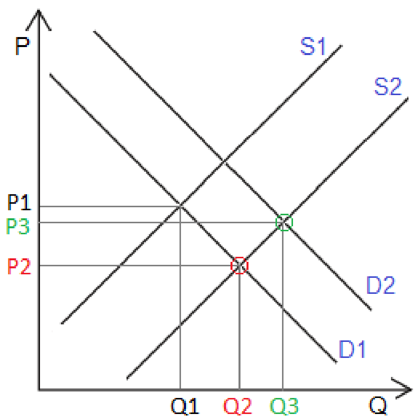


Figure 4.3: Graphical representation of SID: the viewpoint of "narrows" and "broads" (adapted from Bickerdyke et al., 2002)

After a supply shifting from S1 to S2, "narrows" expect to achieve the equilibrium defined by the lower price P2 and the greater quantity Q2 (see red circle) but no changes in demand. "Broads" rely on SID theory and predict the shifting in demand from D1 to D2. This change in demand helps to maintain the relatively high equilibrium price $P3$ in expense of the higher equilibrium quantity Q3 (see green circle).

On this point, it is important to understand the distinction between physicians' useful agency and selfish demand inducement. The definition of SID in relation to the consumer's optimal consumption point leaves the open scope for influence in the interest of the patient: the patient's 'movement' towards the consumer's optimal point encouraged by physicians' decisions and actions would rather be useful providers' agency than demand inducement (Glied and Smith, 2011).

4.4.2.3 Potential drivers of SID: empirical studies and developed models

There are three principal reasons permitting occurrence of SID. The first two are superior information on the part of physicians and specific characteristics of medical markets (see Section 1.3). The third important feature is the dual role of physicians in relation to their patients. Physicians act as both providers and advisers of medical services and this gives them additional motives and occasions for demand inducement (Zweifel et al., 2009). The concept of the dual role which often leads to a conflict of interests is also typical for some other sectors such as law or car repair services.

The most commonly cited motive to induce the demand for health care is physicians' self-interest. In this respect, the additional demand created by physicians is mainly driven by financial considerations. Such medical provider behaviour is linked to an imperfect agency relationship (Bickerdyke et. al, 2002).

The behavioural tendency where a medical provider deliberately delivers unnecessary health goods and services to the patients could be caused by various factors. Diverse studies show that in practice the demand inducement could occur as the result of a decrease in physician fees: Medical providers may use demand inducement to compensate the loss in income (e.g., Schwartz, 1981; Rice, 1983; Yip, 1998). However, the correlations between physician availability and utilisation rates are revealed even though fees do not drop (e.g., Fuchs, 1978). The strongest evidence of possible demand inducement are found in health systems where one reimbursement system was changed to another one that is more favourable for the occurrence of SID (e.g., fee-for-service) (e.g., van Dijk et al., 2013; Shigeoka and Fushimib, 2014).

Relying on the empirical results and seeking to better understand physician behaviour related to demand inducement, economists have developed several models. The three most important approaches will be shortly overviewed in the next paragraphs. For a more detailed discussion of these models see Folland et. al (2004).

<u>The Price Rigidities Model:</u>

One well-known model that explains demand inducement within the context of competitive markets is based on price rigidities. This model asserts that in a competitive market prices do not immediately respond to changes in demand or supply by dropping from their initial equilibrium. An excess supply that occurs as a direct result of such prise rigidities means that at least some physicians are not providing the quantities they would like to sell at current price. Therefore under advantageous circumstances they would clearly have intentions to induce additional quantities. While the physicians' ability to create additional demand depends on their responsibility for the patients, motives and the level of inducement are related to relative gains from the additional earnings versus the costs of the additional inducement activities. The time to convince patients to consume more and potentials loss of patients who notice non-optimal behaviour of their physician reveals as indirect costs.

The Target-Income Model:

The other significant and widely discussed model of SID refers to the target-income hypothesis. It proposes that physicians are concerned to maintain a certain level of income (target-income). If the current income falls below the target level, physicians have a reason to change their behaviour with the purpose to increase the income back up to the target level. This concept comes out when instead of an expected decrease in fees and incomes, increased physician availability leads to higher fees caused by willingness to maintain the earnings. In literature the target-income model is often used as a tool to explain rapid increases in physician fees which occur despite the hand-in-hand going increase in physician availability.

The Disutility of Discretion Model:

The Disutility of Discretion Model introduced by Evans (1974) is closely related to the target-income hypothesis and represents the physician as a utility maximizer. In this model the provider's utility is described by his/her net income Y, hours of work W and discretionary influence used in augmented demand D. Thus the physician's utility function could be expressed as:

$$U_{phys} = U(Y, W, D).$$

The main assumption of this model is increasing marginal disutility of augmenting demand. The Provider prefers to act as the perfect agent but in case of income reduction caused by competition, the physician may induce demand in order to reward the income loss. The more demand he/she induces, the greater is his/her displeasure. This displeasure is though weighted out with achieved greater income. The physician increases demand until the marginal utility of supplemental income equals the marginal disutility of the added work plus the marginal disutility of the discretionary influence.

Zweifel et al. (2009) draw attention to the fact that there are conditions that facilitate the inducement of demand. He and his colleges accentuate comprehensive health insurance and risk-less medical technology as the most important ones. If patients are fully insured for the cost of medical treatment (e.g., in Austria cost of medical services are close to 100 percent covered by the public insurance) their consumption of services is not limited due to personal financial issues. In this case the only relevant cost concomitant the consumption of medical services is the time cost. In respect of the riskless medical technology, it implies that providing more of a certain medical service than is necessary does not harm. If physicians have this kind of services at their disposal, they could have fewer scruples about inducement of some additional demand.

4.4.2.4 The identification problems of SID

The question whether SID in actual fact exists in physician practice patterns has been concerning researchers for a long time. Although previously mentioned studies showing correlations between physician availability and utilization rates are consistent with SID theory, these correlations are as well compatible with standard economic analysis: in standard theory the higher utilization also leads to fall in price and increase in quantity demanded of physician services (Folland et al., 2004). Researchers also argue that established correlations between supply and utilisation in the health care sector do not necessarily point to a causal effect (McPake et al., 2002). For example, physicians may settle in areas where demand for medical services is high, patients may choose popular physician practices because of their good reputation or demand may be high where fewer services are offered. Nevertheless, a large variety of researches in different countries encouraged the presumption that the connection between higher supply of medical services and increase of utilisation in some cases might be explained by the phenomenon of SID.

The literature emphasizes that the main problem related to evidence on SID is that in spite of various empirical researches in many countries, SID still lacks a definitive test and it is very difficult to evaluate it (Bickerdyke et al., 2002). For the most part, it is depend upon the fact that SID can only be estimated indirectly and the health care market is characterised by government interventions, which may affect the underlying data. It is important to mention that in many empirical works the SID effect cannot be econometrically identified. This issue, better known as identification problem, is more specifically described in “The economics of health and health care“ by S. Folland et al. (2004).

SID is difficult to identify also in practice. Physicians’ behaviour and practice patterns suggesting the occurrence of SID may be consistent with appropriate medical treatment (Bickerdyke et al., 2002). As presented in Section 2.1, a physician could provide additional goods and services because of clinical uncertainty or in an attempt to protect him/her from possibility of malpractice suits. Therefore, the delivery of additional health care to the patients does not necessarily reflect a physician’s intent to induce demand. However, if the changes in provided medical goods and services are observed under retrospective reimbursement system, e.g., after reduction in physicians’ fees or changing the reimbursement method, there is a strong suggestion that physicians are inducing demand.

4.4.2.5 Overview

The assumption that a physician, being a perfect agent for the patient, takes exactly the same decisions the patient would have chosen if he/she had the same information and knowledge the physician has disregards the medical providers’ objectives, market power and other external factors which affect physician behaviour. Besides a patient’s welfare, according to his/her personal characteristics and values, the medical specialist also weights his/her income, leisure, workload, professional interest, reputation and other personal objectives. The physician’s behaviour could be as well influenced by medical uncertainty, fear of malpractice suits, patient’s characteristics, ownership structure of the physician practice, competition with other providers and operating environment. The provider’s actions are controlled and restricted by ethical codes as well as the institutional and regulatory environment.

When it comes to physicians’ desire for greater income, there is a strong suspicion that the providers intend to exploit the reimbursement system for their own benefit. Under a prospective payment system, especially, under a case-based method, additional earnings may be achieved by reducing inputs per care, reducing the length of the visit and thus increasing the volume of patients. Prospective reimbursement also gives physicians incentives to select more profitable patients and ’misdiagnose’ individuals with more expensive medical problems. The possible side effects of income-oriented physician behaviour under a case-based payment system are an undersupply of medical goods and services and a decrease in quality of health care. Under retrospective reimbursement providers have a financial incentive to provide as many medical goods and services as possible and thus affect the patients' demands for health care. If inducement of demand is a common feature of physician practice patterns, its negative impact on the health expenditures could be significant.

Income-oriented physicians' behaviour could result in a higher than necessary share of the nation's resources being assigned to the health care sector or deterioration in state of health of some patients happened due the non-optimal treatment (Bickerdyke et al., 2002). In some cases physicians' decisions and actions motivated by their desire for income can also have positive outcomes when the changes in treatment applied by medical providers are the more effective package of care for a patient. However, the model presented in the next chapter income-oriented physicians' behaviour has no impact on the quality of health care but does affect health expenditures. This assumption reflects the ethical consideration that a provider's financial incentives should have no impact on his/her serving as the patient's clinical agent.

Chapter 5

Simulation of the Model with Income-Oriented Physician Behaviour

This chapter presents the simulation of income-oriented physician behaviour under certain limitations on the physician actions. Assuming that the medical provider characterised by desire for greater income still acts as the patient's clinical agent or at least does not provide the health care which harm the patient's health, four different income-oriented behavioural strategies are integrated into the simplified health care system defined in Chapter 3. These strategies illustrate the different theoretical possibilities to gain more income under a fee-for-service and case-based reimbursement methods.

5.1 General model assumptions

For the set of all physicians $\mathbf{P} = \{P_1, \ldots, P_p\}$ define two index sets **P1** and **P2**. The elements of the set **P1** are indices of the medical specialists, who behave as the perfect patient's agents (i.e., act as in the Model with the Perfect Agency). The set **P2** includes the indices of the physicians described by opportunistic behaviour. Under the certain circumstances, these medical specialists follow their financial incentives and for this reason are called as income-oriented physicians. In other words, while the set **P1** indicates the perfect agency, the physicians 'collected' in the set **P2** are the imperfect patient's agents. The main assumptions on the income-oriented physician and his/her aims related to the income are discussed in the following subsections.

5.1.1 Income-oriented physician

The model with the income-oriented physicians' agency is built on the basis of a simplified health system presented in Chapter 3, i.e., the structure, the components and the dynamics of the previously introduced model remain unchanged. There is, though, one essential modification in the model assumptions related to the medical providers' behaviour. The assumption of all operating physician agents being the perfect agents for their patients is no longer relevant (see assumption A13 Table 3.3, p. 33). In the extended model, some medical providers are willing to behave as the income seekers and thus, under certain minimal assumptions on the limitations of the opportunistic physician behaviour, are 'allowed' to use the possible methods to gain more financial benefit. All other assumptions given in the Table 3.3 remain the same. The summarised model assumptions on the income-oriented physician are given Table 5.2.

The imperfect agent $P_i, i \in \mathbf{P2}$ affects the supply of medical services only if he/she experiences a loss in the income caused by a 'shock' in the health system. Chapter 4 discussed the existence of the empirical evidence about the changes in the physician practice pattern after reduction in their fees. Thus, this circumstance (i.e., reduction in physician fees at the time step t_r) is considered as the cause of the opportunistic physician behaviour which is integrated into the model: the income-oriented medical providers try to compensate the loss in their income rather than maximize their earnings.

A physician agent characterised by income-oriented behaviour is seen as a self-interested medical provider aiming for the target income TI received before the change in the physician fees. As will be described in the next section, the physician $P_i, i \in \mathbf{P}$ aims to increase his/her earnings per quarter of the year by $\Delta q I_i$. The provider tries to gain this amount by using certain possible methods available under the existing reimbursement system. These methods are assumed to have no adverse influence on the patient's health. That means that the medical provider, who acts as the imperfect agent, still cares for the ordinary individuals' medical needs and delivers all necessary health goods and services to the patients. However, he/she clearly pays no regard to the patient's 'invisible' costs (e.g., transportation costs), the time costs and the individual's convenience. Therefore, the income-oriented physician $P_i \in \mathbf{P2}$ cannot be described as the perfect patient's agent as it was presented in the Chapter 2, but he/she still acts as the patient's clinical agent.

The chosen representation of the physician $P_i \in \mathbf{P2}$ as the target income seeker rather than income-maximizer is more realistic. It reflects the fact that the physician's $P_i \in \mathbf{P2}$ utility function U_{Pi} depends not only on his/her income I_{Pi} and the patient's health H, but also has other arguments such as the physician's leisure, workload, etc. (see Table

5.1).

Utility function of $P_i, i \in \mathbf{P1}$	Utility function of $P_i, i \in \mathbf{P2}$
$U_{Pi} = U_{pat} = U(W)$	Before the reduction in physician fees: $U_{Pi} = U_{pat} = U(W)$ After the reduction in physician fees: $U_{Pi} = U(I_{Pi}, H, X)$

Table 5.1: The utility functions of the perfect patient's agent and income-oriented physician

The physician $P_i, i \in \mathbf{P1}$ who acts purely on the patient's behalf considers only the patient's well-being W. Utility of the income-oriented medical provider $P_i, i \in \mathbf{P2}$ depends on his/her income I_Pi, the patient's health H and other factors X such as the physician's leisure, work-life balance, etc.

Assumption ID	Subject	Description
A13a	The income-oriented physician	The opportunistic physician's behaviour is caused by reduction in physician fees
A13b		The physician is a target income seeker
A13c		The target income are intended to be achieved by using certain possible methods available under the existing reimbursement system
A13d		The physician still acts as the clinical patient's agent

Table 5.2: The assumptions and limitations of the Model with the Income-Oriented Physician Behaviour

This table contains the main assumptions on the income-oriented physician behaviour. These assumptions replace the assumption A13 in the Table 3.3 (Chapter 3, p. 33). The other major foundations for the presented health care system given in the Table 3.3 remain relevant.

In the real health systems, the income-oriented provider who constantly enlarges his/her earnings would receive a response from the patients and the payer. These factors are not directly included into the model. The integration of the patient's and payers reaction to the opportunistic physician's behaviour would require more detailed specification of the health care system and an additional literature research in regulation methods for the medical markets. The different scenarios of the income-oriented physician behaviour though considers several other limitations related to the physicians' available resources and occupation level.

5.1.2 The target income

If the provider's $P_i, i \in \mathbf{P}$ occupation level before and after the changes in physician fees remains resembling, the reduction in physician fees causes the decrease in his/her income. Assume that this loss in the physician's earnings per quarter of the year Q is equal to

$$\Delta qI_i = qAI_i^{\star} - qAI_i \tag{5.1}$$

where $qAI_i^{\star}$ and qAI_i are the average physician's income received before and after the reduction in the fees.

While the perfect agents $P_i \in \mathbf{P1}$ accepts the loss in earnings by ΔqI_i and does not change his/her practice pattern, the income oriented physician $P_i \in \mathbf{P2}$ seeks to maintain the same income level $qAI_i^{\star}$. Therefore, the physician's $P_i \in \mathbf{P2}$ target income per quarter Q is given by

$$qTI_i = qAI_i^{\star}. \tag{5.2}$$

This value is determined after running the perfect scenario (i.e., the Model with the Perfect Agency) for all given agents s times:

$$qTI_i = qAI_i^{\star} = \sum_{i=1}^{s} \frac{aqInc_i}{s}. \tag{5.3}$$

Here qTI_i is physician's $P_i \in \mathbf{P2}$ target income per quarter Q, $qAI_i^{\star}$ defines the physician's income level received before the reduction in physician fees and $aqInc_i$ is the average physician's income per quarter Q gained per one simulation run.

When seeking the target income per quarter Q qTI_i, the provider behaves based on his/her income expectations. These expectations are considered as the physician's $P_i \in \mathbf{P2}$ perceived income PI_{ti} at the time step t. This indicator is defined as:

$$PI_{ti} = \mathbb{E}(I_{ti}) = PI_{(t-1)i} + \frac{AI_{(t-1)i} - PI_{(t-1)i}}{r}. \tag{5.4}$$

Here $\mathbb{E}(I_{ti})$ is the physician's income expectations on the day, $PI_{(t-1)i}$ describes his/her perceived income on the previous day, $AI_{(t-1)i}$ is the provider's actual income (i.e., the income from the optimal delivery of the health care) and r is a delay time. This approach expresses the viewpoint that the physician perceives changes in his/her daily income not immediately but after a certain delay in time.

On the day $t \in \{t_r, \ldots, t_{max}\}$, the physician's $P_i \in \mathbf{P2}$ behaviour depends on the difference between his/her target income TI_{ti} and perceived income P_{ti}. It is based on the following *Target Income Condition*:

- If $\Delta I_{ti} = TI_{ti} - PI_{it} < 0$ (i.e., the provider's perceived income on the day t is greater than his/her target income), the physician does not deviate from the optimal provision of health care. The physician's charged amount per this day is equal to:

$$I_{ti} = AI_{ti}.$$

- If $\Delta I_{ti} \geq 0$, the income-oriented physician behaves opportunistic and increases his/her income by ΔI_{ti}:

$$I_{ti} = AI_{ti} + \Delta I_{ti}.$$

From this condition follows that the provider's $P_i \in \mathbf{P2}$ income qI_i in the end of a quarter Q which starts with a time step $t = Qbegin$ and ends with $Qend$ is equal to:

$$qI_i = \sum_{t=Qbegin}^{Qend} I_{it} = \sum_{t=Qbegin}^{Qend} AI_{it} + \sum_{t \in t: \Delta I_{ti} \geq 0} (T_{Iti} - PI_{ti}). \tag{5.5}$$

The effect of the target income condition applied in the Model with the Income-Oriented Physician is represented in the figures 5.1 and 5.2. These plots illustrate the physician's opportunistic behaviour indicators and the alternation in the provider's income during the simulation run of the years 2013 – 2014. After one year (i.e., on the time step $t = 252$), physician fees were reduced by 30%. As can be seen in the Figure 5.1, starting from this time step, the physician behaves opportunistically. The red line reflects the physician's target income per day, which in this case is equal to 60 Euro. The green line shows the changes in the provider's actual income over time that he/she would get by delivering optimal care. The physician's perceived income for optimal care over time is pictured by the blue line. Figure 5.1 indicates that the provider's income expectations vary in delay with the changes in his/her actual income from optimal care. Figure 5.1 displays the comparison of the physician's benefit under perfect agency and the received income due his/her opportunistic behaviour. In every time step t, the difference between these two different indicators is equal to ΔI_{ti}. It can be observed that the physician's gained income (see black line in Figure 5.2) is practically not affected by the reduction in physician fees. It confirms that the strategy described by the Target Income Condition allows an income-oriented physician to maintain his target income level.

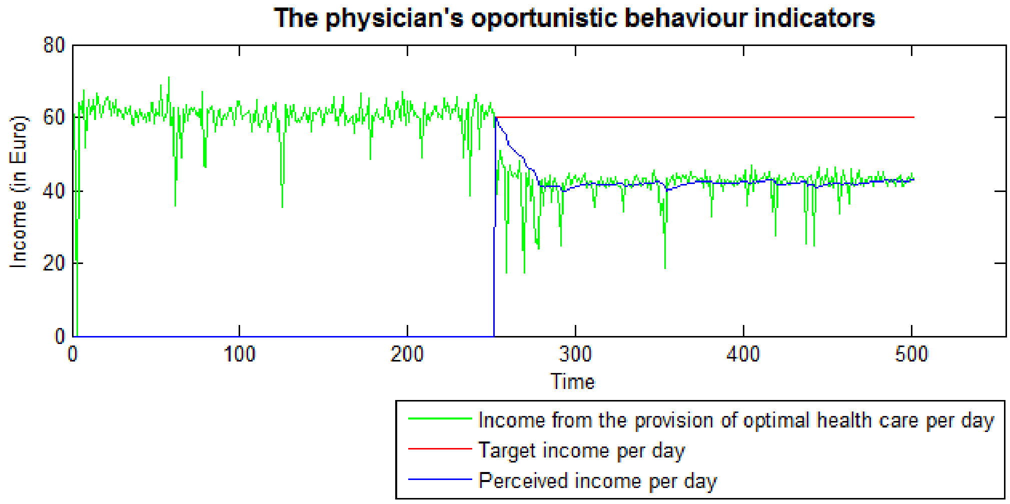


Figure 5.1: The physician's opportunistic behaviour indicators

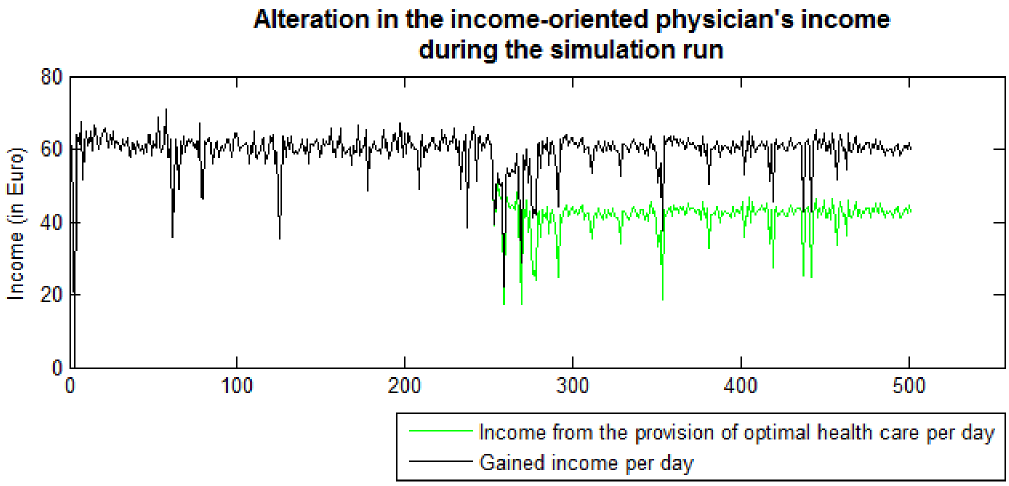


Figure 5.2: The physician's opportunistic behaviour indicators

5.2 Simulation of the income-oriented physician behaviour

This section is devoted to the integration of the income-oriented physician's behaviour into the simplified health care system introduced in the Model with the Perfect Agency.

For this purpose, the model presented in the Chapter 3 is extended with the simulation of four different scenarios:

1) **Scenario 1**: Affecting the provision of medical services under a fee-for-service reimbursement;
2) **Scenario 2**: Additional patient visits under a fee-for-service reimbursement system;
3) **Scenario 3**: An intentional misdiagnosis under a case-based reimbursement system; and
4) **Scenario 4**: Decreasing the number of patient visits under a case-based reimbursement system.

The empirical evidence on the income-physician's behavioural tendencies discussed in the section 4.4. indicates that the provider $P_i \in \mathbf{P2}$ may use the strategies 1) - 4) to achieve the target income qTI_i. The simulation of these strategies aims to investigate the influence of the opportunistic physician behaviour limited by the assumptions A13a - A13d given in the Table 5.2 on the health costs. In this attempt, the financial outcomes are compared with the results which would be obtained under the perfect physician's agency. All four scenarios are applied to the health system described in the next section. The target income value is calculated based on the statistics received from the simulation of the Model with the Perfect Agency for the year $2010 - 2013$ $s = 100$ times. The chosen simulation duration after reducing the physician fees is one year starting with 1st of January 2014.

5.2.1 Model initialisation: the simplified health system

Consider the health care system consisting of $n = 400$ ordinary individuals and $p = 6$ physician agents. The individuals operating in this system can get one of $d = 4$ medical problems with predefined IDs D_ID_j, the fix predetermined fee for the treatment $CFix_j$, the average cost for all medical services provided during the treatment $aCms_j$, the average number of all necessary patient visits caused by this problem av_j and the number of days between two patient visits $days_j$ and the category Dcg_j. The information is given in the Table 5.3). The chosen parametrisation is based on the Example No. 1 introduced in 3.3.1.1.

The chosen initial values of the physician's $P_1, \ldots, P_6$ attributes are illustrated in the Table 5.4. As can be seen in the column **Pi_D**, each medical problem D_j, $j \in \{1, \ldots, 4\}$ is assigned to two medical providers. Moreover, last two columns show that one of these

D_ID_j	$CFix_j$	$aCms_j$	av_j	$days_j$	Dcg_j
1	55	15	4	2	1
2	35	5	3	3	2
3	40	10	3	4	2
4	70	30	4	4	3

Table 5.3: The attributes of $d = 4$ medical problems defined in Scenario 1, 2, 3 and 4.

specialists is described by income-oriented behaviour and the second one is the perfect patient's agent. Thus: $\mathbf{P1} = \{2, 3, 5\}$ and $\mathbf{P2} = \{1, 4, 6\}$.

P_ID_i	Pcg_i	**Pi_D**	**P1**	**P2**
1	3	4	0	1
2	1	1	1	0
3	2	2 and 3	1	0
4	1	1	0	1
5	3	4	1	0
6	2	2 and 3	0	1

Table 5.4: The main information about the medical providers operating in the Scenario 1, 2, 3 and 4.

The information represented in this table reveals that the physicians P_1 and P_5 both are serving the patients suffering from the medical problems D_4. Respectively, P_2 and P_4 are specialised to treat D_1 as well as P_3 and P_6 are responsible for D_2 and D_3. It is Assumed that physicians P_1, P_4 and P_6 are income-oriented and will affect the prices in provided medical services.

The critical probabilities to get diseases and disorders follows the Beta(5, 0.1) distribution. The relevant shape parameters of Beta distribution were selected in order to obviate waiting list problems caused by too many ill individuals in the system at the same time. As presented in Chapter 3, these values directly affect the number of individuals who get ill per time step.

The agents are randomly located in the model environment of size 20 x 20 (see Figure 5.3). In order to compare the simulation results, this physician and patient distribution as well as the same critical probabilities for getting certain medical problem assigned to patients at the time step t_0 are used in all four income-oriented physician behaviour scenarios.

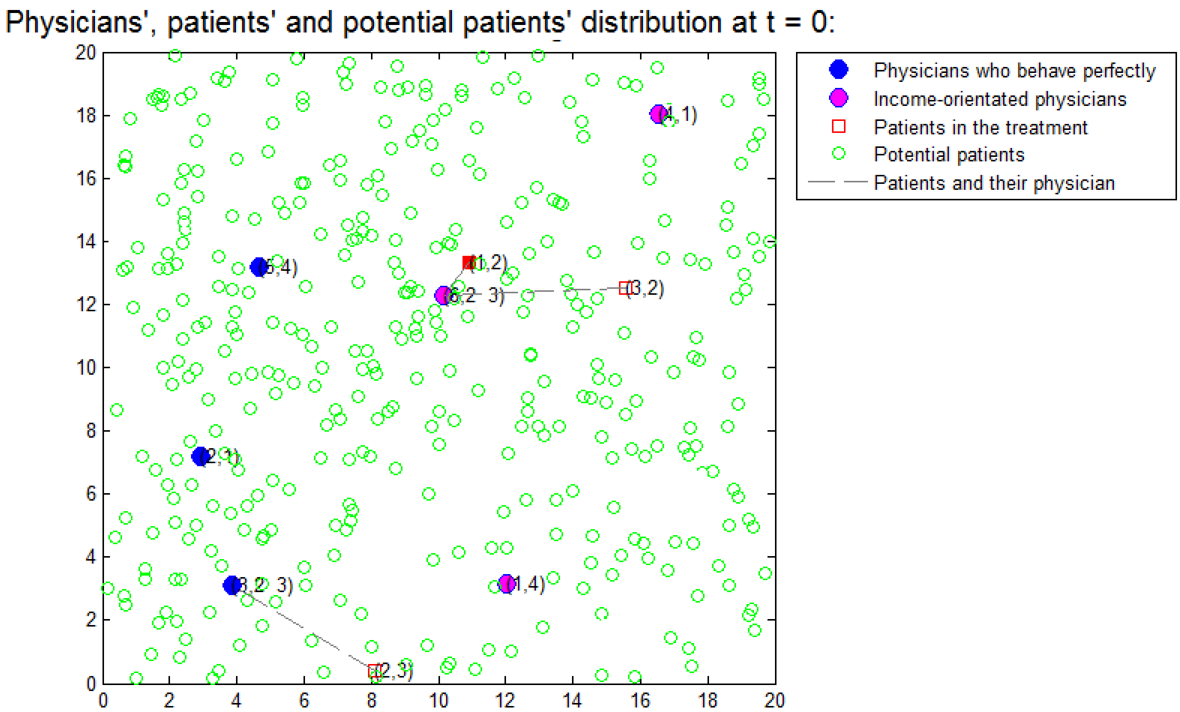


Figure 5.3: The distribution of physicians and ordinary individual agents in the model environment at t_0

5.2.2 The perfect scenario

Considering the agent distribution illustrated in Figure 5.3 and the same critical probabilities in each of $s = 100$ runs, the simulation of the model with the perfect agency (i.e., assuming that all physicians $P_i, i \in \mathbf{P2}$ act as perfect agents of their patients) for the year $2010 - 2013$ provides the following average results per quarter Q:

$\mathbf{P\_ID_j}$	$\mathbf{D_{j100}}$	$\mathbf{aD_j}$	$\mathbf{aFFSQ_{100}}$	$\mathbf{aM2Q_{100}}$	**aPvisit**	$\mathbf{TI_t}$
1	69.85	70	4157.75	59.52	246.48	66.52
2	55.19	55	4049.64	73.37	294.12	
3	37.59	37.5	3862.52	102.75	305.22	
4	54.53	55	3591.89	65.87	263.48	57.47
5	69.49	70	5243.02	75.45	302.82	
6	37.24	37.5	3781.18	101.53	308.29	60.50

Table 5.5: The perfect scenario: the average simulation results per quarter Q

This table provides the average values per quarter Q determined after 100 simulation runs assuming that all physician acts as the perfect patient's agents. These include: the physician's ID $\mathbf{P\_ID_j}$, the benefit per medical case $\mathbf{D_{j100}}$, the cost per medical case assigned to the medical problem in the model initialisation $\mathbf{aD_j}$, the total benefit $\mathbf{aFFSQ_{100}}$, the number of the patients who ended the treatment by their medical provider $\mathbf{aM2Q_{100}}$, the number of patient visits **aPvisit** and the income per day $\mathbf{TI_t}$. The costs are evaluated under fee-for-service payment system.

The results show that the physician's $P_i, i \in \mathbf{P2}$ (see $\mathbf{P\_ID_j}$) average benefit $\mathbf{D_{j100}}$ per single medical case is similar to the average cost for medical problems **aDj** assigned to each medical problem $D_j, j \in \{1, \ldots, 4\}$ in the model initialisation. The slight deviation between $\mathbf{D_{j100}}$ and **aDj** could be explained by the random generation of av_{jl} and Cms_{jl} (i.e., the average number of all necessary patient visits caused by $D_j, j \in \{1, \ldots, 4\}$ and the average cost for all medical services provided during the treatment of $D_j, j \in \{1, \ldots, 4\}$) used for the cost evaluation for the fee-for-services reimbursement. The column $\mathbf{aFFSQ_{100}}$ gives the physician's average total income per Q. The values of $\mathbf{TI_t}$ are equal to physicians' average total benefit $\mathbf{aFFSQ_{100}}$ per Q divided by the average number of the patients who ended their treatment per Q. This parameter is calculated only for the income-oriented physicians P_1, P_4 and P_6. In the following scenarios $\mathbf{TI_t}$ will be used the physicians' target income per day.

5.2.3 The reduction in physician fees

The model assumes that at the beginning 2014 the physician fees are reduced by C_{red} %. This change in costs affects the corresponding case-based and fee-for-service payment systems in the following way:

- $CFix_j$ (i.e., fix predetermined fee for the treatment of $D_j, j \in \{1, \ldots, d\}$ used under the case-based reimbursement) is decreased directly. The new fee after the cost reduction for each physician is evaluated by

$$CFix_j\_new = \frac{CFix_j \cdot C_{red}}{100}. \tag{5.6}$$

- Under the fee-for-service reimbursement, the cost per patient visit *Cvisit* is reduced by C_{red} %:

$$Cvisit\_new = \frac{Cvisit \cdot C_{red}}{100}. \tag{5.7}$$

  The average costs for all medical services provided during the treatment of $D_j, j \in \{1, \ldots, d\}$ are evaluated as follows:

$$aCms_j\_new = CFix_j\_new - Cvisit\_new \cdot av_j. \tag{5.8}$$

In this way, the *(3.2) Cost condition* is satisfied, i.e., a medical provider reimbursed under the case-based method becomes about the same benefit as under the fee-for-service payment system.

5.2.4 Scenario No. 1: Affecting the provision of medical services under a fee-for-service reimbursement

The theory of supplied-induced demand suggests that under a free-for-services reimbursement system a physician may receive the greater income by influencing demand for medical services and goods. In the context of the health system introduced above, when seeking for target income, the income-oriented physician would affect the cost for the medical services provided during the patient's treatment.

5.2.4.1 Assumptions

In the Model with the Perfect Agency (see Chapter 3), the sum of all medical services delivered during the treatment of a patient $M_l, l \in \mathbf{M2}$ are charged by amount Cms_{lj}. For each income-oriented medical provider $P_i, i \in \mathbf{P2}$ define a set $\mathbf{R_{ti}} = \{M_l \mid l \in \mathbf{M2}\}$ of all patients $M_l, l \in \mathbf{M2}$ visiting the physician $P_i, i \in \mathbf{P2}$ on the day $t \in \{1, \ldots, t_{max}\}$. Accordingly, the other set $\mathbf{R\_new_{ti}} \subseteq \mathbf{R_{ti}}$ includes all new patients on this day. These sets have a variable cardinality, i.e., the elements of the set $\mathbf{R_{ti}}$, $\mathbf{R\_new_{ti}}$ changes with every time step.

After reduction in physician fees on the day $t_r \in \{1, \ldots, t_{max}\}$, the new fees are equal to:

$$Cvisit = Cvisit\_new,$$

$$Cms_j = Cms_j\_new.$$

Taking into account the parameters and variables described above or used in the Model with the Perfect Agency, Scenario 1 presents two possible approaches to the physicians' ability to influence the costs Cms_{lj}. The increase in the costs indicates either the provision of an extra medical service or the alteration in the service mix by changing the usual services with more expensive units.

1) **Scenario 1 A**

   Assume that per every patient visit, all services provided to the patient $M_l \in \mathbf{R_{ti}}$ are charged by:

$$vCms_{lj} = \frac{Cms_{lj}}{v_{lj}}. \tag{5.9}$$

Here v_{lj} is the number of all visits necessary for the treatment of the patient's medical problem $D_j, j \in \{1, \dots, d\}$.

If on the day $t \in \{t_r, \dots, t_{max}\}$ the physician's $P_i, i \in \mathbf{P2}$ perceived income is below the target income level, i.e., $\Delta I_{ti} \geq 0$, the income-oriented provider intends to achieve the income ΔI_{ti} by increasing the cost of health care $vCms_{lj}$ provided to his/her patients $M_l \in \mathbf{R_{ti}}$.

Since the model is limited to non-complicated medical problems, the physician can be assumed to have no preferences in specific patients or diseases. When applying this assumption straightforwardly, on the day $t \in \{t_r, \dots, t_{max}\}$ the amount ΔI_{ti} could be gained by extra charging each patient $M_l \in \mathbf{R_{ti}}$ by

$$\Delta_{ti} vCms_{lj} = \frac{\Delta I_{ti}}{\mathbf{R_{ti}}}. \tag{5.10}$$

Thus, at the end of the treatment a patient $M_l \in \mathbf{R_{ti}}$ can be unnecessary charged by a maximum of:

$$\Delta_i Cms_{lj} = \sum_{t \in \mathbf{Tvis_{lj}}} \Delta_{ti} vCms_{lj}$$

where the set $\mathbf{Tvis_{lj}}$ collects the days t of the patient visits v_{lj} designated to the patient $M_l \in \mathbf{R_{ti}}$.

2) **Scenario 1 B**

In a real world, the physician has a limited choice of the quantity and the type of services he/she is willing to prescribe to the patient in order to increase his/her income. Usually, the medical provider has a greater degree of freedom when it comes to the patients with more complex states of health. Since the ill individuals have different characteristics, the physician also would rather prescribe different quantity and the type of services to different patients.

Assuming that the longer duration of the treatment indicates the more complex patient's state, the income-oriented physician behaviour related to the costs of the medical services could be modelled as follows:

On the day $t \in \{t_r, \dots, t_{max}\}$, the patients $M_l \in \mathbf{R\_new_{ti}}$ have their first visit to the physician $P_i, i \in \mathbf{P2}$. Because of random generation of the parameter v_{lj}, some of these patients have the health state which requires shorter as the average duration of the treatment (i.e, $T_{explj} \leq T_{expj}$). Therefore, if $\Delta I_{ti} \geq 0$, the physician $P_i, i \in \mathbf{P2}$ changes the price Cms_{lj} of all medical services which will be provided to these patients during their treatment to

$$Cms_{lj} + q1 \cdot Cms_{lj}. \tag{5.11}$$

The patients $M_l \in \mathbf{R\_new_{ti}}$ with $T_{explj} > T_{expj}$ are charged by

$$Cms_{lj} + q2 \cdot Cms_{lj}. \tag{5.12}$$

Here $q1, q2$ are the random numbers from the intervals $(0,\ 0.5)$ and $[0,\ 1]$.

The expected duration of the treatment of the patient $M_l \in \mathbf{R\_new_{ti}}$ suffering from the medical problem $D_j, j \in \{1, \ldots, d\}$ as well as the average expected duration of the treatment of $D_j, j \in \{1, \ldots, d\}$ is calculated as in Chapter 3:

$$T_{explj} = 1 + days_j \cdot (v_{lj} - 1),$$
$$T_{expj} = 1 + days_j \cdot (av_j - 1).$$

This physicians' $P_i, i \in \mathbf{P2}$ behavioural tendency may not be sufficient to achieve the target income qTI_i per quarter Q but this scenario is more realistic.

5.2.4.2 Simulation run and results

Scenario No. 1 A: Reduction in physician fees by 15%:

After reducing the costs by 15 %, the simulation of Scenario No 1 A for the year 2014 was repeated $s = 100$ times. The calculated statistics are given in the tables 5.6, 5.7 and 5.8. These results reveal that the income-oriented physicians P_1, P_4 and P_6 gained significantly more income per medical case than the perfect agents P_2, P_3 and P_5 (see $\mathbf{aD_{j100}}$ in Table 5.6). While the reduction in physician fees caused the decrease in the perfect agents' income approximately by 15%, the minimum decrease in the income-oriented physicians' earnings are related only with the slight changes in the average volume of the patients per quarter Q (see $\Delta(\%)$ in Table 5.7). The figures 5.4 and 5.5 provide the comparison of the results where all physician agents would act perfectly with the outcomes of Scenario

No. 1 A. For example, if the physician P_1 accepted the reduced cots, because of the lower number of the patients he/she would have gained 11.6 % less than the physician P_5. The opportunistic physician's P_1 behaviour diminish this difference to -3.9 %. All providers characterised by opportunistic behaviour achieved (or nearly achieved) their target income. The calculation of the costs related to the provided medical services shows that the income oriented physician prescribed relatively high number of unnecessary units to the patients (see Table 5.8). For instance, when seeking the target income, the provider P_6 increased the price of medical services almost 3 times (see **a∆Cms** (%) in Table 5.8). The opportunistic costs make approximately $7 - 8$ % of the health expenditures (see Figure 5.6).

$\mathbf{P\_ID_j}$	$\mathbf{aD_{j100}}$	$\mathbf{aD_j}$	$\mathbf{aI_t}$	$\mathbf{TI_t}$
1	69.48	59.5	65.83	66.52
2	46.34	46.75		
3	31.67	31.88		
4	54.62	46.75	56.98	57.47
5	59.1	59.5		
6	37.31	31.875	60.31	60.50

Table 5.6: The simulation results of Scenario No. 1 A (per medical case and per day): physicians' response to the reduction in their fees by 15%

This table provides the average values per medical case and per day after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the benefit per medical case $\mathbf{aD_{j100}}$, the benefit per medical case after the reduction in physician fees $\mathbf{aD_j}$, the gained income per day $\mathbf{aI_t}$ and the target income per day $\mathbf{TI_t}$.

$\mathbf{P\_ID_j}$	$\mathbf{aM2Q_{100}}$	$\mathbf{aFFSQ_{100}}$	$\mathbf{aFFSQ\_PA_{100}}$	∆(%)
1	60.12	4177.14	3577.14	- 0.74
2	72.17	3344.36	3344.36	- 15.75
3	101.76	3222.73	3222.73	- 15.55
4	66.23	3617.48	3096.25	- 0.69
5	76.42	4516.42	4516.42	- 15.57
6	101.03	3769.43	3220.33	- 0.51

Table 5.7: The simulation results of Scenario No. 1 A (per quarter Q): physicians' response to the reduction in their fees by 15%

This table provides the average values per quarter Q determined after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the number of the patients $\mathbf{aM2Q_{100}}$ who ended the treatment, the total benefit $\mathbf{aFFSQ_{100}}$, the total benefit which would be achieved under the perfect agency (for the imperfect agents: $\mathbf{aFFSQ\_PA_{100}} = \mathbf{aD_j} \cdot \mathbf{aM2Q_{100}}$) and the changes in physician income after the reduction in physician fees ∆(%).

P_ID_j	**aΔqI**	**aΔCms**	**aCms**	**aΔCms** (%)
1	600.00	9.98	29.5	33.83
4	521.23	7.87	16.75	46.99
6	549.10	5.44	1.875	290.13

Table 5.8: The simulation results of Scenario No. 1 A: The statistics related to unnecessary or more expensive medical services delivered by the income-oriented physician

This table provides information about the physicians' average total benefit **aΔqI** and the benefit per patient **aΔCms** gained from the provision of unnecessary or more expensive medical services per quarter Q determined after 100 simulation runs. The last two columns give the average costs **aCms** of unnecessary or more expensive medical services per medical case after reducing the physician fees and the percentage increase in the costs **aCms** induced by income-oriented physician.

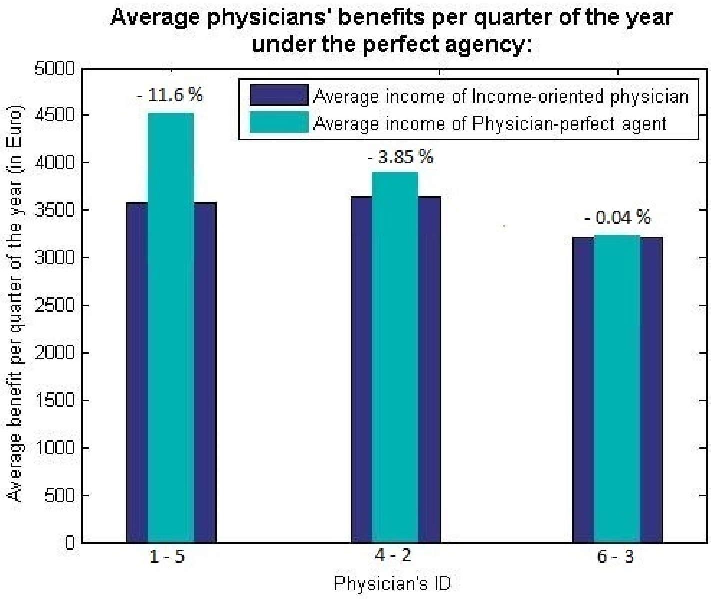


Figure 5.4: Scenario No. 1 A: Comparison of the average total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 %

The numbers above the columns describe the difference in % between the average total income of the physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results would have been achieved after reducing the physician fees by 15 % if all medical providers have acted perfectly.

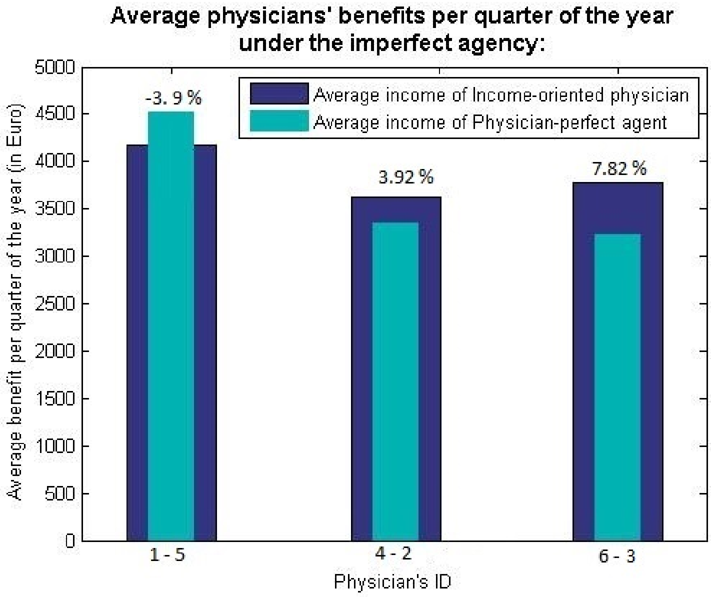


Figure 5.5: Scenario No. 1 A: Comparison of the total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 15 %

The numbers above the columns describe the difference in % between the average total income of the income-oriented physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results are obtained after reducing the physician fees by 15 %.

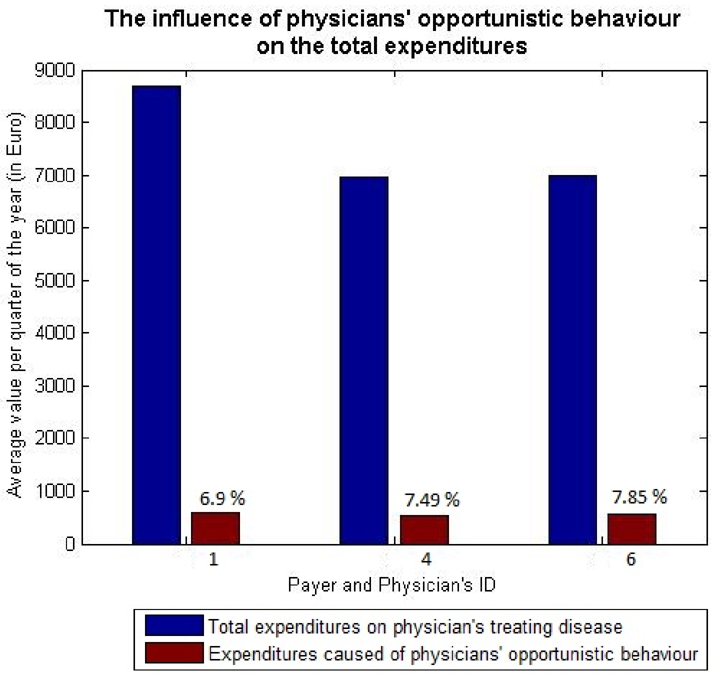


Figure 5.6: Scenario No. 1 A: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field

Scenario No. 1 B: Reduction in physician fees by 15%:

After reducing the costs by 15 %, the simulation of Scenario No 1 B for the year 2014 was repeated $s = 100$ times. The calculated statistics are given in the tables 5.9, 5.10 and 5.11. These simulation outcomes show that compared with the Scenario No. 1 A, the limitations on the income-oriented physician's influence on the cost *Cms* per medical case results in the lower their income. The medical providers P_1, P_4 and P_6 did not fulfil the target income expectations (see $\mathbf{aI_t}$ and $\mathbf{TI_t}$ in Table 5.9). All three income-oriented specialists suffered the significant decrease in their income caused by the reduction in the physician fees (see $\Delta(\%)$ in Table 5.10). The physician P_1, who under the perfect agency has the greatest charge for the provided medical services, was still able to increase his/her income approximately by 10 %. In this scenario, the physician P_6 increased his/her earnings only by 0.67 Euro per medical case while the reduction in the fees decreased his/her income by 1.5 per single patient visit (see Table 5.11). By increasing the income by 0.67 Euro per patient, the provider P_6 additionally charged the provision of medical services by 35.73%. The comparison between the perfect and the imperfect agency as well as the share of income-oriented physicians' benefit gained due to the opportunistic behaviour compared with the total expenditures are illustrated in the figures 5.7, 5.8 and 5.9.

$\mathbf{P\_ID_j}$	$\mathbf{aD_{j100}}$	$\mathbf{aD_j}$	$\mathbf{aI_t}$	$\mathbf{TI_t}$
1	65.85	59.5	62.17	66.52
2	46.34	46.75		
3	31.67	31.875		
4	50.5	46.75	53.62	57.47
5	59.1	59.5		
6	32.545	31.875	53.32	60.5

Table 5.9: The simulation results of Scenario No. 1 B (per medical case and per day): physicians' response to the reduction in their fees by 15%

This table provides the average values per medical case and per day after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the benefit per medical case $\mathbf{aD_{j100}}$, the benefit per medical case after the reduction in physician fees $\mathbf{aD_j}$, the gained income per day $\mathbf{aI_t}$ and the target income per day $\mathbf{TI_t}$.

$\mathbf{P\_ID_j}$	$\mathbf{aM2Q_{100}}$	$\mathbf{aFFSQ_{100}}$	$\mathbf{aFFSQ\_PA_{100}}$	$\Delta(\%)$
1	59.01	3885.81	3511.10	- 5.93
2	73.43	3402.75	3402.75	- 15.75
3	103.12	3265.81	3265.81	- 15.55
4	66.36	3351.18	3102.33	- 8.18
5	74.53	4404.72	4404.72	- 15.57
6	102.40	3332.61	3264.00	- 13.21

Table 5.10: The simulation results of Scenario No. 1 B (per quarter Q): physicians' response to the reduction in their fees by 15%

This table provides the average values per quarter Q determined after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the number of the patients $\mathbf{aM2Q_{100}}$ who ended the treatment, the total benefit $\mathbf{aFFSQ_{100}}$, the total benefit which would be achieved under the perfect agency (for the imperfect agents: $\mathbf{aFFSQ\_PA_{100}} = \mathbf{aD_j} \cdot \mathbf{aM2Q_{100}}$) and the changes in physician income after the reduction in physician fees $\Delta(\%)$.

$\mathbf{P\_ID_j}$	$\mathbf{a\Delta qI}$	$\mathbf{a\Delta Cms}$	**aCms**	$\mathbf{a\Delta Cms}$ (%)
1	374.71	6.35	29.5	21.52
4	248.85	3.75	16.75	22.38
6	68.61	0.67	1.875	35.73

Table 5.11: The simulation results of Scenario No. 1 B: The statistics related to not necessary or more expensive medical services delivered by income-oriented physician

This table provides information about the physicians' average total benefit $\mathbf{a\Delta qI}$ and the benefit per patient $\mathbf{a\Delta Cms}$ gained from the provision of not necessary or more expensive medical services per quarter Q determined after 100 simulation runs. The last two columns give the average costs **aCms** of not necessary or more expensive medical services per medical case after reducing the physician fees and the percentage increase in the costs **aCms** induced by income-oriented physician.

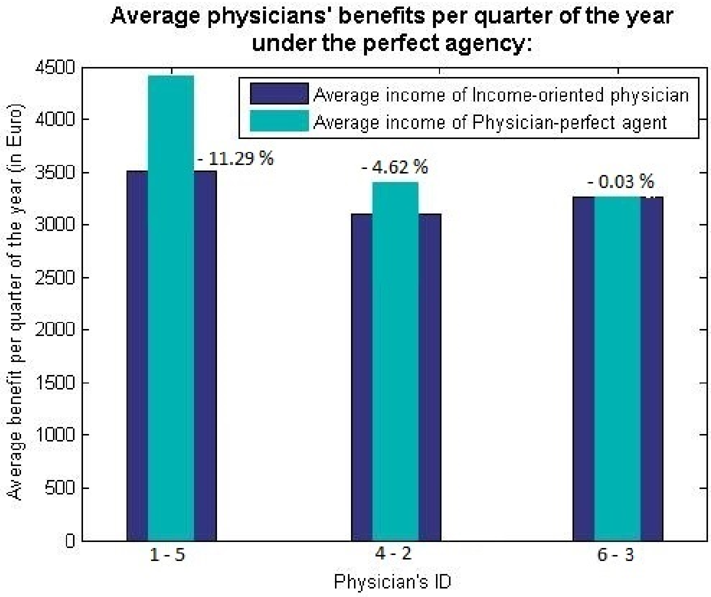


Figure 5.7: Scenario No. 1 B: Comparison of the average total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 %

The numbers above the columns describe the difference in % between the average total income of the physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results would have been achieved after reducing the physician fees by 15 % if all medical providers have acted perfectly.

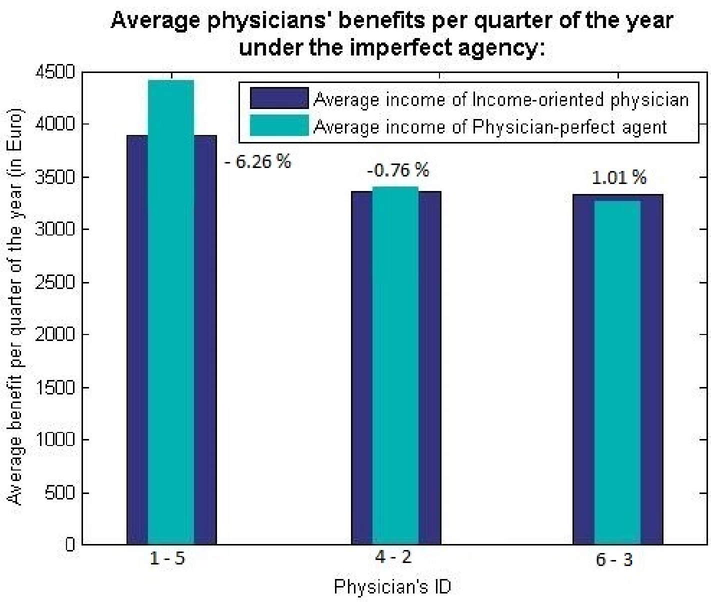


Figure 5.8: Scenario No. 1 B: Comparison of the total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 15 %

The numbers above the columns describe the difference in % between the average total income of the income-oriented physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results are obtained after reducing the physician fees by 15 %.

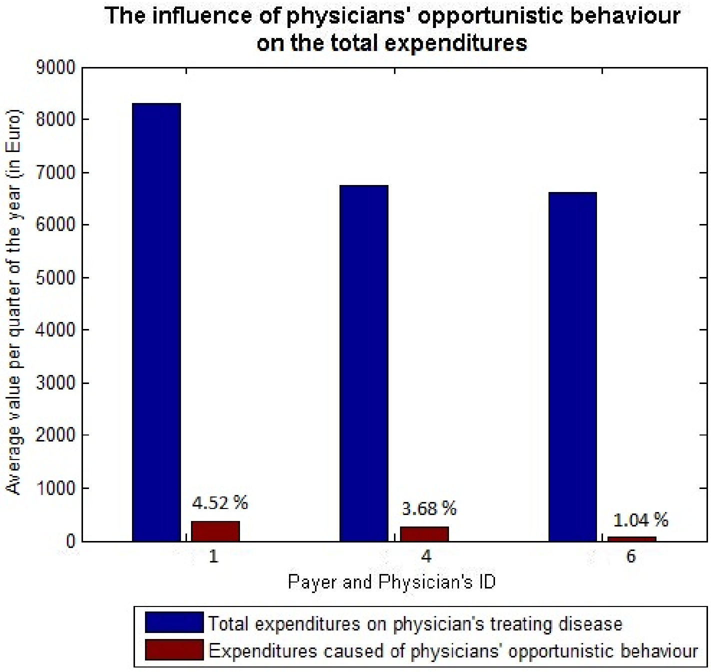


Figure 5.9: Scenario No. 1 B: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field

5.2.5 Scenario No. 2: Additional patient visits under a fee-for-service reimbursement system

Under a fee-for-service payment system, an income-oriented medical provider is separately reimbursed not only for every single medical service provided to the patient but also for each patient visit. Thus an increase in the physician's income could be achieved by designating additional visits for current patients.

5.2.5.1 Assumptions

Modelling of this scenario faces the problem of the physician's scheduling. An additional visit designated for a patient A takes the place in the physicians' schedule of the visit of a patient B. Since the provider can serve a maximum of *Pcapacity* patients per working day and receives the constant fee *Cvisit* for every patient visit, an extra visit would bring zero benefit to a fully occupied physician. In such a situation, the physician could simply increase the number of possible patient visits per day. It could though cause undersupply of the medical care provided per shorter patient visit and consequentially harm the patients' state of health. Since the assumes that the imperfect agent still acts as the perfect patients' clinical agent, the physician $Pi \in \mathbf{P2}$ will not affect the number of patient visits *Cvisit* because of his/her financial incentives. Thus under Scenario No. 2 the income-oriented physician $Pi \in \mathbf{P2}$ designates an additional visit for his/her patient on the day t only if:

(1) the physician's perceived income per day is lower than his/her target income (i.e., $\Delta I_{ti} \geq 0$) and

(2) the number of all patients (i.e., $|\mathbf{R_{ti}}|$) who are visiting the physician $Pi \in \mathbf{P2}$ in $days_j$ - 1, $days_j$ or $days_j$ +1 days is lower than *Pcapacity.* That means that one of the conditions

- $|\mathbf{R_{ti+days_j-1}}| < PCapacity$
- $|\mathbf{R_{ti+days_j}}| < PCapacity$
- $|\mathbf{R_{ti+days_j+1}}| < PCapacity$

must be satisfied. Here the item (1) describes the target income condition introduced in Section 5.1.2. The condition (2) reflects the consideration that the physician $Pi \in \mathbf{P2}$ is willing to designate an additional visit only if he/she is undersupplied.

5.2.5.2 Simulation run and results

Since a quarter of the year 2014 has on average working 62.5 days and each medical provider sees 5 patients per working day (i.e., $PCapacity = 5$), a simple calculation reveals that under the full occupation level (i.e., when physician have 5 patients per every day), a medical provider would have $AVisit$ = 312.5 patient visits per quarter Q on average. The comparison of $AVisit$ with the values given in the last column **PVisit** of Table 5.5 shows that the physicians P_1 and P_4 have the lowest number of patient visits per quarter Q (see $\mathbf{aM2Q_{100}}$). The reasons of this result are related to their location in the model environment (see Figure 5.3). Since the physicians P_1, P_4 and P_6 are characterised by opportunistic behaviour, it allows to predict that the first two providers will induce more patient visits than the physician P_6 (see ($V2$)).

It was assumed that at the beginning of 2014 the physician fees are reduced by 30%. The average statistics determined after running the Scenario No. 2 s = 100 times are illustrated in the tables 5.12, 5.13 and 5.14. As can be seen, the application of the conditions (1) and (2) for the physician agents P_1, P_4 and P_6 caused several changes in the model outcomes. The average total income of P_1, P_4 and P_6 under the perfect and imperfect agency (i.e., $\mathbf{aFFSQ_{100}}$ and $\mathbf{aFFSQ\_PA_{100}}$) significantly differs. The comparison of what a provider would achieve after the reduction in his/her fees under perfect agency (i.e., **aDj**) with the average amount he/she charged for the treatment of one patient $\mathbf{Dj_{100}}$ indicates that the physicians P_1, P_4 and P_6 deviate from the perfect scenario.

The statistics related to their prescribed patient visits (see Table 5.14) show that the physician P_1, who has the lowest occupation level among all medical providers, initiated the average of 65.12 patient visits per quarter Q (see $\mathbf{aInitVisit_{100}}$). On average, this provider designated 1.07 additional visits per patient (see $\mathbf{aInitVM2_{100}}$). When comparing the total benefit of P_1 with the income he/she would have achieved under perfect agency (i.e., under prices given in the column **aDj** in the Table 5.14), the opportunistic behavioural tendency increased his/her income (in average) by 455.84 Euro per quarter Q (see $\mathbf{a\Delta qI}$, Table 5.14). The provider P_6, who has a relatively high occupation level, gained only an average of 26.32 Euro due to additional patient visits and prescribed 0.04 additional visits per patient.

$\mathbf{P\_ID_j}$	$\mathbf{aD_{j100}}$	$\mathbf{aD_j}$	$\mathbf{aI_t}$	$\mathbf{TI_t}$
1	56.46	49	55.17	66.83
2	38.19	38.19		
3	26.73	26.73		
4	43.63	38.5	45.05	57.88
5	49.42	49.42		
6	26.51	26.25	42.77	60.31

Table 5.12: The simulation results of Scenario No. 2 (per medical case and per day): physicians' response to the reduction in their fees by 30%

This table provides the average values per medical case and per day after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the benefit per medical case $\mathbf{aD_{j100}}$, the benefit per medical case after the reduction in physician fees $\mathbf{aD_j}$, the gained income per day $\mathbf{aI_t}$ and the target income per day $\mathbf{TI_t}$.

$\mathbf{P\_ID_j}$	$\mathbf{aM2Q_{100}}$	$\mathbf{aFFSQ_{100}}$	$\mathbf{aFFSQ\_PA_{100}}$	$\Delta(\%)$
1	61.07	3448.27	2992.43	- 17.81
2	75.17	2870.74	2870.74	- 30.56
3	101.82	2721.65	2721.65	- 30.02
4	64.53	2815.37	2484.41	- 19.34
5	74.84	3698.59	3698.59	- 29.4
6	100.82	2672.85	2646.53	- 29.54

Table 5.13: The simulation results of Scenario No. 2 (per quarter Q): physicians' response to the reduction in their fees by 30%

This table provides the average values per quarter Q determined after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the number of the patients $\mathbf{aM2Q_{100}}$ who ended the treatment, the total benefit $\mathbf{aFFSQ_{100}}$, the total benefit which would be achieved under the perfect agency (for the imperfect agents: $\mathbf{aFFSQ\_PA_{100}} = \mathbf{aD_j} \cdot \mathbf{aM2Q_{100}}$) and the changes in physician income after the reduction in physician fees $\Delta(\%)$.

$\mathbf{P\_ID_j}$	$\mathbf{a\Delta qI}$	$\mathbf{aInitVisit_{100}}$	$\mathbf{aInitVM2_{100}}$
1	455.84	65.12	1.07
4	330.96	47.28	0.63
6	26.32	3.76	0.04

Table 5.14: The simulation results of Scenario No. 2: The statistics related to physician initiated not necessary patient visits

This table provides information about the physicians' average total benefit $\mathbf{a\Delta qI}$, the average number of physicians' initiated visits $\mathbf{aInitVisit_{100}}$ and the average number of physician initiated visits per medical case $\mathbf{aInitVM2_{100}}$ per quarter Q.

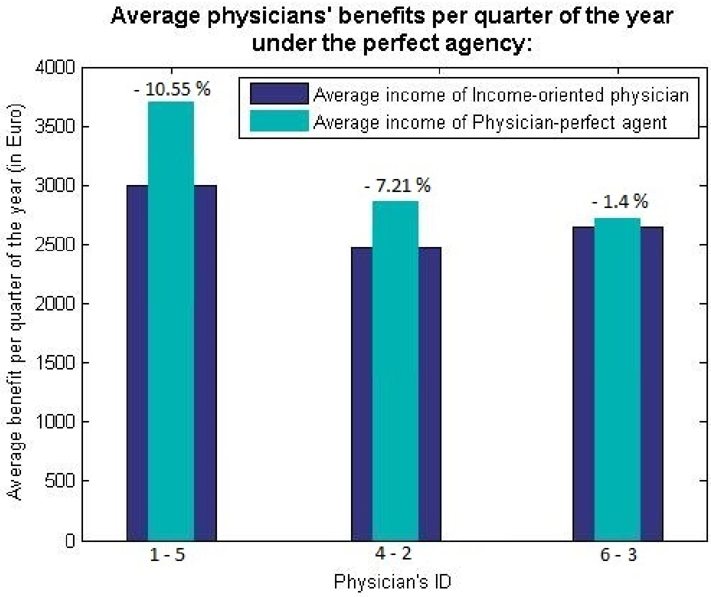


Figure 5.10: Scenario No. 2: Comparison of the average total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 %

The numbers above the columns describe the difference in % between the average total income of the physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results would have been achieved after reducing the physician fees by 30 % if all medical providers have acted perfectly.

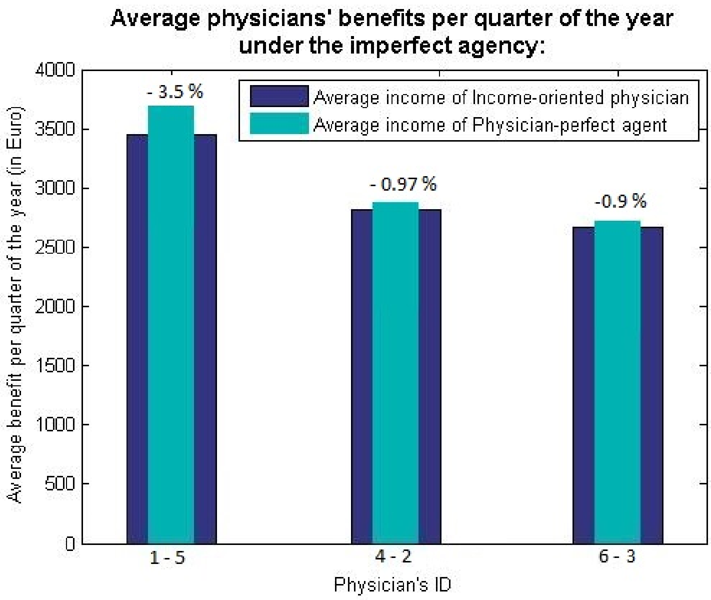


Figure 5.11: Scenario No. 2: Comparison of the total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 30 %

The numbers above the columns describe the difference in % between the average total income of the income-oriented physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results are obtained after reducing the physician fees by 30 %.

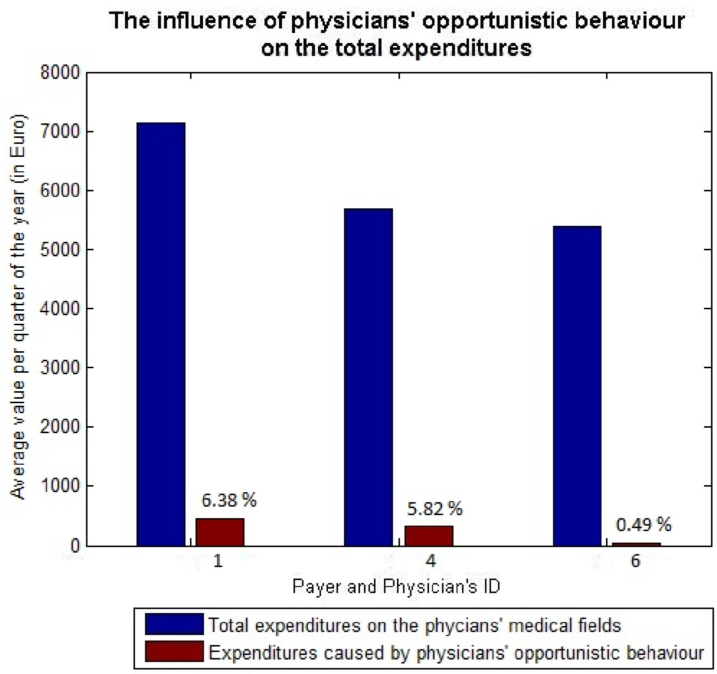


Figure 5.12: Scenario No. 2: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field

5.2.6 Scenario No. 3 and Scenario No. 4: An intentional misdiagnosis and decreasing the number of patient visits under a case-based reimbursement system

Chapter 4 discussed the fact that there is less evidence about the physicians' opportunistic behaviour under the case-based reimbursement system. The literature though provides several studies on the initial diagnosis of more expensive medical problems. Some other works investigate the increase in the number of physicians' patient achieved by decreasing the number of the patient visits.

5.2.6.1 Assumptions

A physician specialised in a certain medical field usually deals with several diseases or disorders. These medical problems often require various time input devoted to the treatment and bring different benefit for the physician. Therefore, an income oriented provider clearly prefers the patients with more expensive medical problems. In order to gain additional financial benefit, he/she could even diagnose more expensive disease or disorder for the patients with the problems which are less costly for the payer.

The assumption that income-oriented physician still care for the patients' health indicates that designation of more beneficial medical problem cannot affect the patient's treatment. Moreover, the provider should be able to cover his/her misdiagnosed diseases and disorders in the medical records. These considerations lead to the following conditions:

After reducing the physician fees, the income-oriented $Pi \in \mathbf{P2}$ diagnoses for the patient $M_l \in \mathbf{R\_new_{ti}}$ the false and more expensive medical problem if:

(1) the physician's perceived income per day is lower than his/her target income (i.e., $\Delta I_{ti} \geq 0$) and

(2) The expected duration of the treatment assigned to the real medical problem T_{explj1} is equal or longer than the average duration of the treatment of more expensive medical problem T_{expj2} (i.e., $T_{explj1} \geq T_{expj2}$ and $CFix_{j1} < CFix_{j2}$).

The condition (2) guarantees that in case of the wrong diagnosis, the patient will be not undersupplied with the provision of the health care.

The last Scenario No. 4, chosen as a possible opportunistic behavioural tendency, is the designation of less than necessary patient visits under the case-based reimbursement. This scenario is contradictory with the physicians' perfect clinical agency. Therefore, the integration of the Scenario No 4 into the model is very limited. The simulation described below relies on the assumption that there is 50% probability that the provider decreases the number of the patient visits by 1 for the individuals with less complex medical state (i.e., $T_{explj} \leq T_{expj}, v_{lj} > 1$).

5.2.6.2 Simulation run and results

The average results per quarter Q obtained after $s = 100$ simulation runs are presented in the tables 5.15, 5.16 and 5.17. The physician P_3 specialised in treating two medical problems (D_2 and D_3) were assumed under certain conditions described above to misdiagnose the patient with the more expensive problem D_3. The results show that this method did not help him/her to avoid the loss in income after the reduction in physician fees. Additional calculation reveals that in average the physician misdiagnosed 13.73 medical cases per quarter Q. Such results could be explained by only 5 Euro difference between the fix fees $Cfix$ of the medical problems D_2 and D_3. If the price difference would be 11.78 Euro, the same amount of misdiagnosed medical cases would help to achieve the target physician's P_6 income.

In this simulation example, the providers P_1 and P_4 tried to achieve the perceived income by reducing the number of patient visits for the patients with less complex medical condition. This strategy brought good results to the physician P_4: the reduction in physician fees by 10 % affected this provider just by 2.25 % decrease in his/her income. Compared with the physician P_1, the specialist P_4 has a higher occupation level. It shows that the decrease in the number of patient visits pay off for the oversupplied physicians. It can be concluded that the limitations on the income-oriented physicians' degree of freedom introduced in order to avoid the undersupply of health care to the patient as the model assumptions do not allow to achieve the target income level.

$\mathbf{P\_ID_j}$	$\mathbf{aD_{j100}}$	$\mathbf{aD_j}$	$\mathbf{aI_t}$	$\mathbf{TI_t}$
1	64.64	63	61.19	66.83
2	48.98	49.5		
3	33.49	33.75		
4	53.76	49.5	45.05	57.88
5	63.12	63		
6	34.34	33.75	42.77	60.31

Table 5.15: The simulation results of Scenario No. 3 and 4 (per medical case and per day): physicians' response to the reduction in their fees by 10%

This table provides the average values per medical case and per day after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the benefit per medical case $\mathbf{aD_{j100}}$, the benefit per medical case after the reduction in physician fees $\mathbf{aD_j}$, the gained income per day $\mathbf{aI_t}$ and the target income per day $\mathbf{TI_t}$.

$\mathbf{P\_ID_j}$	$\mathbf{aM2Q_{100}}$	$\mathbf{aCB_{100}}$	$\mathbf{aCB\_PA_{100}}$	$\Delta(\%)$
1	59.16	3824.10	3727.08	- 7.66
2	72.56	3553.99	3553.99	- 10.95
3	102.02	3416.65	3416.65	- 10.69
4	65.45	3518.59	3239.78	- 2.25
5	75.66	4775.66	4775.66	- 9.83
6	102.83	3531.60	3470.51	- 8.42

Table 5.16: The simulation results of Scenario No. 3 and 4 (per quarter Q): physicians' response to the reduction in their fees by 10%

This table provides the average values per quarter Q determined after 100 simulation runs. These include: the physician's $P_i \in \mathbf{P}$ ID $\mathbf{P\_ID_j}$, the number of the patients $\mathbf{aM2Q_{100}}$ who ended the treatment, the total benefit $\mathbf{aCB_{100}}$, the total benefit which would be achieved under the perfect agency (for the imperfect agents: $\mathbf{aCB\_PA_{100}} = \mathbf{aD_j} \cdot \mathbf{aM2Q_{100}}$) and the changes in physician income after the reduction in physician fees $\Delta(\%)$.

P_ID$_j$	aΔqI
1	97.2
4	278.82
6	61.09

Table 5.17: The simulation results of Scenario No. 3 and 4: The statistics related to physicians' designated lower number of patient visits and initial diagnosis of more expensive medical problem

This table provides information about the physicians' average total benefit **aΔqI** per quarter Q.

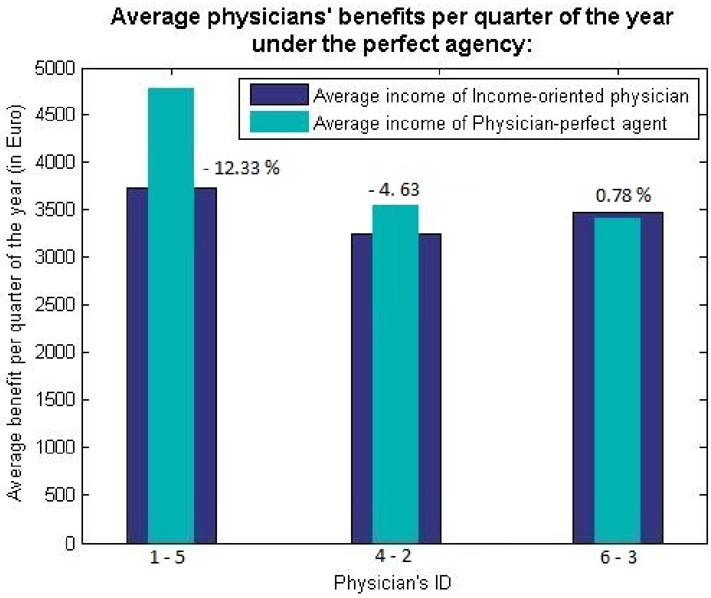


Figure 5.13: Scenario No. 3 and 4: Comparison of the average total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 %

The numbers above the columns describe the difference in % between the average total income of the physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results would have been achieved after reducing the physician fees by 30 % if all medical providers have acted perfectly.

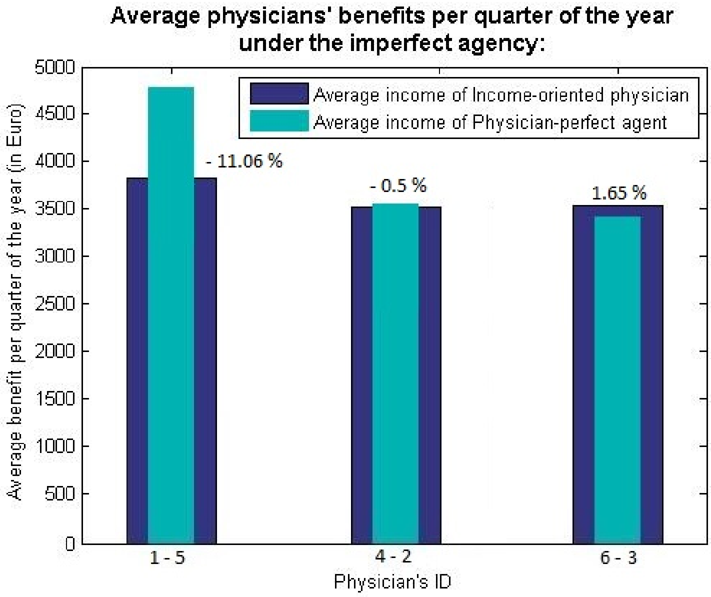


Figure 5.14: Scenario No. 3 and 4: Comparison of the total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 30 %

The numbers above the columns describe the difference in % between the average total income of the income-oriented physicians (i.e., P_1, P_4 and P_6) and the perfect patient's agents (P_2, P_4 and P_5). These results are obtained after reducing the physician fees by 30 %.

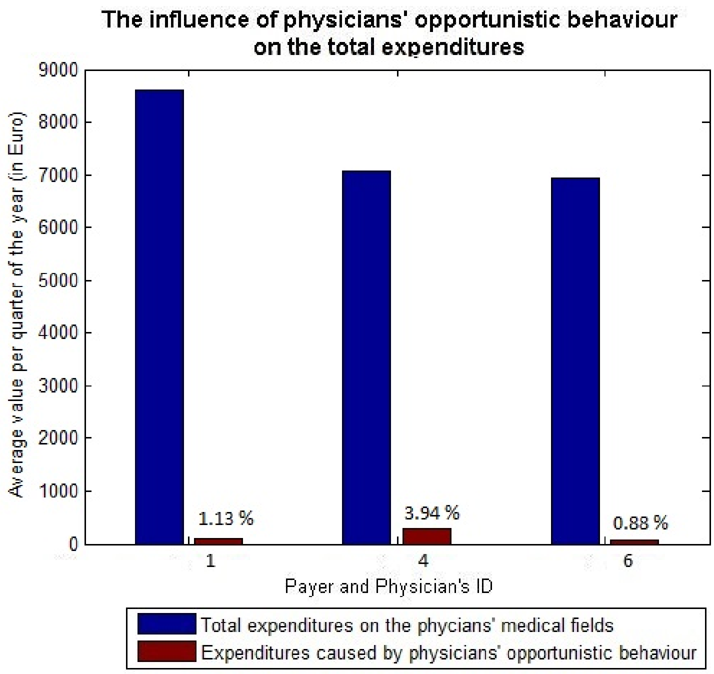


Figure 5.15: Scenario No. 3 and 4: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field

5.3 Overview

Simulation of four different income-oriented physician behavioural tendencies revealed the existence of the conflict between the financial providers' objectives and the patients' welfare in the presented theoretical model. In all scenarios the income-oriented physician was assumed to seek for a certain target income while acting as the patients' clinical agent. The assumptions introduced in order to guarantee a quality provision to the patient resulted in the lower, than aimed, physicians' income. The attempts to integrate the income-oriented physicians' behaviour into the simplified health care system show that even minimum limitations on the physician behaviour do not allow the misusing of the physicians' market power. However, the applied methods help for income-oriented physicians to gain more benefit. In future the presented scenarios could be applied for bigger simplified health care system consisting of more individuals and medical problems.

Chapter 6

Conclusions

The physician behaviour encouraged by their desire for money has received particularly much attention from health care economists. Numerous data researches in different countries suggest that medical providers may use their supplementary information about the patients' true medical needs as well as their market power to gain additional financial benefit.

When seeking to understand physicians' decision to take certain measures to increase their income, this work reviewed the existing theories and studies on physician practice patterns. The thesis used the concept of perfect physician agency. This behavioural tendency occurs when a physician is acting purely on the behalf of his/her patient and disregards his/her own interests. Although perfect agency is a favourable feature in heath markets, the empirical studies show that in practice it does not exist. The data researches and physician surveys were able to reveal the main factors influencing physician practice patterns. Besides the interest for the welfare of the patient, the medical provider's behaviour is also affected by his/her personal goals, the institutional setting and certain external factors such as medical uncertainty. However, the studies which aim to investigate the economic results in the health sector lack of methods for establishing the specific causes of non-optimal outcomes. Often the same economic results could be related to different incentives for physicians. Therefore simulation models and, especially, the agent-based simulation approach, is an important tool to study how different physician objectives and existing restrictions on the health system could affect the overall health costs.

This work introduced a theoretical discrete time agent-based simulation model for extramural health care sector. The presented model contains appropriate structures to integrate the physicians' deviation from perfect agency caused by their desire for greater income. Physician agents characterised by income-oriented behaviour were seen as self-interested medical providers aiming for a target income. Their behaviour was mostly influenced by their income expectations and considerations about the patient health outcomes. Assuming that the public insurance covers all health costs and reflecting physicians' opportunistic behaviour as the respond to the reduction in physician fees, the simulation sought to compare the economic model outcomes under perfect agency with the scenario when the physician's financial incentives are affecting their behaviour. Based on the literature research on opportunistic physicians under different reimbursement systems, the model presented four different behavioural tendencies under prospective and retrospective payment systems.

The modelling of various opportunistic behaviour scenarios showed that the different methods used by physicians to increase their income gives not maximum effect. Under a fee-for-service reimbursement system, the income-oriented physician agents were assumed to increase the price of the delivered health services and initiate unnecessary patient visits. The simulation outcomes showed that the possibility to prescribe additional health care or change the mix of services provided to the patients is a well-functioning strategy. However, after limiting the physicians' ability to prescribe the amount and type of services to the patients, the increase in income was significantly lower. The other method relevant under this payment system, designation of unnecessary patient visits, seems to be restricted by the providers' workload. If a physician has a high occupation level and is not willing to increase the maximum number of patients he/she is seeing per working day, additional patient visits are not sufficient to achieve the target income level. The opportunistic strategies related to the case-based reimbursement system also faced several problems. The degree of the physician's ability to boost his/her income by diagnosing the patients with more expensive medical problems over time depends on the provider's benefit per misdiagnosed case and the number of the patients who are seeking for medical help by this provider. If the physician is treating a low number of patients and the additional income achieved due the wrong diagnosis is not high, he/she is not able fulfil his/her financial expectations. If the physician is acting only based on his/her aim for greater income, this behavioural strategy could lead to constant misdiagnosis. The other opportunistic strategy under the case-based reimbursement, the reduction of the designated visits which in case of oversupply of the physician results in a higher volume of the patients, pays off only if physicians are oversupplied.

In real health systems there are more factors restricting physician behaviour than were considered in the presented model. The evident physician opportunistic behaviour over time would receive a rigid answer from the payer such as supplementary limitations on the physician's degree of freedom in his/her medical decision-making or changes in the existing reimbursement system. The introduced model also assumed that the physician's actions do not affect the patient's trust in his/her provider. The studies on the physician-patient relationship indicate that the patients do react to the decisions and actions related to their treatment and thus should not be described as 'passive' observers. Even if the public insurance covers all treatment costs, the opportunistic physician behaviour often causes the patient time costs. These costs cannot be underestimated: The high amount of services provided to the individual as well as longer or shorter than usual treatment time could impel the patient to question about his/her real health status and/or the competence of the treating medical provider. In an extreme scenario, the patient would decide to change his/her physician or to choose the other medical provider in the future. Therefore, the intervention of the payer and the patient's reaction to the imperfect physician behaviour could be useful material for future works.

The simulation results confirmed that the imperfect physicians' agency affect the economic outcomes of the modelled health system. However, the modelling revealed that even the minimum assumptions on the limitations of the income-oriented physician behaviour restrict the physicians' ability to achieve their target income. In context of modelling and simulation, it would be challenging to supplement the model with the real world costs and apply the simulation of income-oriented physician behaviour for the bigger simplified health system. When taking into account the possible adverse reaction of the patient and the sensible intervention of the payer, it could be concluded that, in real word, the health care sector is relatively well protected from the physicians' opportunistic behaviour.

Appendix

Appendix A

Appendix to Chapter 2

Element / Abbreviation	**Definition**
P $= \{P_1, \ldots, P_p\}$	A set of all p physicians defined in the model
M1	An index set of all m1 potential patients defined in the model
M2	An index set of all m2 patients defined in the model
M $= \{M_1, \ldots, M_m\}$ **M1** $\cup$ **M2**$= \{1, \ldots, m\}$	A set of all m ordinary individuals defined in the model. A union of two non-overlapping sets **M1** and **M2** gives the set of all indexes of **M**
M3 $\subseteq$ **M2**	A set of all persons that become patients at the current day $t_m, m \in \{1, \ldots, t_{max}\}$
D$= \{D_1, \ldots, D_d\}$	A set of all d medical problems defined in the model
Pi_D$= \{D_{ij} \| j \in 1, \ldots, d\}$	A set of all medical problems which correspond to physician's $P_i, i \in \{1, \ldots, p\}$ medical specialisation
Pi_M2$= \{M_{il} \| l \in$**M2**$\}$	A set of all current patients of the physician $P_i, i \in \{1, \ldots, p\}$
P_Dj	An index set of all medical specialists who are qualified to treat $D_j, j \in \{1, \ldots, d\}$
D_cg$_\mathbf{k}$,$k \in \{1, 2, \ldots, c\}$ **D_cg$_\mathbf{1}$** $\cup$ **D_cg$_\mathbf{2}$** $\cup \ldots \cup$ **D_cg$_\mathbf{k}$** $=$ **D**	A set of all medical problems of category k

$\mathbf{P\_cg_k}, k \in \{1, 2, \ldots, c\}$ $\mathbf{P\_cg_1} \cup \mathbf{P\_cg_2} \cup \ldots \cup \mathbf{P\_cg_k} = \mathbf{P}$	A set of all physicians with a medical speciality k
$\mathbf{U_{lj}} = [u_{l1}, \ldots, u_{ld}]$	A list which contains the critical probabilities for potential patient $M_l, l \in \mathbf{M1}$ to get the medical problems $D_1, \ldots, D_d$
$\mathbf{W_{lj}} = [w_{l1}, \ldots, w_{ld}]$	A list which contains the deciding random numbers for potential patient $M_l, l \in \mathbf{M1}$ to become the medical problems $D_1, \ldots, D_d$ at the current day $t_m, m \in \{1, \ldots, t_{max}\}$
FFS	Fee-for-service reimbursement system
CB	Case-based reimbursement system
Q1, Q2, Q3, Q4	Quarters of the year
FIFO method	A scheduling algorithm which queues processes in the order that they arrive in the ready queue
Minimum distance method MDM	An algorithm which for a given point calculates minimum length of any curve between two points
Y	Year
Q	Quarter of the year
$aCBQ_s$	Average physician's benefit per simulation run obtained per certain Q of the year Y under the CB payment system (in Euro). The calculation is based on the results received after performing s simulation runs.
$aFFSQ_s$	Average physician's benefit per simulation run obtained per certain Q of the year Y under the FFS payment system (in Euro). The calculation is based on the results received after performing s simulation runs.
$aM2Q_s$	Average number of patients who finished the treatment by their medical provider $P_i, i \in \{1, \ldots, 5\}$ in the certain Q the year Y. The calculation is based on the results received after performing s simulation runs.

aCB_s	Average physician's benefit per simulation run obtained per quarter of the year under the CB payment system (in Euro). The calculation is based on the results received after performings simulation runs.
$aFFS_s$	Average physician's benefit per simulation run obtained per quarter of the year under the FFS payment system (in Euro). The calculation is based on the results received after performing s simulation runs.
$aM2_s$	Average number of patients who finished the treatment by their medical provider $P_i, i \in \{1, \ldots, 5\}$ per quarter of the year. The calculation is based on the results received after performing s simulation runs.

Table A.1: The other important elements and abbreviations used in the description of the Model with the Perfect Agency. The table presents the list of all sets introduced in Chapter 2, the relations between these sets and the abbreviations of the notions used in the model presentation.

Variable / Parameter	Definition	Initialisation	Variation
$k1$, $k2$	Size of the model's environment	Manually defined at the beginning of simulation	Remains constant during the simulation
t_{max}	Simulation length	Manually defined at the beginning of simulation	—
s	Number of simulation runs	Manually defined at the beginning of simulation	—
nQ	Number of time steps in which occurs the cost determination	Manually defined at the beginning of simulation	—
p	Number of physicians	Manually defined at the beginning of simulation	Remains constant during the simulation
$m1$	Number of patients	Manually defined at the beginning of simulation	May change in each simulation step t_m, $m \in \{1, \ldots, t_{max}\}$
$m2$	Number of potential patients	Manually defined at the beginning of simulation	May change in each simulation step t_m, $m \in \{1, \ldots, t_{max}\}$
$m4$	Number of patients who have their first visit to the physician at the current day t_m, $m \in \{1, \ldots, t_{max}\}$	Depends on the satisfaction of (2.3) Probabilities Comparison Condition	May change in each simulation step t_m, $m \in \{1, \ldots, t_{max}\}$
$m = m1 + m2$	Number of ordinary individuals (size of the target population)	Defined by values of m1 and m2	Remains constant during the simulation

$n = m1 + m2 + p$	Size of the total population	Defined by values of m1, m2 and p	Remains constant during the simulation
d	Number of medical problems	Manually defined at the beginning of simulation	Remains constant during the simulation
P_ID_i	Unique physician's P_i, $i \in \{1, \ldots, p\}$ ID	Randomly assigned to each P_i, $i \in \{1, \ldots, p\}$ at the beginning of simulation	Remains constant during the simulation
$Pcoord_i$	Physician's P_i, $i \in \{1, \ldots, p\}$ coordinates (x_{Pi}, y_{Pi}) in two-dimensional environment k1xk2	Randomly assigned to each P_i, $i \in \{1, \ldots, p\}$ at the beginning of simulation; Uniformly distributed in the environment k1xk2	Remains constant during the simulation
Pcg_i	Physician's P_i, $i \in \{1, \ldots, p\}$ medical speciality; $Pcg_i \in \{1, \ldots, c\}$	Randomly assigned to each P_i, $i \in \{1, \ldots, p\}$ at the beginning of simulation	Remains constant during the simulation
$PCapacity$	A fixed number of patient visits supplied per working day t_m, $m \in \{1, \ldots, t_{max}\}$	Manually defined at the beginning of simulation; The same value of $Pcapacity$ for all physicians	Remains constant during the simulation
$Cvisit$	Cost per patient visit	Manually defined at the beginning of simulation	Remains constant during the simulation
D_ID_j	Unique medical problem's ID	Randomly assigned to each D_j, $j \in \{1, \ldots, d\}$ at the beginning of simulation	Remains constant during the simulation
Dcg_j	Medical problem's D_j, $j \in \{1, \ldots, d\}$ category; $Dcg_j \in \{1, \ldots, c\}$	Randomly assigned to each D_j, $j \in \{1, \ldots, d\}$ at the beginning of simulation	Remains constant during the simulation

$Cfix_j$	Fix predetermined fee for the treatment of D_j, $j \in \{1, \ldots, d\}$	Manually defined for each D_j, $j \in \{1, \ldots, d\}$ at the beginning of simulation	Remains constant during the simulation
$aCms_j$	Average cost for all medical services provided during the treatment of D_j, $j \in \{1, \ldots, d\}$	Manually defined for each D_j, $j \in \{1, \ldots, d\}$ at the beginning of simulation	Remains constant during the simulation
av_j	Average number of all necessary patient visits caused by D_j, $j \in \{1, \ldots, d\}$	Manually defined for each D_j, $j \in \{1, \ldots, d\}$ at the beginning of simulation	Remains constant during the simulation
$days_j$	Number of the days between two patient visits caused by D_j, $j \in \{1, \ldots, d\}$	Manually defined at the beginning of simulation	Remains constant during the simulation
M_ID_l	Unique ordinary individual ës M_l, $l \in \{1, \ldots, m\}$ ID	Randomly assigned to each M_l, $l \in \{1, \ldots, m\}$ at the beginning of simulation	Remains constant during the simulation
$Mcoord_l$	Ordinary individual's M_l, $l \in \{1, \ldots, m\}$ coordinates (x_{ml}, y_{ml}) in two-dimensional environment k1xk2	Randomly assigned to each M_l, $l \in \{1, \ldots, m\}$ at the beginning of simulation; Uniformly distributed in the environment k1xk2	Remains constant during the simulation
U_{lj}	Critical probability: a probability for an ordinary individual M_l, $l \in \{1, \ldots, m\}$ to get a medical problem D_j, $j \in \{1, \ldots, d\}$	Randomly assigned to each M_l, $l \in \{1, \ldots, m\}$ at the beginning of simulation; Follow Beta distribution with shape parameters $\alpha, \beta > 0$	Remains constant during the simulation

W_{lj}	Deciding random number: a number which by comparing it with corresponding U_{lj} shows the chances for an healthy individual M_l, $l \in \mathbf{M1}$ to became the medical problem D_j, $j \in \{1,\dots,d\}$ at the current day t_m, $m \in \{1,\dots,t_{max}\}$	Randomly generated based on the uniform distribution for every potential patient M_l, $l \in \mathbf{M1}$ in each simulation step t_m, $m \in \{1,\dots,t_{max}\}$	Changes in each simulation step t_m, $m \in \{1,\dots,t_{max}\}$
$D_I Dlj$	ID of patient's M_l, $l \in \mathbf{M2}$ medical problem D_j, $j \in \{1,\dots,d\}$	Assigned to each person M_l, $l \in \mathbf{M3}$, $\mathbf{M3} \subseteq \mathbf{M2}$ which based on (2.3) *Probabilities Comparison Condition* becomes ill at the current day t_m, $m \in \{1,\dots,t_{max}\}$	Remains constant during the treatment of problem D_j, $j \in \{1,\dots,d\}$; Set to 0 when $M_l, l \in \mathbf{M2}$ becomes healthy again
Dcg_{lj}	Category of patient's M_l, $l \in \mathbf{M2}$ medical problem D_j, $j \in \{1,\dots,d\}$	Assigned to each person M_l, $l \in \mathbf{M3}$, $\mathbf{M3} \subseteq \mathbf{M2}$ which based on (2.3) *Probabilities Comparison Condition* becomes ill at the current day t_m, $m \in \{1,\dots,t_{max}\}$	Remains constant during the treatment of problem D_j, $j \in \{1,\dots,d\}$; Set to 0 when $M_l, l \in \mathbf{M2}$ becomes healthy again

MP_l	Patient's M_l, $l \in \mathbf{M2}$ treating physician (i.e., corresponding P_ID_i)	Assigned to each person M_l, $l \in \mathbf{M3}$, $\mathbf{M3} \subseteq \mathbf{M2}$ which based on (2.3) *Probabilities Comparison Condition* becomes ill at the current day t_m, $m \in \{1, \ldots, t_{max}\}$; If there is more than one for M_l appropriate physician, unique MP_l is chosen by (2.4) Minimum distance principle	Remains constant during the treatment of problem D_j, $j \in \{1, \ldots, d\}$; Set to 0 when $M_l, l \in \mathbf{M2}$ becomes healthy again
Cms_{lj}	Cost for all medical services provided during the treatment of patient's M_l, $l \in \mathbf{M2}$ medical problem D_j, $j \in \{1, \ldots, d\}$	Randomly generated for each medical case; Follows Gamma distribution with the mean $aCms_j$	Remains constant during the treatment of problem D_j, $j \in \{1, \ldots, d\}$; Set to 0 when $M_l, l \in \mathbf{M2}$ becomes healthy again
V_{lj}	Number of all necessary patient M_l, $l \in \mathbf{M2}$ visits caused by D_j, $j \in \{1, \ldots, d\}$	Randomly generated for each medical case; Follows Poisson distribution with the mean av_j	Remains constant during the treatment of problem D_j, $j \in \{1, \ldots, d\}$; Set to 0 when $M_l, l \in \mathbf{M2}$ becomes healthy again
$Vleft_{lj}$	Number of patient M_l, $l \in \mathbf{M2}$ visits caused by D_j, $j \in \{1, \ldots, d\}$ remaining until the end of the treatment	Calculated by subtracting every passed day from corresponding v_{lj}	Changes in each simulation step t_m, $m \in \{1, \ldots, t_{max}\}$

$daysleft_{lj}$	Number of days left until the next patient M_l, $l \in \mathbf{M2}$ visit to his physician caused by D_j, $j \in \{1, \ldots, d\}$	Calculated by subtracting passed day from day_{sj}	Changes in each simulation step t_m, $m \in \{1, \ldots, t_{max}\}$
WQ_l	Binary variable (i.e. a variable with the values 0 or 1) showing if the patient's M_l, $l \in \mathbf{M2}$ visit to his physician is referred to the next day	Is equal to 1 if M_l must visit his physician at the current day t_m, $m \in \{1, \ldots, tmax\}$ and has higher !!! than the value of *Pcapacity* position in the waiting line	May change during the simulation
T_{explj}	Expected duration of the treatment required for a patient M_l, $l \in \mathbf{M2}$ suffering from a certain disease or disorder D_j, $j \in \{1, \ldots, d\}$	Precalculated at the beginning of the treatment (see (2.1) Expected duration of the treatment)	—
T_{lj}	Actual duration of the treatment required for a patient M_l, $l \in \mathbf{M2}$ suffering from a certain disease or disorder D_j, $j \in \{1, \ldots, d\}$	Obtained after the end of the treatment	—

Table A.2: Variables and parameters of the Model with the Perfect Agency

This table contains all variables and parameters used in the model description submitted in the Chapter 3 and its implementation. Together with their names and definition, it is also submitted the information about the initialisation and changes of the values during the simulation run.

Number of the working days per Q2 (1.4-30.6)	Number of the working days per Q3 (1.7-30.9)	Number of the working days per Q4 (1.10-31.12)	Number of the working days per year
61	66	63	252
61	65	61	250
60	64	62	250
60	65	63	251
60	65	63	250

Table A.3: Number of working days in the years 2010-2014

The table gives the information about the number of the working days per a certain year and each of its quarters Q1, Q2, Q3, Q4.

Time step for the cost evaluation for Q1	Time step for the cost evaluation for Q2	Time step for the cost evaluation for Q3	Time step for the cost evaluation for Q4
63	124	190	253
316	377	442	503
64	125	190	251
567	627	691	753
315	375	439	501
65	125	189	251
816	876	941	1004
564	624	689	752
314	374	439	502
64	124	189	252
1066	1126	1191	1254
815	875	940	1003
564	624	689	752
314	374	439	502
63	123	188	251

Table A.4: Time steps in which occurs the cost evaluation depending on the simulation start

Time steps in which occurs the cost evaluation depending on the simulation start. The information submitted in this table helps to initialise the vector t.

References

J. Adwok and E. H. Kearns. Defensive medicine effect on costs, quality, and access to healthcare. *Journal of Biology, Agriculture and Healthcare*, 3(6):29–35, 2013.

A. Afkhamebrahimi and M. Nasr Esfehani. Patients' expectations and satisfaction with their health providers. *Global Journal of Community Psichology Practice*, 3(4), 2013. Retrieved 2014-12-03, from http://www.gjcpp.org/pdfs/2012-Lisboa-001-Patients.pdf.

G. C. Alexander and L. P. Casalino. Barriers to Patient-physician Communication About Out-of-pocket Costs. *Journal of General Internal Medicine*, 19(8):856–860, 2004. Epub ahead of print.

J. J. Allison, C. I. Kiefe, E. F. Cook, et al. The association of physician attitudes about uncertainty and risk taking with resource use in a medicare hmo. *Medical Decision Making*, 18(3):320–9, 1998.

American Medical Association. Principles of Medical Ethics, 1957. Retrieved 2014-11-17, from http://www.ama-assn.org/ama/pub/physician-resources/medical-ethics/code-medical-ethics/principles-medical-ethics.pag.

American Medical Association. Opinion 10.01 - Fundamental Elements of the Patient-Physician Relationship, 1992. Retrieved 2014-11-25, from http://www.ama-assn.org/ama/pub/physician-resources/medical-ethics/code-medical-ethics/opinion1001.page.

G. Anderson and Glesnes-Anderson. *Health Care Ethics.* 1987. Publication, Rockville, MD: Aspen Publication.

J. D. Anderson, S. J. Jay, H. C. Weng, and Anderson. M. M. Studying the effect of clinical uncertainty on physicians' decision-making using iliad. *Medinfo*, 8:869–72, 1995.

American Speech-Language-Hearing Associacion. Question and answer: Self-referral/stark law and anti-kickback regulations, 2014a. Retrieved 2014-12-08, from http://www.asha.org/practice/reimbursement/medicare/QAs/.

American Speech-Language-Hearing Associacion. Medicare prospective payment systems (pps), 2014b. Retrieved 2014-12-07, from http://www.asha.org/practice/reimbursement/medicare/pps_sum.htm.

Liverpool Health Authority. Health care system, 2009. Retrieved 2014-09-03, from `http://www.liverpool-ha.org.uk/`.

H. Barnum, J. Kutzin, and H. Saxenian. Incentives and provider payment methods. *The International Journal of Health Planning and Management*, 10:23–45, 1995.

E. J. Belzer. Improving patient communication in no time. *Family Practice Management*, 6(5):23–28, 1999. Here are quick ways to evaluate and refine your communication style to better suit your patients' needs.

K. D. Bertakis, R. Azari, E. J. Callahan, et al. Comparison of primary care resident physicians' practice styles during initial and return patient visits. *Journal of General Internal Medicine*, 14(8):495–8, 1999.

L. Bickerdyke, R. Dolamore, Monday L., and Preston R. *Supplier-Induced Demand for Medical Services*. 2002. Canberra: Productivity Commission.

R. Busse, M. Blümel, and S. Stock. *The German Health Care System*. 2011. In: Thomson S., Osborn R., Squires D., Reed S. J. (eds.) International Profiles of Health Care Systems, 2011, The Commonwealth Fund, available at: http://www.commonwealthfund.org.

C. Cashin, S. O'Dougherty, Y. Samyshkin, et al. *Case-Based Hospital Payment Systems: a step-by-step guide for design and implementation in low- and middle-income countries*. Bethesda, 2005. MD: United States Agency for International Development (USAID) ZdravPlus Project.

A. B. Casto and E. Layman. *Principles of Healthcare Reimbursement*. American Health Information Management Association, 4th edition edition, 2006.

T. Cayirli and E. Veral. Outpatient scheduling in health care: a review of literature. *Production and Operations Management*, 12(4):519–549, 2003.

S. R. Chakravarty. *Microeconomics*. Allied Publishers Pvt. Ltd., 2002.

E. Chilet-Rosella, M. T. Ruiz-Canteroa, J. Fernández Sáeza, et al. Desigualdad en prescripción de analgésicos en españa. una cuestión de desarrollo de género. *Gaceta Sanitaria*, 27:135–42, 2013.

F. A. Connel, R. W. Day, and J. P. LoGerfo. Hospitalisation of medicaid children: analysis of small area variations in admission rates. *American Journal of Public Health*, 77:606, 1981.

R. F. Coulam and G. L. Gaumer. Medicare's prospective payment system: A critical appraisal. pages 45–77, 1992. Health Care Financing Review 1991 Annual Supplement.

C. Donaldson and K. Gerard. *Economics of health care financing: the visible hand*. St. Martin's Press, 1993.

J. M. Eisenberg. Physician utilization: The state of research about physicians' practice patterns. *Medical Care*, 40(11):1016–35, 2002. First published in Medical Care, 23(5):461–83, 1981.

J. M. Eisenberg and D. Kicklin. Use of diagnostic services by physicians in community practice. *Med Care*, 19:297, 1981.

R. Ellis and T. McGuire. Hospital response to prospective payment: moral hazard, selection, and practice-style effects. *Journal of Health Economics*, 15:257–277, 1996.

R. P. Ellis. Creaming, skimping and dumping: provider competition on the intensive and extensive margins. *Journal of Health Economics*, 17:537–555, 1998.

R. P. Ellis and T. G. McGuire. Provider behavior under prospective reimbursement. Cost sharing and supply. *Journal of Health Economics*, 5(2):129–151, 1986.

B. Essue, Kelly, P., M. Roberts, et al. We can't afford my chronic illness! The out-of-pocket burden associated with managing chronic obstructive pulmonary disease in western Sydney, Australia. *Journal of Health Services Research and Policy*, 16(4): 226–231, 2011.

R. G. Evans. Supplier-induced demand: Some empirical evidence and implications. 1974. In Culyer (Ed.), The economics of health and medical care, 1991, p. 66-77, London and Basingstoke: Macmillan.

R. G. Evans. *Strained Mercy: the Economics of Canadian Health Care*. Butterworth and Co, 1984.

S. Felder, A. Schmid, and V. Ulrich. Medical decision making and demand. In Culyer, A. J. (Ed.), Encyclopedia of Health Economics, Amsterdam, 2014, p.255-259.

R. Feldman and F. Sloan. Competition among physicians, revisited. *Journal of Health Politics*, 13:239–261, 1988.

J. J. Fenton, A. F. Jerant, K. D. Bertakis, and P. Franks. The cost of satisfactiona national study of patient satisfaction, health care utilization, expenditures, and mortality. *Archives of Internal Medicine*, 172(5):405–11, 2012. doi: doi:10.1001/archinternmed.2011.1662.

S. Folland, A. C. Goodman, and M. Stano. *The economics of health and health care*. 4th edition, 2004. Pearson Prentice Hall.

M. W. Friedberg, P. G. Chen, K. R. Van Busum, et al. *Factors Affecting Physician Professional Satisfaction and Their Implications for Patient Care, Health Systems, and Health Policy*. 2013. Research Report, Santa Monica: RAND Corporation.

V. R. Fuchs. The supply of surgeons and the demand for operations. *Journal of Human Resources*, page 35–56, 1978.

Nigel G. *Agent-Based Models*. SAGE, 2008.

T. Galama and A. Kapteyn. Grossman's missing health threshold. *Journal of Health Economics*, 30(5):1044–1056, 2011.

S. W. Glickman, W. Boulding, M. Manary, et al. Patient satisfaction and its relationship with clinical quality and inpatient mortality in acute myocardial infarction. *Circulation: Cardiovascular Quality and Outcomes*, 3(2):188–95, 2010. doi: 10.1161/CIRCOUTCOMES.109.900597.

S. Glied and P. C. Smith. *The Oxford handbook of health economics*. Oxford University Press, 2011.

B. Gonzalez Lopez-Valcarcel, J. Librero, G. Sanfelix-Gimeno, S. Peiro, and The Group for Drug Utilization Research in the Spanish National Health System (IUM-SNS Group). Are prescribing doctors sensitive to the price that their patients have to pay in the spanish national health system? *BMC Health Services Research*, 11(1):333, 2011. Retrieved 2014-11-16, from `http://www.biomedcentral.com/1472-6963/11/333`.

D. Green. *Challenge to the NHS*. 1986. Institute of Economic Affairs.

R. Grol, H. Mokkink, A. Smits, et al. Work satisfaction of general practitioners and the quality of patient care. *Family Practice*, 2(3):128–35, 1985.

M. Grossman. On the concept of health capital and the demand for health. *The Journal of Political Economy*, 80(2):223–255, 1972.

J. S. Haas, Cook E. F., A. L. Puopolo, et al. Is the professional satisfaction of general internists associated with patient satisfaction? *Journal of General Internal Medicine*, 15(2):122–128, 2000. doi: doi:10.1046/j.1525-1497.2000.02219.x.

K. H. Hall. Reviewing intuitive decision-making and uncertainty: the implications for medical education. *Medical Education*, 36(3):216–24, 2002.

M. F. Hall. Looking to improve financial results? Start by listening to patients. *Healthcare financial management*, 62(10):76–80, 2008.

H. Hennig-Schmidt, R. Selten, and D. Wiesen. How payment systems affect physicians' provision behaviour: an experimental investigation. *Journal of Health Economics*, 30 (4):637–646, 2011.

J. Hickner, P. J. Thompson, T. Wilkinson, et al. Primary care physicians' challenges in ordering clinical laboratory tests and interpreting results. *Journal of the American Board of Family Medicine*, 27(2):268–74, 2014.

H. M. Hofmarcher, M. M.and Rack. Austria: Health system review. *Health Systems in Transition*, 8(3):1–247, 2006.

M. Jegers, K. Kesteloot, D. De Graeve, and W. Gilles. A typology for provider payment systems in health care. *Health Policy*, 60(3):255–73, 2002.

R. L. Kane, M. Maciejewski, and M. Finch. The relationship of patient satisfaction with care and clinical outcomes. *Medical Care*, 35(7):714–30, 1997.

S. H. Kaplan, S. Greenfield, and J. E. Ware. Assessing the effects of physician-patient interactions on the outcomes of chronic disease. *Medical Care*, 27(3 Suppl):S110–27, 1989.

J. P. Kassirer. Managed care and the morality of the marketplace. *The New England Journal of Medicine*, 333(1):50–2, 1995.

H. E. Klarman. *The Economics of Health.* Columbia University Press, 1965.

J. M. Kupfer and E. U. Bond. Patient satisfaction and patient-centered carenecessary but not equal. *JAMA: Journal of the American Medical Association*, 308(2):139–140, 2012. doi: doi:10.1001/jama.2012.7381.

T. K. Lake and R. F. St Peter. Payment arrangements and financial incentives for physicians. *Fall*, 8:1–2, 1997. Data Bull (Cent Stud Health Syst Change).

L. Lasagne. Hippocratic Oath (Modern version), 1964. Retrieved 2014-11-17, from `http://guides.library.jhu.edu/content.php?pid=23699&sid=190964`.

S. Li and R. Laxminarayan. Are Physicians' Prescribing Decisions Sensitive to Drug Prices? Evidence from a Free-Antibiotics Program. *Health Economics*, 2013. doi: 10.1002/hec.3008. Epub ahead of print.

L. S. Linn, R. H. Brook, V. A. Clark, et al. Physician and patient satisfaction as factors related to the organization of internal medicine group practice. *Medical Care*, 23(10): 1171–8, 1985.

P. Little, M. Dorward, G. Warner, et al. Importance of patient pressure and perceived pressure and perceived medical need for investigations, referral, and prescribing in primary care: nested observational study. *BMJ*, 21(8):328–444, 2004.

J. Logan, E. Woodfield, and D. G. Green. *Healthy Competition.* 1989. Centre for Independent Studies Limited.

C-tA. Ma. Health care payment systems: cost and quality incentives. *Journal of Economics and Management Strategy*, 3:93–112, 1994.

G. M. Macdonald. New directions in the economic theory of agency. *The Canadian Journal of Economics*, 17(3):415–440, 1984.

A. P. Manner. Practicing defensive medicine—not good for patients or physicians, 2007. Retrieved 2014-11-28, from `http://www.aaos.org/news/bulletin/janfeb07/clinical2.asp`.

M. K. McClellan. Do doctors practice defensive medicine? *The Quarterly Journal Economics*, 11:353–90, 1996.

T. G. McGuire. Physician agency. *Handbook of Health Economics*, 1A:461–536, 2000. In Culyer, A. J. and Newhouse J.P. (Eds) 'Handbook of Health Economics', Amsterdam:Elsevie.

B. McPake, L. Kumaranayake, and C. Normand. *Health Economics: An International Perspective*. Routledge, 2002.

R. E. Mechanic and S. Altman. Payment reform options: Episode payment is a good place to start. *Health Affairs*, 28(2):pw262, 2009. pw262.

L. Melichar. The effect of reimbursement on medical decision making: Do physicians alter treatment in response to a managed care incentive? *Journal of Health Economics*, 28 (4):902–907, 2009.

S. Morris, N. Devlin, and D. Parkin. *Economic Analysis in Health Care*. John Wiley and Sons, 2007.

National Center on Addiction and Substance Abuse (CASA). Under the counter: The diversion and abuse of controlled prescription drugs in the u.s. 2005. A report by CASA at Columbia Universit. Retrieved 2014-11-28, from http://www.amednews.com/article/20050808/profession/308089966/2/.

E. Neuman and N. Shoshana. Agency in health-care: Are medical care-givers perfect agents? *Applied Economic Letters*, 16(13-15):1355–1360, 2009.

J. Newhouse. Do unprofitable patients face access problems? 11:32–42, 1989. Health Care Financing Review.

J. Newhouse and D. Byrne. Did medicares prospective payment system cause length of stay to fall? *Journal of Health Economics*, 7:413–416, 1988.

J. P. Newhouse. Health plans and health providers: Efficiency in production versus selection. *Journal of Economic Literature*, 34:1236–1263, 1996.

M. K. O'Brien, K. Petrie, J. Raeburn, et al. Adherence to medication regimens: updating a complex medical issue. *Medical Care*, 49(4):435–54, 1992.

American Academy of Orthopaedic Surgeons (AAOS). Information statement patient-physician communication, 2000. Retrieved 2014-09-01, from http://www.aaos.org/about/papers/advistmt/1017.asp.

Office of Technology Assessment. *Variations in hospital length to stay: their relationship to health Outcomes*. 1983. Office of Technology Assessment, Congress of United States.

World Health Organisation. Key components of a well functioning health system, 2010. Retrieved 2014-09-01, from http://www.who.int/healthsystems/EN_HSSkeycomponents.pdf.

World Health Organisation. Healt systems, 2014. Retrieved 2014-09-01, from http://www.who.int/topics/health_systems/en/.

Organisation for Economic Co-operation and Development (OECD). Health at a Glance 2013: OECD Indicators, 2013. OECD Publishing, Retrieved 2014-11-15, from http://www.oecd.org/els/health-systems/Health-at-a-Glance-2013.pdf.

M. Pauly. *Doctors and Their Workshops: Economic Models of Physician Behavior.* 1980. University of Chicago Press, Bureau of Economic Research. Retrieved 2014-11-25,from http://www.nber.org/chapters/c11521.pdf.

M. V. Pauly. Editorial: A re-examination of the meaning and importance of supplier-induced demand. *Journal of Health Economics*, 13:369–372, 1994.

G. A. Poulas, R. T. Brodell, and E. N. Mostow. Improving quality and patient satisfaction in dermatology office practice. *Archives of Dermatology*, 144(2):263–5, 2008. doi: 10.1001/archdermatol.2007.58.

U. E. Reinhardt. Economists in health care: saviours, or elephants in a porcelain shop? *American Economic Association Papers and Proceedings*, 79(2):337–342, 1989.

T. H. Rice. The impact of changing medicare reimbursement rates on physician-induced demand. *Medical Care*, 21:803–815, 1983.

E. P. Richards and K. C. Rathbun. *Medical Care Law.* Aspen Publishers, 1999. Inc.

J. Richardson. The inducement hypothesis: that doctors generate demand for their own services. 1981. In van der Gaag, J. and Perlman, M. (Eds.) Health, Economics and Health Economics, p. 189–214, North-Holland Publishing Co., Amsterdam.

J. R. Richardson and S. J. Peacock. Supplier-induced demand: reconsidering the theories and new australian evidence. *Applied Health Economics and Health Policy*, 5(2):87–98, 2006.

J. C. Robinson. Hmo market penetration and hospital cost inflation in california. *Journal of the American Medical Association*, 266(19):2719–2723, 1991.

M. I. Roemer. Bed supply and hospital utilization: a natural experiment. *Hospitals*, 35: 36–42, 1961.

W. H. Rogers, D. Draper, K. L. Kahn, et al. Quality of care before and after implementation of the drg-based prospective payment system. a summary of effects. *JAMA*, 264 (15):1989–1994, 1990.

N. P. Roos. Hysterectomy variation in rates across small areas and across physicians' practices. *American Journal of Public Health*, 74:327, 1984.

L. F. Rossiter and G. R Wilensky. A reexamination of the use of physician services: the role of physician-initiated demand. *Inquiry*, 20(2):162–72, 1983.

M. Ryan. Agency in health care: Lessons for economists from sociologists. *The American Journal of Economics and Sociology*, 53(2), 1994.

R. E. Say and R. Thomson. The importance of patient preferences in treatment decisions–challenges for doctors. *BMJ*, pages 327(7414):542–5, 2003.

P. Schuetz, W. C. Albrich, I. Suter, et al. Quality of care delivered by fee-for-service and drg hospitals in switzerland in patients with community-acquired pneumonia. *Swiss Medical Weekly*, 141:w13228, 2011.

M. Schwartz, S. G. Martin, D. D. Cooper, et al. The effect of thirty percent reduction in physician fee on medicaid surgery rates in massasutchetts. *American Public Health*, 71:370, 1981.

H. Shigeoka and K. Fushimib. Supplier-induced demand for newborn treatment: Evidence from japan. *Journal of Health Economics*, 35:162–178, 2014.

W. H. Shrank, S. M. Asch, G. J. Joseph, et al. Physicians' perceived knowledge of and responsibility for managing patients' out-of-pocket costs for prescription drugs. *Ann Pharmacother*, 40(9):1534–40, 2006.

E. Silverman and Skinner J. Medicare upcoding and hospital ownership. *Journal of Health Economics*, 23:369–89, 2004.

K. Socha-Dietrich and P. Zweifel. Creaming and dumping: Who on whom? *COHERE Working Paper*, 4, 2014. University of Southern Denmark, Retrieved 8 December from http://static.sdu.dk/mediafiles/1/2/B/

J. Solomon. How strategies for managing patient visit time affect physician job satisfaction: A qualitative analysis. *Journal of General Internal Medicine*, 23(6):775–780, 2008. doi: 10.1007/s11606-008-0596-y.

R. L. Street, G. Makoul, N. K. Arora, and R. M. Epstein. How does communication heal? Pathways linking clinician-patient communication to health outcomes. *Patient Education and Counseling*, 74(3):295–301, 2009.

D. Studdert, M. M. Mello, A. A. Gawande, et al. Claims, errors, and compensation payments in medical malpractice litigation. *The New England Journal of Medicine*, 354:2024–2033, 2006. doi: 10.1056/NEJMsa054479.

C. E. van Dijk, B. van den Berg, R. A. Verheij, et al. Moral hazard and supplier-induced demand: empirical evidence in general practice. *Health Economics*, 22(3):340–52, 2013. doi: 10.1002/hec.2801.

J. C. Warren and B. K. Smalley. *Rural public health: best practices and preventive models.* Springer Publishing Company, 2014.

N. Weissenberger, D. Thommen, P. Schuetz, et al. Head-to-head comparison of fee-for-service and diagnosis related groups in two tertiary referral hospitals in switzerland: an observational study. *Swiss Medical Weekly*, 143:w13790, 2013.

L. Wendy and G. Scott. *Service Quality Improvement. The customer satisfaction strategy for health care.* AHA company, 1994.

S. Willems, S. De Maesschalck, M. Deveugele, et al. Socio-economic status of the patient and doctor-patient communication: does it make a difference? *Patient Education and Counseling*, 56(2):139–46, 2005.

World Health Organisation. What is universal health coverage, 2012. Retrieved 2014-11-15, from `http://www.who.int/universal_health_coverage/en/`.

W. C. Yip. Physician response to medicare fee reductions: changes in the volume of coronary artery bypass graft (cabg) surgeries in the medicare and private sectors. *Journal of Health Economics*, 17(6):675–99, 1998.

P. Zweifel, F. Breyer, and M. Kifmann. *Health Economics*. Springer-Verlag, 2nd edition edition, 2009.

List of Figures

1.1 The main components of the simplified health care system (adapted from WHO, 2014) . . . 4
1.2 Relationship between a physician and his patient in the medical market . 9

2.1 Physician serving as the Patient's Agent . . . 11
2.2 Physician's benefits achieved from the Perfect Agency . . . 21

3.1 The structure of the Model with a Perfect Agency . . . 27
3.2 Relations between the sets **M**, **D** and **P** . . . 31
3.3 Representation of the treatment process . . . 32
3.4 Minimum distance principle . . . 36
3.5 Patient's attributes and relations between them . . . 37
3.6 The dynamics of the Model with a Perfect Agency . . . 39
3.7 The probability density function of the Beta distribution with shape parameters $\alpha = 5$ and $\beta = 0.1$ . . . 42
3.8 The health care system presented in Example No. 1 at t_0 . . . 44
3.9 The health care system in the Example No. 1 at t_1 . . . 44
3.10 The health care system presented in the Example No. 1 at t_2 . . . 45
3.11 The health care system presented in the Example No. 1 at t_3 . . . 46
3.12 The health care system presented in the Example No. 1 at t_4 . . . 46
3.13 The average physicians' benefits per simulation run obtained per a quarter of the year after performing $s = 100$ simulation runs . . . 50
3.14 Beta probability density function B (α, β) and the corresponding changes in average number of patients based on the average results of 100 simulation runs of the Example No. 1 . . . 51
3.15 The health care system presented in the Example No. 1 at t_0 after changing the ordinary individuals' distribution in the model environment . . . 53
3.16 The average physicians' benefits per simulation run obtained per quarter of the year after changing patients' location in the two-dimensional space and performing the simulation $s = 100$ times . . . 54

4.1 Main influences on physician behaviour . . . 62
4.2 The standard theory vs. SID theory (adapted from Fuchs, 1978) . . . 69
4.3 Graphical representation of SID: the viewpoint of "narrows" and "broads" (adapted from Bickerdyke et al., 2002) . . . 70

5.1 The physician's opportunistic behaviour indicators . . . 81

5.2 The physician's opportunistic behaviour indicators 81
5.3 The distribution of physicians and ordinary individual agents in the model environment at t_0 84
5.4 Scenario No. 1 A: Comparison of the average total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 % 90
5.5 Scenario No. 1 A: Comparison of the total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 15 % . . 91
5.6 Scenario No. 1 A: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field 91
5.7 Scenario No. 1 B: Comparison of the average total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 % 94
5.8 Scenario No. 1 B: Comparison of the total income per quarter Q between the providers specialised to treat diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 15 % . . 94
5.9 Scenario No. 1 B: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field 95
5.10 Scenario No. 2: Comparison of the average total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 % 99
5.11 Scenario No. 2: Comparison of the total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 30 % . . 99
5.12 Scenario No. 2: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field 100
5.13 Scenario No. 3 and 4: Comparison of the average total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under perfect agency after reducing the physician fees by 15 % 103
5.14 Scenario No. 3 and 4: Comparison of the total income per quarter Q between the providers specialised to treat the diseases or disorders of the same medical field under imperfect agency after reducing the physician fees by 30 % 104
5.15 Scenario No. 3 and 4: The share of income-oriented physicians' income gained due to opportunistic behaviour compared with the total expenditures spent on his/her medical field 104