Fyodorov's Radial Keratotomy: Technological Diffusion Under Different Institutional Regimes

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Introduction

It had been widely argued that stronger intellectual property rights protection results in faster diffusion of new technologies. Strong protection creates more attractive and advantageous conditions for foreign firms' production and distribution. It provides guarantee that the technology used would not be copied or infringed upon by a competitive firm and induces significantly more international technology transfers¹.

We investigate the role of institutional frameworks in the diffusion of the inventions of the famous Russian eye surgeon, academician Svyatoslav Fyodorov, the author of surgical procedure of radial keratotomy (RK). By tracking the dissemination of his innovative methods and devices through patenting and licensing during the Soviet period and later during the transition period, we analyse the impact of technological diffusion under different institutional regimes.

Some empirical studies have emphasized the role of human capital in absorbing international technology spill-overs. The level of human capital is argued to have a large positive effect on the speed of technology catch-up². Both IPR regime and trade policy facilitate technology transfers and result in productivity gains. According to Xu, Chiang (2005), a change in IPR policy seems to bring more productivity gains than a comparable change in trade policy. Thus economic policies play a significant role in the amount and form of foreign technology spill-overs.

In our paper, we will try to analyze these hypotheses. We will start by looking into the inventions produced by Svyatoslav Fyodorov and his Inter-Sectoral Research and Technology Complex

¹ Lee Branstetter, Raymond Fisman, c. Fritz Foley, 'Do Stronger Intellectual Property Rights increase International Technology Transfer? Empirical Evidence from the U.S. Firm-Level Data', NBER Working Paper Series, Working Paper 11516 July 2005

² Bin Xu, Eric P. Chiang 'Trade, Patents and International Technology Diffusion', Journal of International Trade and Economic Development, Vol. 14, No. 1, March 2005

"Eye Microsurgery" (MNTK) within a diapason of about 40 years. We will then present unique technology diffusion channels introduced by Fyodorov. Finally, we will describe the business and property rights structures established within Fyodorov's Institute with their implications and effects on quality and treatment rate.

More generally, the work provides an insight into the structure of property rights that would lead to more optimum usage of innovative resources.

Innovation rate

Fyodorov's invention that got mostly known around the world is radial keratotomy (RK), which gave its title to our paper³. RK is though far from being the only contribution to ophthalmology made by Fyodorov. Here, we are presenting a chronological list of principal new operational methods and devices introduced by Fyodorov himself, as well as developed by his Institute.

Table 1.

Years	New technologies and methods			
1960	Developed an artificial crystalline lens. Performed the first-ever operation to implant it.			
1966	Implanting a special hydrophilic elastic lens.			
Mid 1960s	Development of new intraocular lens 'Sputnik' (40 times lighter than artificial crystalline, and better in its optical characteristics by 40%).			
1967	Started research on implantation of artificial cornea. keratoprosthetic method used in MNTK to treat dystrophic and burn leucomas.			
Around 1966	Development of a diamond knife.			
Early	Developing a complex of surgical methods to prevent myopia, astigmatism,			
1970s	hyperopia (farsightedness), refractive surgery devices and instruments.			
1972	Development of radial keratotomy (RK)			

 $^{^{3}}$ A surgical correction of myopia (nearsightedness) by making superficial radial incisions on the surface of the cornea.

1972	Fyodorov-Zuev prostesis (inventor's Certificate No 506964). A new type of penetrating keratoprosthesis.		
1973	First operation ever to treat glaucoma at early stage using the method of scleroplastics.		
1974	The method of implanting artificial lens is officially recognized in the USA. Creatio of the US Fyodorov's Artificial Lens Implant Society.		
	Numerous forced inventions, e.g. 'special support for surgeon's hand', 'cornea marking device'.		
Mid 1970s	The first in the country to start practicing laser operations.		
1975	Developing various models of rear lenses.		
	Developing 'Vitreotom' (device for treatment of hyaline dimness as a consequence of hemorrhage, injury or inflammation)		
	New theory of open-angle glaucoma		
	For the first time in the USSR, Fyodorov used non-conserved donor cornea for keratoplastics procedure, and perfected the corresponding technique.		
	Introduction of a conveyor for surgical operations.		
Mid 1980s	Developed new method of treatment of cornea vein thromboses, secondary cataract, and glaucoma, using laser eye surgery.		
1980s	Based on implantation of artificial lens, MNTK developed a new complex of operations to fight nearsightedness and farsightedness of high degree of complexity. Only starting from late 1990s, the technique gets worldwide application.		
1988	Developing 'Endolaser', a unit for getting laser ray into an eye during an operation.		
1995	Together with other researchers (Nobel prizes) creates a series of excimer laser unit 'Profile'. Excimer laser unit 'Profile 2005' (operation without technical impact on the eye.		
1990s	Developing devices and thick cataract removal methods (mechanical fragmentation of the nucleus). New variations of open-angle and closed-angle glaucoma operations.		
	Institute's development (in cooperation with the Institute of Organic Chemistry) of compounds used for treating severe forms of cornea detachment.		
1997- 1998	MNTK developing a technique of treating glaucoma by means of excimer laser. It is a unique and very costly operation only performed in this center in the whole country.		
2000	Unique method of dissolving artificial lens by means of laser rays (post-operation rehabilitation time decrease to 2-3 hours)		
2001	Approbation of the Institute's newly developed laser unit 'Profile 500 Miniscan'		

The total number of Fyodorov's inventions amounts to more than 180⁴. As to the innovative activity of MNTK in general, there were 236 inventions made during the first four years of its existence, 87 receiving patents in foreign countries. From 1986 to 2001, MNTK employees published about 1500 scientific papers, received 247 patents and defended 31 dissertation. It was partially due to the system of compensation for inventions established by the Institute. Between 1993 and 1994, the total number of applications for inventions within MNTK increased y 72 %, whereas it decreased by 30% across the country. The Institute innovation rate increased in the last years, producing 532 patents over the period 2000-2005, and 49 doctoral dissertations.

The Soviet system did not facilitate production and introduction of new technologies. One of the major issues was the lack of funds for buying equipment and developing new methods of treatment, being financially dependent on the monopoly of the Ministry of Health. For instance, in the mid 1980s, the Institute's needs for R&D were amounting to 10-15 million roubles. Nevertheless, they would receive 1.3 million roubles a year from the state budget, of which only being able to spend 900 000 on equipment⁵. Consequently, the introduction of new methods was retarded by 15 to 20 years. Medicine was getting obsolete. There was a lack of adequate equipment, qualified personnel and economic motivation to work. Around 1986, 500 000 people annually were not able to receive eye treatment due to the limited capacity of the medical system⁶. In addition, a patient would have no power to choose a physician and would be assigned to a particular doctor within the area he lived. Curiously, at the early stage of Fyodorov's research activity, many of the devices he used were developed by his own patients and their relatives. In the USSR, it was a physician alone who decided on whether to use new instruments

⁴ Most of the data on inventions comes from "Fenomen Svyatoslava Fyodorova", B. Sh. Nuvakhov. Moskva, 1997

⁵ "Meet the third millennium without spectacles. Interview granted to Viktor Zatevakhin", USSR, 1987

⁶ "Svyatoslav Fyodorov: Put' Istseleniya", Moskva, 1995

or methods of treatment. The goal to meet in the face of the Ministry of Health was the number of people treated, not the quality of treatment. In the 1980s, a Soviet physician would perform 100 operations a year, as compared to 500-1000 performed by an American or German.

Technological Diffusion

Svyatoslav Fyodorov was not only a pioneer in his professional field, but equally in the way of organizing his institute and diffusing his methodologies. As will be described in this section, diffusion was effectuated across many different axes.

Mobile Units:

The first operational bus was introduced around 1978, which constituted a total phenomenon at the times. Svyatoslav Fyodorov was following the principle that a physician has to go towards a patient. The bus travelled mostly across the European part of Russia, providing treatment to patients and exchanging knowledge with local ophthalmologists. In total, three generations of buses were introduced. The second bus was equipped with two operation tables and a small sector for diagnostics. The latest development was a set of two buses, one of which included laser equipment and a diagnostics sector, and the second one equipped exclusively for performing operations. Connecting the two would result in 80 square meters of functional space. For teaching purposes, a special hall for holding conferences with demonstrations was designed on buses. About 70% of all operations done in MNTK could be performed on such a mobile unit. In addition to Russian territory, these buses were also operating in India and Yemen. In those countries, the total volume of operations amounted to 1224.

Floating Clinic:

The floating clinic 'Peter I' equipped with the newest technology was first put out to sea in July 1989. It was first tested in the ports of Yalta, Sochi, and Odessa, then travelled to Bulgaria, Turkey, Cyprus, Egypt, UAE, and Gibraltar. During the first year of operating, 12 000 patients from 47 countries were consulted aboard and more than 4000 got operated.

Several countries expressed discontent regarding the stay of 'Peter I' on their territories, in particular for stealing jobs from local ophthalmologists. Nevertheless, the ship was received with big enthusiasm in Yemen, Cyprus, Gibraltar, and UAE. In UAE, for instance, the ship stayed between October 1989 and April 1990. Several days after the arrival of the ship, more than 5000 patients were on the operations waiting list, and 60 ophthalmologists from different countries were waiting to assist the operations. They could follow the procedure by means of special monitors established in the operational sector. During that stay 15000 patients got examined on the ship from 45 countries, and 7500 operations of high degree of complexity performed. The revenues received amounted to \$14 millions. In the summer of 1990, the ship returned to the Black sea. It stayed in Cyprus until January 1991 performing more than 3500 operations. It travelled to Gibraltar in 1993, treating patients from England, Spain, Portugal, and Morocco. In total more than 21000 operations were performed on 'Peter I'.

Apart from the floating clinic, Fyodor also had an idea to launch a flying clinic, which unfortunately was ever made reality due to high costs imposed by governmental officials.

Eye Microsurgery Centers outside Russia:

MNTK has collaborated in establishing eye microsurgery complexes in 9 countries: Japan, Cuba, Albania, Bulgaria, Italy, UAE, San Marino, China, and Egypt. Clinics were also established in

Yemen, Poland, Albania, and Malaysia. In exchange for technology and training provided, the 'Eye Microsurgery' receives a certain percentage of revenues gained by these centres abroad. For instance, a clinic in Dubai, UAE, brings about \$15 000 daily.

In the late 1980s, the expansion of MNTK to other soviet republics was being negotiated between the Russian Ministry of Health and the Ministries of the corresponding republics. In 1989, Lithuania banned the construction of an 'Eye Microsurgery' complex on its territory. Lithuanian ophthalmologists claimed to be against RK methods. Constructing a branch in Vilnius would also be viewed as an expansion of Russia's power and control over the rest of the republics. Similar situations resulted in Estonia, Latvia, Ukraine, Belarus, Moldavia, and Georgia⁷.

Teaching:

MNTK possesses a teaching center with an extensive scientific library, and a conference room in which operations performed in the complex are transmitted on special screens. Conference participants can lead an interactive discussion with the operating surgeon. During the first 15 years, 3200 Russian ophthalmologists and 500 physicians from 43 different countries got training in MNTK.

According to the current general director of MNTK, Khristo Takhchidi, the distinctive feature of the technologies developed and tested by Fyodorov was their level of perfection that allowed even ophthalmologists of medium qualification to easily start introducing them into practice.

⁷ "Skal'pel' Protiv Absurda", E. P. Dobrynina, Moskva, 1997

Scientific exchange:

One of the most precise ways of tracking international diffusion of knowledge might be to look chronologically at scientific papers published that reveal that information, as well as scientific congresses that take place internationally. Due to the lack of time and resources, we leave it as a task to attempt accomplishing in the future. We were still able to track several important conferences where Fyodorov presented his inventions.

In 1960, the time, when nobody in Soviet Russia believed in the method of implanting artificial lens, Fyodorov was the first ophthalmologist in the world to talk about his experience of implanting 200 artificial lenses during a small conference in Europe. In 1966, he presented at a conference in London. In 1978, the methodology was recognized in the US. In the fall of 1982, he visited the US for the first time, where he demonstrated an operation of implanting a crystalline lens and talked about his method of RK.

During 1986-2001, 283 MNTK employees took part in congresses in 89 different countries. Over the period of 2000-2005, MNTK researchers participated in 245 national and 63 international conferences.

Intellectual Property Rights (IPR) involved:

We calculate the total number of patent filings made by Fyodorov and his co-authors, over the period of 1970-2000. In Chart 1, we depict the trend in filings outside Russia (foreign countries as well as international patents). In Chart 2, we present the trend that existed in Russian filings. As to international filings, we can observe a peak around the years 1990-1991. Most of the applications were made in the US, where Fyodorov's inventions were widely diffused. High rates of patenting may indicate expectation to use patented technology in that particular country. The 1980s' figures might also be due to a partial opening of the Soviet State internationally.

Prior to 1992, when the Russian Patent and Utility Model Protection Law was passed, there was essentially no protection provided to inventions made on Russian (Soviet) territory. Certificates of authorship were the primarily type of protection designated for the inventions produced by soviet citizens. A certificate of authorship provided recognition of the authorship, but transferred the exclusive right in the invention to the Soviet State. According to the 1973 Statute, inventions protected by certificates of authorship could be freely used by the soviet state, public enterprises and organizations without getting any special permission from the part of the inventor. Prior to 1992, the biggest amount of filings in the Soviet Russia is observed in the mid and late 1980s. This might be due to the high rates of inventive activity observed in those times, the recognition of both the RK method and the artificial lens implantation. Once protection of intellectual property became accessible within Russia, we can notice a significant increase in filings around 1993-1994.





Source: http://ep.espacenet.com





Source: http://ep.espacenet.com/

MNTK "Eye Microsurgery" business structure:

General Structure:

The Inter-Sectoral Research and Technology Complex "Eye Microsurgery" was created in 1986 on the basis of the Eye Microsurgery Institute in existence since 1974. The Complex includes 12 branches in major Russian cities, experimental technical production plant, biochemical labs, a hotel, and even a farm. Nowadays, the Complex is capable of treating 300 000 and examining 700 000 patients annually.

Table	2:
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Foundation	City	Treatment Statistics
year		
1986	Cheboksary	280 000 operations in 15 years, 12000-15000 operations
		annually.
1986	Moscow	2005: 29 054 operations. Daily examination of 1200 patients.
1987	St Petersburg	>300 000 operations in 20 years.
1987	Krasnodar	374 000 examined, 184 724 operated in 16 years.
1988	Kaluga	>200 000 operated in 19 years.
1988	Volgograd	>50000 operations in 19 years, 15-18000 treated annually. 2006:
		26195 treated, 74428 examined
1988	Ekaterinburg	450 000 treated, 1720 057 examined in 17 years.
1989	Irkutsk	193 400 operations in 15 years. Daily 200-250 people examined,
		60-80 operated.
1989	Novosibirsk	>400 000 examined, >200 000 operated in 17 years.
1989	Tambov	>150 000 operations in 16 years.
1990	Khabarovsk	NA
1990	Orenburg	NA

The motto of Fyodorov's Institute is developing contemporary methods of treating eye diseases and introducing them into practice within the Complex, thus bringing new technologies closer to patients. All branches of the Complex share common technological basis. Russian and worldwide newly developed technologies get tested in the main center in Moscow and then distributed across all other branches. The proportion of high complexity operations withing the Complex rose from 40.7% in 1993 to 62.7% in 2001, and the number of technologies used increased from 8 in 1987 to 87 in 2001⁸.

The Complex per se also constitutes an important diffusion network, with small laser and eye centers, cabinets, correction and plastic surgery laboratories being created around its main branches. It allows an increase in the number of patients examined, improving rehabilitation and prevention of eye diseases.

⁸ "Svyatoslav Fyodorov: Put' Istseleniya", Moskva, 1995

Business Structure and Property Rights:

The success of the "Eye Microsurgery" complex was greatly due to a completely novel organizational structure introduced by academician Fyodorov.

In mid 1980s, the times of perestroika, government officials in Russia were debating the foundation of inter-sectoral scientific complexes across the country. In 1986, after meeting with the Prime Minister Ryzhkov, Fyodorov got assigned a chair of a general director of the eye microsurgery complex yet to be built. At the time, 23 different complexes were founded across the country. By the year 2000, MNTK 'Eye Microsurgery' was the only one remaining. Fyodorov's Institute gained economic freedom, unimaginable for a soviet enterprise of those times. They stopped living on a fixed state budget and could decide for the wages they paid, the personnel hired and licenses sold independently from the Ministry of Health.

The government would pay an average of 214 roubles for every cured patient. In exchange, the Complex was to treat 32000 patients a year. If less than 214 roubles were spent to cure a person, the remaining were kept within the Complexes funds. Through the beginning of the 1990s, treatment of Soviet citizens was still free. The currency received from foreign patients was mostly invested into developing new technologies. The Complex could now organize economic activities in other spheres and keep 95% of the earned hard currency. New organizational methods allowed the Complex to perform 44 000 operations a year, while the Ministry of Health could only afford to pay for 37 000. Hence, to get extra revenues, they began concluding direct agreements with large enterprises on treating their employees in our mobile operational units.

Since 1987, the industrial organization of the Complex has been based on team work. It has shown to provide incentives to increase both productivity and the quality of treatment. A team consists of 25 people, doctors and nurses. It bears material responsibility for the produced results. Around 1987, each team was performing nearly 2500 operations a year. Compensation depends on the complexity of the operation. Similarly, no compensation is received for unsuccessful operations. In only one year after the introduction of team work, the productivity rose by 73% and the wages by $39\%^{9}$.

The methods of treatment introduced in MNTK 'Eye Surgery' were novel both for Russian and foreign medicines. Surgeon's work was divided into different independent stages, which was mostly due to the introduction of the famous Fyodorov's conveyor, 'Camomile'. Remuneration in the Complex is based on a social justice scale. Paramedics' wages were taken as a basis. The General Director cannot earn more than 4.5 times the lowest wage, the head surgeon more than three times the lowest wage, etc.

Svyatoslav Fyodorov was going ahead of time in his organizational methods. In 1988, the Complex signed a 30-year lease over its productive funds with the Ministry of Health, promising to pay 600 000 rubles in annual fees. One year later, the first rental law was passed in Russia. The 'Eye Microsurgery' Complex was further transformed into a state enterprise. This allowed MNTK to become 6-7 times more financially prosperous than other Russian institutes.

The new regime brought a necessity for new business. In the early 1990s, Fyodorov bought a casino, invested in a mobile phones company, in a bank and a hotel. Due mostly to high tax rates, the bank had to be liquidated, the share in the casino was sold.

The organization of property rights within MNTK was neither socialist nor capitalist, but a collective ownership of means of production. It is an invention of Louis O. Kelso¹⁰. More than 11 000 enterprises have adopted his system in the United States. Each employee of MNTK has a share in what the Complex earns every day. Hence decisions about using funds are also taken

⁹ "Meet the third millennium without spectacles.Interview granted to Viktor Zatevakhin", USSR, 1987

¹⁰ 'Capitalist Manifesto', Random House, 1958

collectively via voting. Although a law was passed in Russia in 1998 facilitating the foundation of enterprises with the same property rights structure, governmental official were still imposing obstacles for their creation. In 2000, about 50 such enterprises existed in Russia. According to Fyodorov, having more of this type of enterprises established in the country would eventually help significantly raise the governmental budget. Fyodorov's Institute annually pays two and a half million dollars in taxes. All this given that the Ministry of Health has run into huge debts with the Complex.

MNTK 'Eye Microsurgery' never became owner of its own building and the land that it occupies. The first attempt to privatize the Complex turned into a complete failure. The price Fyodorov was requested to pay was 3.1 times greater than MNTK balance sheet value, and the Ministry was still keeping the control of 51 % of its shares, not making a discount for the profits the complex paid to the government during its years of existence. If one is not able to privatize a state medical enterprise in Russia, the only possibility left is to create a private clinic. That purpose requires getting one's own equipment, a location, hiring personnel, obtaining a high interest loan. All of that is almost impossible to be realized by regular medical workers.

Profit:

In the first years of the existence of MNTK, operations were its main source of income. It then gradually changed to patent revenues and revenues from selling technology abroad. The year the Complex was created, it earned nearly 2 million dollars from technology sales. The Complex also owns an experimental plant and a factory making spectacles frames, diamond knives, and even electronic equipment. The absence of its own production unit would make it difficult to manufacture instruments, because plants usually do not accept orders that do not fit into their production cycle.

Other sources of income include clinics abroad, revenues brought by the hotel and mobile units operations (e.g. a single month in Yemen earned about half a million dollars). Investments made by the Complex during the first six years multiplied the sum it initially obtained from the government by 4.

The revenues of 'Eye Microsurgery' are divided into four uses: the work compensation fund, the R&D fund (both to stimulate innovation and finance establishment of new clinics), the social development fund, and the shared participation fund.

Rate of treatment

Between 1986 and 1990, the productivity of the Complex rose four times. Nowadays, more than 1200 operations are performed daily. Each branch performs 40 to 80% of all operations in their respective regions, and the whole complex performs about 36% of all operations in the whole country. There are about 200 types of different operations performed in the complex with 600 different variations¹¹.

Only a few foreign patients would receive treatment in Fyodorov's Institute before 1985. After abandoning the interdiction, 25 000 operations were performed during the first half of 1987, bringing 6 million rubles of profit. In 1987, an operation on both eyes to correct myopia would cost a little over \$1000. Needless to say, all foreign patients were kept separately from the domestic ones, in a hotel especially equipped for those purposes.

During the first 15 years, 31 724 foreign patients were treated in MNTK from 122 different countries, with the total of 28 763 operations made. 29.6% of the operations performed were laser non-refractive operations, 19.9% were refractive operations and 10.2% were cataract

¹¹ For more, visit www.mntk.ru

treatment. Foreigners are mostly treated in the main clinic in Moscow, but other branches have also started to catch up in the process. In 2001, 13 189 patients originating from 57 countries were treated in branches outside Moscow.

Since 1985, Fyodor had been travelling and operating all over the world: in Columbia, India, Spain, the USA, Venezuela, Malaysia, Algeria, UAE, Bahrain, Oman, Syria, Saudi Arabia, Cuba, etc. Treatments of foreign patients have usually been based on cooperation contracts. 76 of those had been signed up to year 2001. There are special tours organized to send foreign patients for treatment in Russia. In addition, Russian ophthalmologists occasionally go to other countries themselves to perform operations.

Talking about quality, the rate of complications has significantly decreased, from 3.6 % in 1986 to 1.9% in 1988 and further to 0.88% in 2000.

Concluding Remarks

Academician Svyatoslav Fyodorov was a brilliant generator of ideas both within his field of expertise and in managerial and organizational fields. His tenacious efforts contributed to establishing Russian ophthalmology at the head of the world.

Absence of intellectual property rights protection and the obsolete medical system in the Soviet Russia created an important obstacle in accepting and promoting Fyodorov's inventions and resulted in under-use of innovative resources. Loosening of the regime in 1980s allowed him and his Institute to turn more towards foreign markets, which is reflected both in patenting and diffusion rates. The techniques got widely spread through the unique diffusion channels that were established.

The Inter-Sectoral Research and Technology Complex 'Eye Microsurgery' (MNTK) founded by Fyodorov proved that this type of establishments greatly improves the quality of treatment and facilitates development and introduction of new technologies. The success of 'Eye Microsurgery' was due to a combination of different factors. First, the system of property rights established in the Institute, i.e. collective ownership of the means of production, provided all employees the right incentive to contribute to the prosperity of the firm. This type of property rights organization is especially important for technologies demanding big investment. Second, the Complex was granted unprecedented freedom by the Ministry of Health in deciding upon their personnel, commercial activities, the use of their revenues, while the rest of Russian enterprises had to cope with fixed prices, increasing costs of equipment, medicines and the lack of funds for quality improvement.

Regardless of the obvious success of Fyodorov's Institute as shown by the high quality, innovative and treatment rates, there was still a persistent lack of interest in his achievements by the government. During the 20 years of the Institute's existence, Fyodorov didn't receive a single 'social order' from the part of governmental officials, aiming at developing new methods for treating severe diseases.

According to Fyodorov, providing ownership of the means of production to as many Russian employees as possible is an important factor for establishing a strong democratic state and creating a class of agents with significant economic power.

Fyodorov's example shows the importance of economic policies and opening up to international trade in technology diffusion. In addition, it points to the role of human capital in absorbing international technology spill-overs. Training specialists is essential for innovative and diffusion processes. We can argue that diffusion within Russia could be facilitated by rather high technical

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and scientific potential possessed by the country. On a micro-economical level, the problem lies in the absence of initiative and of the impossibility to realize oneself. These inefficiencies should be corrected by the right property rights and managerial policies. On a global level, one of the biggest impediments still remains the highly bureaucratic political and administrative system, preventing privatization and the establishment of the rule of law.

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