

Nizalova, Olena; Shepotylo, Oleksandr

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Impact of TB Epidemic on Worker and Firm Productivity: Regional Perspective from Ukraine

Olena Nizalova^{*1} and Oleksandr Shepotylo²

¹University of Kent, GLO, IZA, E-mail: o.nizalova@kent.ac.uk,
<https://glabor.org/user/olenanizalova/>,

²Aston University, E-mail: o.shepotylo@aston.ac.uk

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Abstract

This paper investigates the indirect economic impact of tuberculosis epidemic in one of the high-burden countries, focusing on the productivity at the individual level measured by the average wages and at firm level measured by the average total factor productivity (TFP). We use unique administrative data collected at the level of firms and regions for 2003-2009 and find that the ongoing tuberculosis (TB) epidemic has considerable indirect economic costs in terms of lost productivity and related inefficiencies. First of all, both firms and individuals in regions with higher TB prevalence have significantly lower TFP and wages. Moreover, consistent with the Compensating Wage Differentials theory and after controlling for the TB prevalence, the risk of contracting the disease - TB incidence rate - is associated with higher wages and higher productivity - a kind of premium for individuals and firms to operate in a risky environment. The latter can also be viewed as a source of inefficiency as this may prevent firms from entering more competitive markets. Additional analysis reveals strong spatial effects which are consistent with the infectious nature of the diseases and emphasize the importance of containing the epidemic. Overall, we estimate that a 10% decrease in the TB prevalence can lead to a 1.05% gain in GDP: 0.15% in terms of higher individual productivity and 0.89% in terms of firms' productivity.

1 Introduction

Worldwide tuberculosis (TB) is one of the top ten leading causes of death and the leading cause of death from one single infectious agent. Although the epidemic is mostly affecting developing countries, the globalisation of trade and migration flows ensures that TB remains a global threat requiring attention from both developing and developed nations. In September 2018, the United Nations held its first high-level meeting on TB at its headquarters in New York. The need for immediate action to combine efforts towards the goal of ending the TB epidemic by 2030 was highlighted even in the title of the meeting - “United to End TB: An Urgent Global Response to a Global Epidemic”. One of the targets of the Sustainable Development Goal 3 “Good Health and Wellbeing” is a reduction of TB deaths by 90% and of TB incidence rates by 80% by the year 2030 as compared to 2015. The End TB Strategy goes further to reduce TB deaths by 95% and TB incidence rates by 90% by the year 2035 (WHO 2018, 2019). However, it is now obvious that these targets will have to be reviewed, given the potential setback due to the COVID-19 pandemic (Cilloni et al. n.d.). In 2018, 10 million people were infected and 1.5 million people died from this disease (WHO 2018). Majority of the population (over 95%) infected with tuberculosis live in low- and middle-income countries. According to the World Health Organization, in developing countries tuberculosis has become the third leading cause of death among women of reproductive age.

In addition to being a treacherous infectious disease, tuberculosis draws other increasingly high risks. In particular, increases in the rates of multi-drug resistant (MDR) and extra-drug resistant (XDR) forms of tuberculosis have been reported in almost every country. Moreover, tuberculosis has become tightly connected with HIV/AIDS. It is estimated that around 25% of

all people with HIV-positive status die from tuberculosis every year. Finally, tuberculosis is not only adversely affecting health of people in the most productive age group, but at the same time, brings numerous undesirable social consequences. In 2009 approximately 10 million children became orphans as a result of their parents' deaths from tuberculosis (WHO 2009).

In order to stop epidemics of tuberculosis and reduce the incidence rate a number of directly targeted programs have been developed all over the world: for example, DOT (directly observed treatment), immunization with BCG medicine (Bacilli Calmette Guerin), and others. There are also indirect programs which target incomes of poor families, educate the population on healthy lifestyles, etc. All these programs require considerable public funds. And in order to make decisions on which programs to implement, the governments have to compare their costs to the costs of doing nothing (Laxminarayan et al. 2007).

The economic burden of TB comprises several components: (i) the direct cost of diagnoses and treatment, (ii) the loss of GDP related to the reduction in productive population due to premature death, (iii) lost productivity due to the illness and death of the directly affected individuals, (iv) lost productivity of care-providers and other family members. In addition, if people do not expect to live long, they may not engage in investing either in their own education or in the education of their children, and they may have no motivation to engage in entrepreneurial activities. This has a further dampening effect on the productivity of the affected country's workforce and, as a result, on the overall economic development. Despite these theoretical considerations, existing empirical evidence is limited to the estimates of the economic burden of TB due to the cost of treatment, loss of earnings by affected individuals for the duration of the treatment and economic losses due to mortality

effects of the TB epidemic (KPMG 2017, Ahlburg 2000, Laxminarayan et al. 2007).

Using data from Ukraine, a country with a high TB burden during the study period, we present a unique approach to estimate two of the neglected elements of the cost of the TB epidemic. Our findings show that these elements are quite considerable and should be taken into account when assessing the benefits of any interventions aiming to end the TB epidemic.

After the collapse of the USSR, Ukraine as well as the other post-Soviet countries have experienced continuous worsening of the population health, including an enormous growth of tuberculosis prevalence (Vassal et al. 2009). This has been aggravated by a substantial under-financing of organizations responsible for tuberculosis control (Hammers & Downs 2003), increased poverty among the population, and abolishing of social security benefits for tuberculosis patients such as disability pensions or job security (Drobniewski et al. 2004). Ukraine is a country which had the TB incidence rate of 127 per 100,000 population in 2004-2005, reduced to 91 by 2015¹ and to 84 by 2017 (WHO 2018), while still being among the 30 countries with the highest burden of multi-drug resistant TB (16% of newly registered cases being MDR TB compared to the average of 3.8% for this group of countries) (WHO 2015, Lytvynenko et al. 2014) or 30 per 100,000 population in 2017 (WHO 2018). The situation has been further complicated by the spread of the HIV/AIDS epidemics - Ukraine has the most severe epidemics contributing more than 20% of the newly diagnosed cases in Europe and Eurasia region (Vassal et al. 2009), high rates of urbanisation (70% of Ukrainian population live in cities), illegal immigrants infected with HIV or tuberculosis, homeless and mobile population (Codecasa & Migliori 2004). There are two other concerns that

¹<http://data.worldbank.org/indicator/SH.TBS.INCD?locations=UA>

aggravate the situation in the region. One is the ongoing Russian aggression which started in the summer of 2014 in two regions - Donetsk and Luhansk. These regions have historically been the most TB-burdened regions in the country. The ongoing military conflict implies, among other things, considerable disturbance to the TB surveillance and treatment due to interruptions in the supply of medicine in occupied territories - a factor directly linked to the development of MDR and XDR forms of TB. Currently, there are 1.5 mln internally displaced persons in Ukraine ² who are more likely to have been either infected by or in contact with those infected, be unemployed, live in poverty and have worse access to health care. Moreover, (Burman et al. 2018) highlights the challenge with the retention of the health care workforce specialising in the tuberculosis treatment, not only in the conflict zone but throughout the country. The other concern is the ongoing COVID-19 pandemic. Cilloni et al. (n.d.) considered the cases of Ukraine, India and Kenya and estimated that a 2-3 months lockdown in early 2020 would lead to a "setback of at least 5 to 8 years in the fight against TB" due to delays with diagnostics and treatment arrangements (StopTBPartnership 2020). Since this publication, Ukraine, like many other countries in the world, has been experiencing further lockdowns and other restrictive measures introduced to curtail the pandemic.

This study relies on two unique data sets which allow combining epidemiological data on TB-related indicators with the socio-economic information from administrative statistics for small administrative units (raions) in Ukraine to estimate the cost of TB epidemics. Out of the overall 669 raions, the resulting analytical sample contains 609 over the period from 2003 to 2009. Using two measures describing TB epidemics - prevalence and

²<https://reliefweb.int/report/ukraine/national-monitoring-system-report-situation-internally-displaced-persons-june-2018>

incidence rate per 100,000 population and applying fixed effects modeling, we find that indeed the ongoing TB epidemic brings about considerable indirect economic costs in terms of lost productivity and related inefficiencies. First of all, both firms and individuals in regions with higher TB prevalence have significantly lower Total Factor Productivity (TFP) and wages. For example, an increase in TB prevalence rate by 10 percent leads to a 0.3% decrease in wages and 0.9% lower total factor productivity. Moreover, consistent with the Compensating Wage Differentials theory (Rosen 1986) and after controlling for the prevalence of TB, the risk of contracting the disease - TB incidence rate - is associated with higher wages and higher TFP - a kind of premium for individuals and firms to operate in a risky environment. The latter can also be viewed as a source of inefficiency deriving from a negative externality of locating a business in a TB-affected region (Jnawali et al. 2021) as this requires firms to incur higher costs which may prevent them from entering more competitive markets. Additional analysis reveals strong spatial effects which are consistent with the infectious nature of the diseases and emphasize the importance of containing the epidemic. Overall, we estimate that the gain from reducing the TB prevalence by 10% is associated with a 2.4 bln gain in terms of individual productivity which is equivalent to 0.15% of GDP in year 2014 and 0.89% of GDP gain in terms of total factor productivity of firms.

The paper proceeds as follows. Section 2 is devoted to the review of the existing literature, followed by the description of the methodology and data in Sections 3 and 4 respectively. Estimation results are provided in Section 5, with Section 6 devoted to their discussion and robustness analysis. Section 7 concludes.

2 Related Literature

There is no doubt that healthier people are more productive as they are capable of exerting more effort, and are less likely to take sick leaves (Strauss & Thomas 1998). Evidence in the literature suggests consistent findings of a strong positive impact of the population's health on economic growth. However, the findings are difficult to compare because of the variation in health measures. In a number of studies life expectancy has been used in the economic growth models as a measure of the population's health. They show that a one-year improvement in the life expectancy of the population contributes to an increase in economic growth by approximately 4-7% (Barro 1996, Barro & Lee 1994, Barro & Sala-I-Martin 1995, Bloom & Canning 2000). However, it is documented that the effect of life expectancy or other measures of population health on economic growth may be heterogeneous across countries and that there is evidence of diminishing returns to health (Bhargava et al. 2001).

Some of the studies in this literature investigate the impact of specific diseases on economic growth. For example, estimates from a cross-country analysis over the period from 1965 to 1990 show that countries with intensive malaria grew 1.3% less per person per year and that a 10% reduction in malaria was associated with a 0.3% higher growth (Gallup & Sachs 2001). Brainerd & Siegler (2003) investigate the influence of 1918 influenza on per capita income growth across different U.S. states and find positive association during 1920s with one more death per capita associated with 0.15% higher growth rate. At the same time, Karlsson et al. (2012) show that the 1918 influenza pandemic caused significant increases in poverty rates and a reduction in capital returns, with no discernible effects on earnings. Concerning tuberculosis, Grimard & Harling (2004) estimate the augmented Solow

growth model on a sample of 91 countries over the period from 1981 to 2000 and find that there is a persistent effect of 0.2 to 0.4 percent lower growth for every 10% higher incidence of TB.

Estimates of TB costs from Thailand (Kamolratanakul et al. 1999) and Philippines (John et al. 2005), as well as for immigrant patients in the Netherlands (Sandra et al. 2009), support this argument: infected people spend their savings, take loans from banks, borrow from relatives, and sell property in order to survive.

However, the above-mentioned studies are subject to one major criticism - potential endogeneity due to a reverse causality as rising incomes may be the cause of better prevention, treatment, and thus, higher life expectancy. To illustrate, (Datta & Reimer 2013) study of the 100 endemic countries over the 17-year period shows that most of the earlier found effect of malaria is due to reverse causality, as rising incomes of the households allow for an increased prevention and treatment of malaria. Similarly, Acemoglu and Johnson exploiting the major international health improvements from the 1940s find that life expectancy has a very small impact on economic performance (Acemoglu & Johnson 2007). This concern is even more serious in the case of tuberculosis as its onset is exceptionally closely related to poverty (Kamolratanakul et al. 1999, John et al. 2005, S. et al. 2006). Moreover, upturns in TB cases and deaths are very likely in the periods of economic recessions (Nimalan & Dye 2010). Delfino & Simmons (2005) apply the Lotka-Volterra type system capturing the dynamics of TB epidemics with a Solow-Swan growth model where output is produced from capital and healthy labour and find significant differences in the effect of epidemic between rich and poor countries. Taking into account the feedback effects, in high-income countries TB infection dies out quickly, while in less wealthy countries it converges to a steady state of

positive prevalence of 2% of the population being infected. Moreover, in poor countries, there is evidence of a vicious circle with high TB rates generating negative effect on economic growth and prosperity.

Despite the mentioned problem the attempts to estimate the economic costs of serious diseases are ongoing. For example, Grimard & Harling (2004) address the issue of endogeneity in a cross-country setting by employing random effects GLS and fixed-effects LSDV models, as well as the correlated-effects GLS to model the impact of the average TB incidence on five-year economic growth.

This paper contributes to the academic literature in several ways. First of all, it turns to a regional level analysis in a one-country setting addressing the concerns about the differences in the health systems which is pertinent to the cross-country studies. Second, it focuses on two previously neglected components of the cost of TB epidemic - the average total factor productivity of all firms in a region and the average regional monthly wage as a measure of individual productivity. Third, it compares the impact of the prevalence of TB to that of the incidence, as they have different interpretations in the context of productivity. Finally, it takes into account unobserved effects and spatial aspects of the TB epidemics and productivity.

Furthermore, this paper has an important policy implication. It is the first study that estimates the effect of the TB epidemic on individual and firm productivity - something that has not been taken into account when considering the full costs of tuberculosis. According to Lomborg (2018) tackling TB epidemic is on the list of ten sustainable development goals with the highest social, economic and environmental benefits per every dollar spent. Yet, these estimates do not take into account the effects on productivity considered in this paper, and therefore, may lead to a considerable under-investment in

measures tackling the TB epidemic.

3 Methodology

3.1 Modeling Productivity

The impact of tuberculosis on the economy is derived from two measures of productivity - a regional total factor productivity (TFP), which is a labor weighted-average TFP of all firms in the region, and an average regional monthly wage. The TFP is often seen as a driver of economic growth, while the average regional wage reflects a marginal product of labor when markets are competitive. The first has mostly been the subject of the analysis in the fields of industrial organization and international trade while the latter - of labor economics. Thus, our models will rely on sources from both fields, subject to data availability. To address the issue of endogeneity we will estimate the effect of TB measures and other control variables on outcomes, exploiting the panel structure of the data.

Therefore, the models of individual and total factor productivity will define respectively the average wage rate ARW_{it} and total factor productivity TFP_{it} for raion i at time t as a function of variables describing TB situation TB_{it} , average quality of human capital and relevant socio-economic characteristic in the following way:

$$\begin{aligned} \ln ARW_{it} = & \alpha_0 + \alpha_1 \ln TB_{it} + \alpha_2 Educ_{it} + \alpha_3 Educ_{it}^2 + \alpha_4 \ln Death_{it} \\ & + \alpha_5 Unempl_{it} + \alpha_6 Urban_{it} + \alpha_7 Density_{it} + \alpha_i + u_{it} \quad (1) \end{aligned}$$

$$\ln TFP_{it} = \beta_0 + \beta_1 \ln TB_{it} + \beta_2 Educ_{it} + \beta_3 Educ_{it}^2 + \beta_4 \ln Death_{it} \\ + \beta_5 Unempl_{it} + \beta_6 Exp_{it} + \beta_7 Imp_{it} + \beta_8 Urban_{it} + \beta_9 Density_{it} + \alpha_i + u_{it}, \quad (2)$$

where *TB* - includes TB incidence rate per 100,000 people (newly diagnosed cases over the course of the year *t* and TB prevalence per 100,000 people (number of people living with a TB diagnosis at the beginning of year *t*) in a raion. *Educ* indicates the share of employees with higher education; *Death* - death rate in a raion as a measure of overall population health; *Unempl* - unemployment rate; *Exp* - share of exports in total output; *Imp* - share of imports in total output; *Urban* - share of urban population; *Density* - population density. α_i reflects the raion level unobserved effects. The coefficient on the TB prevalence is expected to be negative, while the coefficient on the TB incidence - positive.

Estimating these models as ordinary least squares may lead to significant bias in the estimates of the coefficients of interest, if the unobserved time-invariant raion characteristics are correlated with the respective variables. If one considers the degree of corruption of the local government as an example of an omitted variable, higher levels of corruption are likely to be associated with lower TB prevalence (due to the poorer health care provision and, as a result, excessive death rates from TB) and higher TB incidence rates (due to poorer diagnostics and case tracing). At the same time, higher levels of corruption would be associated with lower productivity, because of the poor investment in human capital and hostility of the business environment. Consequently, the effect of the TB prevalence on productivity will be upward biased, while the effect of the TB incidence will be downward biased. Therefore, the preferred estimation approach to these unobserved effect models is

fixed effects.

3.2 TFP Estimation

Regional TFP is computed as follows. Consider a production technology of a single-product firm j at time t described by a production function

$$Y_{jt} = L_{jt}^{\alpha_l} K_{jt}^{\alpha_k} M_{jt}^{\alpha_m} \exp(\omega_{jt} + u_{jt}), \quad (3)$$

where Y_{jt} units of real output are produced using L_{jt} units of labor, K_{jt} units of capital, deflated by producer-price deflator, and M_{jt} units of material inputs. ω_{jt} is firm-specific productivity, unobservable by an econometrician, but known to the firm before it chooses variable inputs. It includes, among other things, unobserved characteristics of the labor force, such as human capital, entrepreneurial talent, and health. We elaborate on this further in the paper. u_{jt} is idiosyncratic shock to production that also captures a measurement error. Y_{jt} is not observable, because we do not know firm-specific prices, p_{jt} . Sales, $R_{jt} = p_{jt}Y_{jt}$, are known. To filter out demand shocks from productivity measure, we introduce a constant elasticity of substitution demand system and estimate 3 by Olley & Pakes (1996), taking into account the relationship between output and price (Loecker 2011). Firm-level TFP is computed as

$$TFP_{jt} = (\ln R_{jt} - \beta_L \ln L_{jt} - \beta_K \ln K_{jt} - \beta_M \ln M_{jt} - \beta_Y \ln Y_{gt}) \frac{\sigma_s}{\sigma_s + 1} \quad (4)$$

where $\beta_f = \frac{\sigma_s + 1}{\sigma_s} \alpha_f$, for $f = \{l, k, m\}$, σ_s is elasticity of substitution, and Y_{gt} is total output of industry g , where firm j operates. Details on the TFP estimation can be found in Shepotylo & Vakhitov (2015). Furthermore, firm-

level TFP estimates are aggregated to the level of region as given by

$$TFP_{it} = \sum_{jt \in i} w_{jt} TFP_{jt} \quad (5)$$

where w_{jt} is the share of firm's j employment in the total employment in the region i , and TFP_{jt} is TFP of firm j . It may be argued that regional variation in TFP is driven by differences in economic structure across regions rather than due to firm and individual level differences. To address this issue, we also computed sector-specific TFP as given by

$$TFP_{k,it} = \sum_{jt \in i,k} w_{jt} TFP_{jt} \quad (6)$$

where $k = agriculture, industry, services$.

3.3 Spatial Determinants of Productivity and TB

In order to account for possible spillovers from TB in the neighboring regions to individual and total factor productivity, which may arise due to commuting and spatial spread of the disease, we augment the models by adding a spatial dimension. We account for cross-region effects by specifying spatial weighting matrix W and adding spatial lags of our variable of interest as follows:

$$\begin{aligned} \ln ARW_{it} = & \alpha_0 + \alpha_1 \ln TB_{it} + \alpha_1^W W * \ln TB_{it} + \alpha_2 Educ_{it} + \alpha_3 Educ_{it}^2 \\ & + \alpha_4 \ln Death_{it} + \alpha_5 Unempl_{it} + \alpha_6 Urban_{it} + \alpha_7 Density_{it} + \alpha_i + u_{it} \end{aligned} \quad (7)$$

$$\begin{aligned}
\ln TFP_{it} = & \beta_0 + \beta_1 \ln TB_{it} + \beta_1^W W * \ln TB_{it} + \beta_2 Educ_{it} + \beta_3 Educ_{it}^2 \\
& + \beta_4 \ln Death_{it} + \beta_5 Unempl_{it} + \beta_6 Exp_{it} + \beta_7 Imp_{it} + \beta_8 Urban_{it} \\
& + \beta_7 Density_{it} + \alpha_i + u_{it} \quad (8)
\end{aligned}$$

where W is a contiguity-based $I \times I$ spatial weighting matrix, and I is the number of regions. Its diagonal elements are equal to zero. An off-diagonal element, w_{ij} is positive if and only if regions i and j share a common border. All neighbors are equally important and the elements of the weighting matrix are row-normalized, so $\sum_{j=1}^R w_{ij} = 1$, $\forall i = 1 \dots R$. As a result for any TB-related variable tb in TB , a spatial lag of TB , expressed as $W * TB$ is interpreted as a simple average of TB in all neighboring regions. We assume that an element of the error term has the following structure $u_{it} = u_i + \varepsilon_{it}$, where u_i is a time-invariant regional effect, and ε_{it} is an idiosyncratic shock in region i at time t . Equations (8) and (7) can be estimated by standard methods with regional fixed effects. The interpretation of the coefficients on spatial terms is straightforward. If TB measure in all neighboring regions increases by 1 percent, then ARW and TFP in region i increases by α_1^W and β_1^W percent respectively.

This model may suffer from misspecification, due to the presence of other spatial effects, which, if omitted, are subsumed as part of the error term and correlate with the included spatial variables. In order to account for such effects, we introduce a spatial autocorrelation model (Anselin 1988). It adds a spatial lag of the dependent variable, Wy , as one of the controls:

$$\begin{aligned}
\ln ARW_{it} = & \alpha_0 + \alpha_1 \ln TB_{it} + \alpha_1^W W * \ln TB_{it} + \alpha_2 Educ_{it} + \alpha_3 Educ_{it}^2 \\
& + \alpha_4 \ln Death_{it} + \alpha_5 Unempl_{it} + \alpha_6 Urban_{it} + \alpha_7 Density_{it} \\
& + \rho * W * \ln ARW_{it} + \alpha_i + u_{it} \quad (9)
\end{aligned}$$

$$\begin{aligned}
\ln TFP_{it} = & \beta_0 + \beta_1 \ln TB_{it} + \beta_1^W W * \ln TB_{it} + \beta_2 Educ_{it} + \beta_3 Educ_{it}^2 \\
& + \beta_4 \ln Death_{it} + \beta_5 Unempl_{it} + \beta_6 Exp_{it} + \beta_7 Imp_{it} + \beta_8 Urban_{it} \\
& + \beta_7 Density_{it} + \lambda * W * \ln TFP_{it} + \alpha_i + u_{it} \quad (10)
\end{aligned}$$

where $\rho < 1$ and $\lambda < 1$ are estimated spatial lag coefficients. The spatial lag variable Wy is endogenous variable. In order to estimate this model, we use the instrumental variable approach, where the spatial lag of the dependent variable is instrumented by the spatial lags of all right-hand side exogenous variables (Kelejian & Prucha 1998).

4 Data

We are using raion-level data collected by the Ukrainian Oblast Centers of Statistics for the period from 2003 to 2009. Table 1 provides information on the average sample characteristics across time with each column providing information on current productivity and TB measures and other control variables. As can be seen, both average regional wage (in 2001 constant prices) and the total factor productivity has been increasing over the considered pe-

riod. The TB prevalence per 100,000 population has been decreasing, while the incidence rate has peaked in 2006 and then fell by the end of the period.

Total factor productivity for a region is the labor weighted-average TFP across all firms in the region. Firm level TFP are recovered from the production functions estimated separately for each manufacturing and service industry (1-digit NACE classification) using Olley-Pakes procedure (Olley & Pakes 1996) controlling for sub-industry-specific demand and price shocks (Loecker 2011). The data for the study come from several statistical statements annually submitted to the Ukrainian Statistics Service (Derzhkomstat) by all commercial firms in 22 manufacturing industries and 15 service sub-sectors. For a more detailed description of the data see Shepotylo & Vakhitov (2015).

The data on average regional wage is routinely collected by the State Statistics Service from all the enterprises of all forms of ownership, including the agricultural sector (which is not accounted for in the TFP). Self-employed people and statistically small enterprises are not taken into account by both measures.

Figure 1 presents the dynamics of the key indicators, and Figures 2-5 – maps for year 2009 for TB measures and outcome variables at the start and the end of the period. As can be seen, over the considered period both average regional wages and average regional TFP have been steadily increasing, while both measures of the TB epidemic have seen a significant increase followed by a decline. Figures 2-5 portray three facts. One is that many regions in Ukraine have observed a considerable decline in the TB prevalence rates from year 2003 to 2009, with a few remaining pockets of the TB prevalence exceeding 300 per 100,000 in the Northern and South Eastern parts of the country. At the same time, the regional pattern of the TB incidence has

show little change, with the Northern and South Eastern regions showing the highest concentrations of raions with the TB incidence exceeding 100 per 100,000 population. The dynamics of regional distribution of both individual and firm level productivity represents puzzling evidence, with regions with pockets of the highest productivity observed in the regions with the highest TB prevalence and incidence - in the North and South East of the country.

5 Estimation Results

5.1 Impact of TB on Individual Productivity

Table 2 presents the results for both ordinary least squares and fixed effect estimation models. First two columns show the effect on the average regional wage. The OLS model shows no significant effect of the TB prevalence on the average regional wage. And, as the FE model shows, this turns out to be an underestimate of the true negative effect - a 10% higher TB prevalence decreases the ARW by 0.3%. Similarly the OLS estimate of the effect of TB incidence (0.04) is lower than that from the FE estimation (0.05) - a 10% higher TB incidence leads to a 0.05% higher ARW. The results are qualitatively similar with regard to the effect of both TB incidence and TB prevalence on productivity at the firm level.

The effects of the control variables on the outcome variables are as expected. The share of employees with higher education has a positive but diminishing effect on wages. Death rate as a measure of the overall population health is positively associated with the average wage in the model when we control for raion fixed effects, which can point to the risks and corresponding compensating wage differentials. The unemployment rate is negatively associated with the average wage, which is consistent with the Efficiency Wage

model. Urbanization level has a positive impact, while population density - a negative effect on wages.

5.2 Impact of TB on the Productivity of Firms

The spread of TB appears to be damaging for the manufacturing firms as well, but the effect is moderate - 10% higher TB prevalence is associated with 0.09% lower TFP in the region. At the same time higher incidence rate has a positive and significant effect when we control for raion fixed effects. In this case, the same 10% increase in the TB incidence rate is associated with a 0.05% higher total factor productivity. To explore potential differences in the effect of TB epidemic on productivity across different sectors, we explored separately TFP in agricultural, manufacturing and service industries. The results for the services sector - where most human-to-human interactions are expected to be happening - are in line with the expectations. However, as the results are not statistically significant in these specifications (given the sample size), they are not be used in further analysis.

With regards to the control variables, all of the local population characteristics have no statistically significant impact on the firm level productivity, which is reasonable, given that TFP is the residual productivity after controlling for labour, capital and raw materials. Only the presence of prisons has been representing a dampening effect on productivity as measured by TFP, growing in magnitude with time.

5.3 Spatial effects

We next model the spatial dependencies, as the spatial correlation in observed and unobserved variables may lead to the biased estimation of the ef-

fect of the TB variables on outcomes. As discussed in the literature (Kelejian & Piras 2017), it allows us to disentangle the effects reported in the previous section into the local and regional effects of the TB shocks. A better understanding of the mechanisms of the effect helps to design more targeted policy responses. High spatial spillovers would suggest wide regional policy responses, while stronger localized effects would indicate the need for very geographically targeted policies.

Since TB like any other contagious disease rapidly spreads across geographical boundaries, it is natural to include in the model the spatial lags of the TB prevalence and incidence. It will allow us to disentangle the effects of TB on wages and productivity into the local impact, stemming from the TB situation in raion i , and the spillovers, which are due to the TB situation in the neighbouring raions, adjacent to i . It is particularly important for policymakers to determine the optimal scale of policy interventions. A stronger local impact would deem relatively more important local, raion-level interventions, while a stronger neighbouring effect requires oblast and nation-wide approaches. This approach leads to the spatially lagged X model (SLX) specification

$$y = X\beta + WX\theta + \epsilon \quad (11)$$

where y is an N vector of the dependent variable, N is the number of the spatial units, X is $N \times k$ matrix of the model variables, including the constant term, W is $N \times N$ spatial weighting matrix that represents the spatial links between the spatial units, which is row-normalized, $\sum_{j=1}^N w_{ij} = 1$ for any $i = 1, \dots, N$. The row-normalization is important for the correct interpretation of the results, such as the spatial stability (stationarity) and economic size of the impact. ϵ is an N vector of error terms, β and θ are k -dimensional

vectors of the coefficients and spatially-lagged coefficients.

Second, due to labour mobility, it may be important to account for the interactions of the labor markets in raions, as wages and productivity are endogenously determined as firms and workers interact across raions as well as higher-order spatial spillovers. This leads to a spatial autoregressive model (SAR) specification

$$y = \rho W y + X\beta + \epsilon, \quad (12)$$

where $|\rho| < 1$, is the spatial lag of the dependent variable which captures spatial interactions. The condition that the spatial lag is less than 1 in absolute value is crucial for the model stability and interpretation of the results, as the model is not spatially stationary if the condition does not hold. It also can be shown that when the model is spatially stable, the SAR model can be represented as

$$y = \sum_{k=0}^{\infty} \rho^k W^k X\beta + \sum_{k=0}^{\infty} \rho^k W^k \epsilon \quad (13)$$

which shows how the SAR model is related to the SLX model, as it captures not only the first-order spatial interactions but also the second and higher-order spatial effects, as well as the spatially correlated error terms. It becomes clear by comparing equations 12 and 13 that SLX model is an approximation of the SAR model when a) the higher order spatial effects, such as the TB situation in the raions, which are adjacent to raions that are adjacent to the raion i (second order spatial effects), are weak and b) there is no/weak spatial correlation in the error term.

Table 3 presents results from the fixed effects estimation with the spatial lags of TB with (SAR model) and without (SLX) controls for the spatial lag

of the dependent variable. Columns (1) and (3) show that, in general, TB in the neighbouring regions have a similar qualitative effect on both wages and productivity as TB in the region itself - a negative effect of the TB prevalence and a positive effect of the TB incidence. Controlling for spatial effects of the TB measures leads to a decrease in the absolute value of the own raion effects, but informs us about a strong spillover of TB incidence and prevalence at a broader regional level, such as oblast. It demonstrates that the labour markets in Ukraine are mobile and defined at an oblast, rather than raion level. Moreover, any policy intervention should be performed at least at an oblast rather than raion level.

The effects are statistically significant and economically important. A one per cent increase in TB incidence in a raion and all adjacent raions is associated with a 0.1618% (0.0397+0.1221) higher average wages, while a one per cent **increase** in the TB prevalence in the same raions leads to 0.0707% (-0.0216-0.0491)**decline** in wage. For productivity, the effects are 0.1238% (0.0401+0.0613) and -0.1365% (-0.0757-0.0446) respectively.

Once we control for the spatial effects of wages in column (3), by estimating the SAR model, we observe that the wages are strongly spatially interdependent. The impacts of incidence and prevalence remain consistent with the previous results, consequently having significantly positive and significantly negative effects on the outcomes of interest. However, it would be misleading to compare the effect of the coefficients across different models. Under the spatial autocorrelation model, the effect of a one-unit change in an explanatory variable x in raion i will have an impact on the dependent variable y not only locally, but also globally on all other regions and can be presented as a vector of outcomes.

$$\Delta y = (I - \rho \times W)^{-1} \times \beta_x \times \Delta x_i \quad (14)$$

where I is an $N \times N$ the identity matrix, Δx_i is a vector where the i -th unit is equal to one and the rest take values of 0, and Δy is the vector of outcomes. Given that the coefficient ρ is estimated as 0.5326, a one per cent increase in the TB incidence level in all raions would lead to

$$\Delta \ln(\text{RegionalWage}) = (1 - 0.53)^{-1} \times (0.0143 + 0.0613) = 0.1617 \quad (15)$$

percent changes in regional wages in all regions. Likewise, a one per cent change in the TB prevalence level would change regional wages by

$$\Delta \ln(\text{RegionalWage}) = (1 - 0.53)^{-1} \times (0.0135 - 0.0446) = -0.0665 \quad (16)$$

Comparing these full impact elasticities of the SAR model in column (2) with the elasticities of the SLX model in column (1), we conclude that the two different specifications of the spatial models lead to quantitatively similar conclusions about the impact of the TB incident and prevalence on wages. However, the first model allows us to decompose the effect into a) direct local effect and b) spatial effect of the TB spillover from the neighbouring regions. We conclude that the impact of the TB variables on local wages is about 25-30% caused by the local situation in the raion, and the remaining effect is caused by the situation in the adjacent region and oblast level.

For the TFP, the estimated spatial lag of Residual Regional TFP is greater than 1, which violates the assumption of the spatial model 8 and makes

the estimated coefficients inconsistent. In particular, it points to the spatial instability of the regional TFP series, which is highly plausible during a period of rapid growth in productivity which Ukraine experienced in this period. Moreover, it makes it impossible to comment on the sign and significance of the coefficients in the regression model because $(I - \lambda W)^{-1}$ does not have an economic interpretation.

5.4 Discussion

This section explores the sensitivity of the findings taking the fixed effects specification in Table 2 as preferred because it allows focusing on the estimated effects for an average raion and using them to assess the country-level effects, without the decomposition.

Table 4 offers two alternative specifications to the main analysis for both average regional wages (top panel) and the average regional TFP (bottom panel). Column (1) shows the results from the preferred specification for convenience. Column (2) corresponds to the specification which in addition to the above-mentioned controls accounts for the industry structure in the raion. Column (3) estimates the main model excluding education as the control variable. As could be seen, in most cases, except for the effect of TB prevalence on wages in Column (2), there is no discernible difference in either the direction or the magnitude of the estimates.

Given that there exists a number of approaches to the estimation of the total factor productivity, we also re-estimated the preferred specification using the measures from these different approaches. Table 5 presents the results with the TFP estimated by the fixed effect (column 1), Olley and Pakes (Olley & Pakes 1996) in (column 2), ACF (Akerberg et al. 2015) in columns (3) and (5) and Levinhson and Petrin (Levinsohn & Petrin 2003) in column

(4). As can be seen, the estimates do not show detectable differences across TFP measures from the five approaches, used in the productivity literature.

Table 6 provides an example of calculation of the overall country-wide benefits of containing the TB epidemic in terms of productivity at individual and firm levels. The calculations are provided using the country level data on GDP, the number of employed individuals and the average monthly wage rate. Applying the estimated wage and TFP elasticities with respect to the TB prevalence to the 2014 figures shows that, *ceteris paribus*, a 10% reduction in TB prevalence would result into a 1.05% increase in GDP (0.89% increase via an increase in TFP and 0.15% via an increase in the individual productivity as measured by the average monthly wages). The numbers are similar for year 2009. One should note, that the *ceteris paribus* condition means holding constant the TB incidence rates and the death rates at the raion level. This implies that the reduction in TB prevalence can only come from the improvement in the treatment levels and the transition of patients to a fully recovered status. To put things into perspective, the total TB-related expenditure in the country (jointly funded by the state and international donors) accounted for only 0.04% of GDP. This clearly points to a significant under-investment in measures targeting the TB epidemic in Ukraine.

The calculation of the economic effects from changes in the TB incidence rates is a much more complicated exercise. First of all, a reduction of the documented incidence rate may not imply a reduction in the risk levels, as it may indicate the failures of the diagnostics and the contact tracing systems. Likewise, an increase in the documented TB incidence rate may actually be a sign of an improvement in the TB diagnostics. Second, as mentioned above, the economic effects of the reduction in the TB incidence would play out via a reduction in costs of production and thus making regional products more

competitive at the national and international levels. Capturing these effects would require a sophisticated modeling of the markets for various industries at regional, national and international levels, which, unfortunately, does not exist in the current literature and is beyond the scope of this paper.

6 Conclusions

This study is the first one focusing explicitly on the relationship between an infectious disease epidemic and labor and firm productivity, documenting indirect costs which reach beyond treatment-related costs often the only ones quantified in academic and policy literature. It builds on two unique data sets, which allows combining epidemiological data on TB-related indicators with the socio-economic information from administrative statistics for small administrative units (raions) in Ukraine to estimate the cost of TB epidemics. Out of the overall 669 raions, the resulting analytical sample contains 609 raions over the period from 2003 to 2009. Using measures describing TB epidemics (prevalence and incidence of the disease) and applying a fixed effects estimation approach, we find that, indeed, the ongoing TB epidemic has considerable indirect economic costs in terms of lost productivity and related inefficiencies. First of all, both firms and individuals in regions with higher TB prevalence have significantly lower TFP and wages. For example, holding other things constant, an increase in the TB prevalence rate by 10 percent leads to a 0.33% decrease in wages and 0.89% lower total factor productivity. Moreover, consistent with the Compensating Wage Differentials theory and after controlling for the prevalence of TB, the risk of contracting the disease - TB incidence rate - is associated with higher wages and higher productivity - a kind of premium for individuals and firms to operate in risky environ-

ments. The latter can also be viewed as a source of inefficiency, which may prevent firms from entering more competitive markets. Additional analysis reveals strong spatial effects which are consistent with the infectious nature of the diseases and emphasize the importance of containing the epidemic. Comparing the nationwide benefit of 1.05% of GDP stemming from reducing TB prevalence by 10% to the actual level of spending on fighting TB in the year 2014 from all sources (0.04% of GDP), we notice a significant under-investment. The spatial analysis decomposes the effects into local and spillover effects and shows the importance of taking into account spatial linkages and applying interventions at least at the oblast level, if not across the whole country.

The importance of this paper reaches far beyond Ukraine. For the post-Soviet region, it sets up a methodology that can be followed to produce similar estimates (given similar data collection tradition) for other countries, which can empower civil activists in their effort to advocate for a strengthened national commitment to end the TB epidemic. For policymakers in other countries worldwide to provide an understanding of the relative magnitude of potential benefits from tackling the TB epidemic as compared to the direct costs of diagnostics and treatment. For researchers, to stimulate further investigations and advancements in data collection and methodology to arrive at the estimates of full costs of such epidemics of infectious diseases as TB and (or) COVID-19.

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7 Appendix

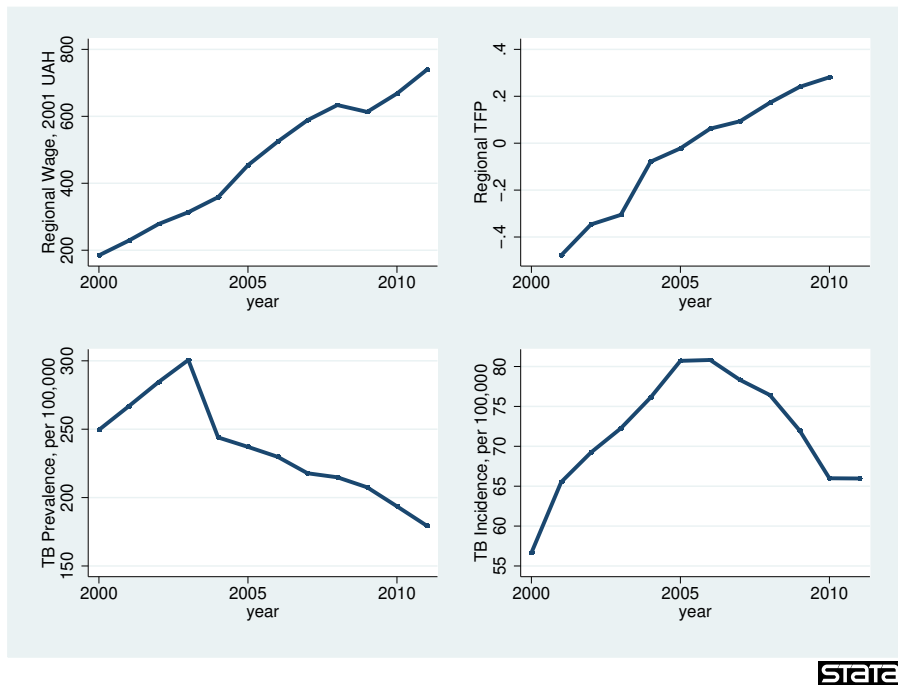


Figure 1: Time Dynamics: Measures of Productivity and TB.

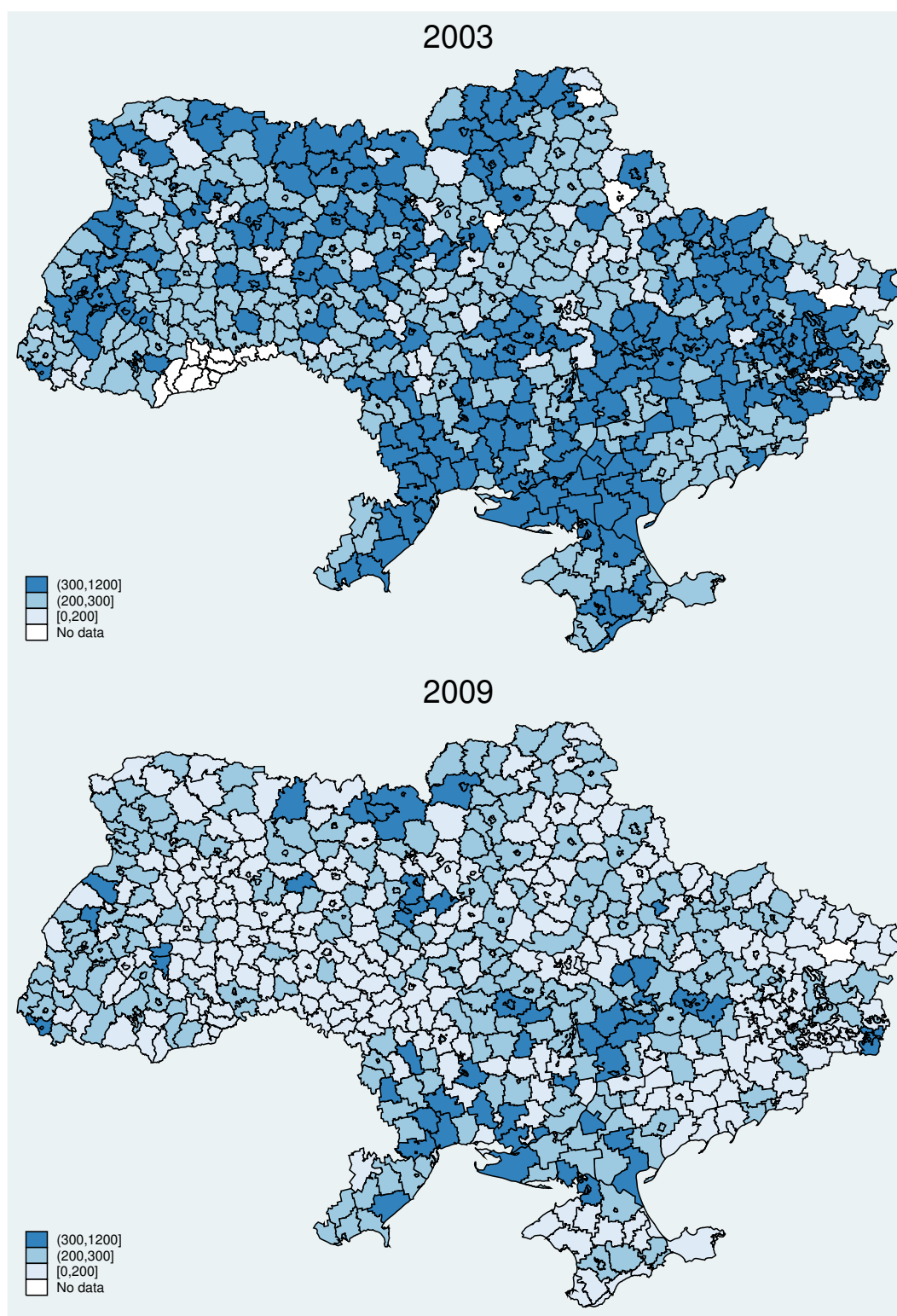


Figure 2: Regional Variation in TB Prevalence, 2003 vs. 2009.

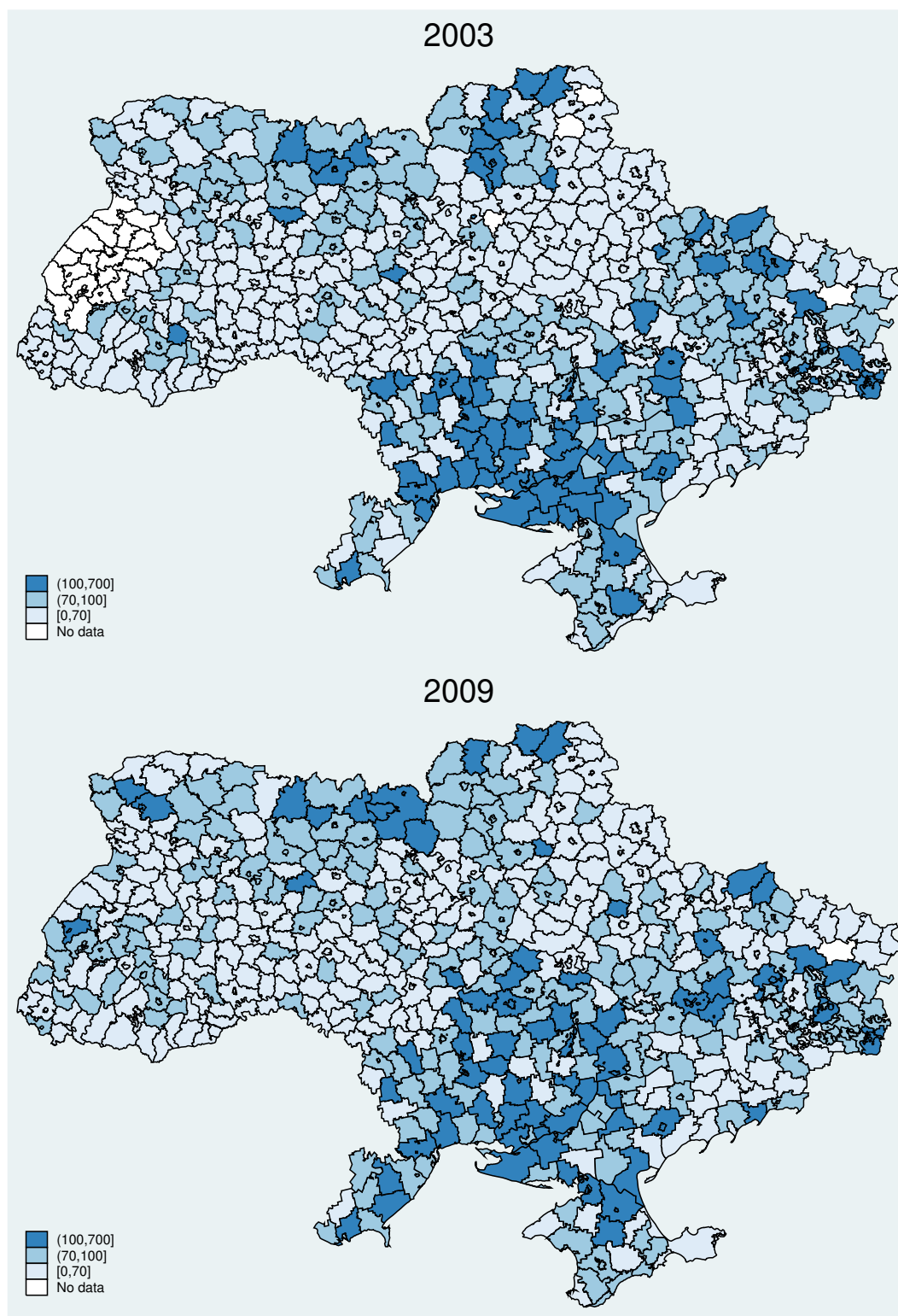


Figure 3: Regional Variation in TB Incidence, 2003 vs. 2009.

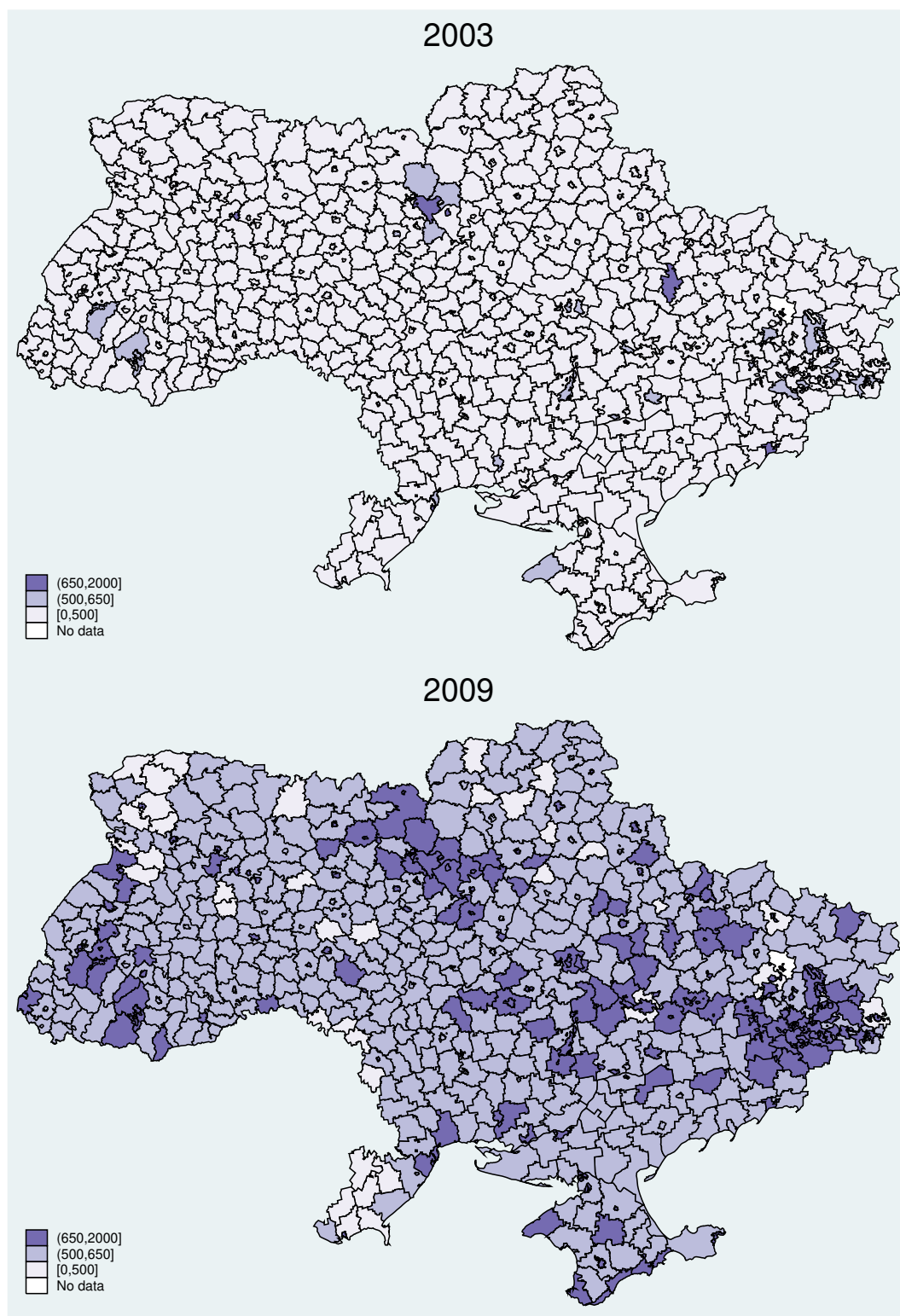


Figure 4: Regional Variation in Average Wage, 2003 vs. 2009.

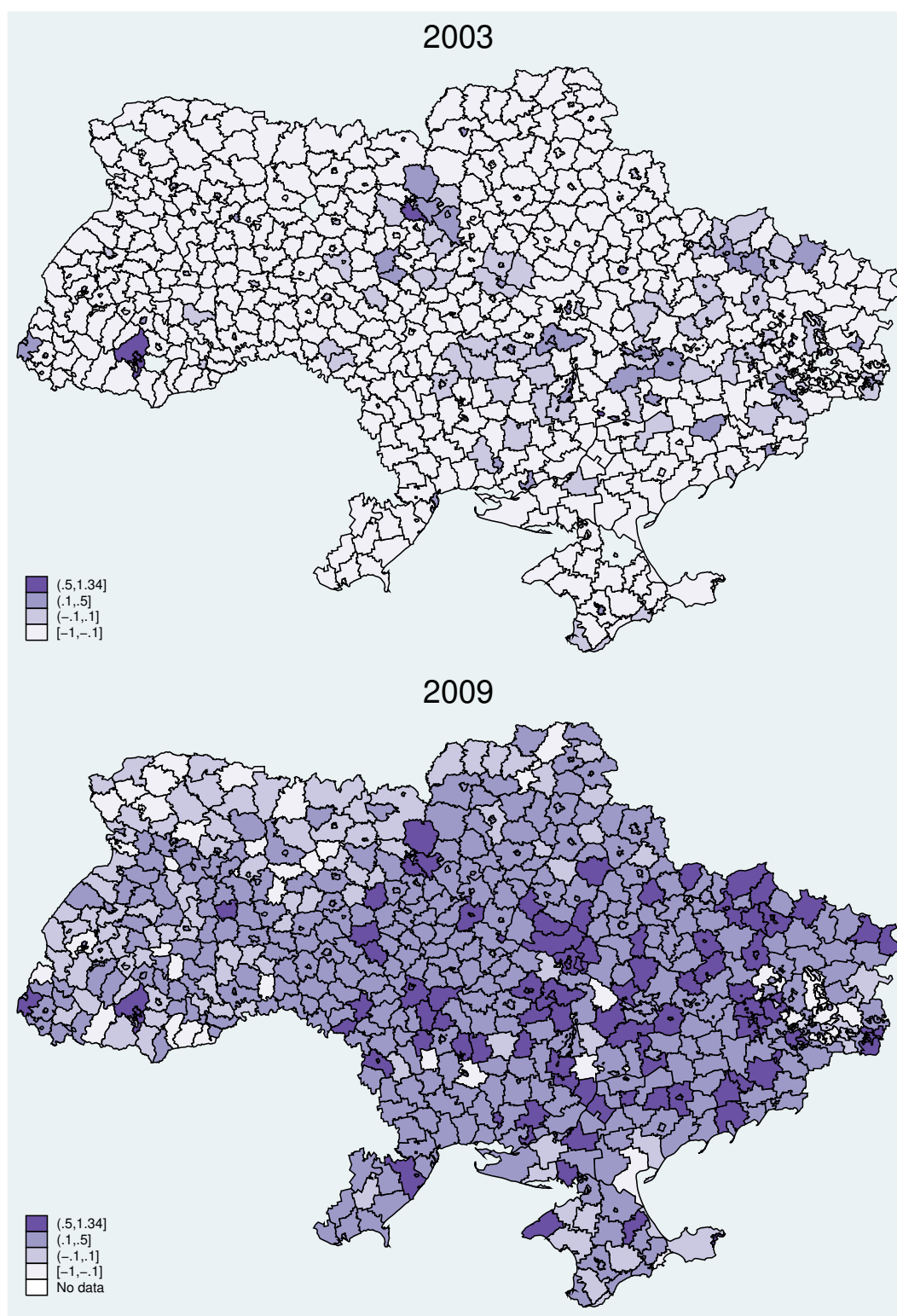


Figure 5: Regional Variation in Residual TFP, 2003 vs. 2009.

Table 1: Descriptive statistics

	2003	2004	2005	2006	2007	2008	2009	Total
Average regional wage, 2001 UAH	312.87 [137.27]	357.94 [138.29]	453.85 [154.71]	527.66 [158.33]	594.60 [165.33]	638.62 [156.82]	617.28 [145.61]	498.38 [192.12]
Average regional TFP (weighted)	-0.32 [0.31]	-0.08 [0.29]	-0.03 [0.27]	0.06 [0.26]	0.10 [0.26]	0.17 [0.23]	0.25 [0.25]	0.02 [0.32]
TB prevalence (per 100,000)	299.63 [98.86]	245.49 [85.83]	237.91 [83.03]	230.05 [75.10]	217.47 [73.15]	211.91 [72.54]	204.35 [69.27]	235.44 [85.34]
TB incidence (per 100,000)	71.76 [29.61]	75.99 [33.58]	80.70 [31.67]	81.10 [32.61]	78.17 [30.85]	75.86 [31.16]	71.39 [27.07]	76.55 [31.24]
Death rate (per 1,000)	18.83 [3.91]	18.55 [4.19]	19.30 [4.33]	18.99 [3.96]	19.09 [4.17]	18.90 [4.34]	17.95 [4.09]	18.82 [4.16]
Workers with higher education, %	17.34 [5.43]	18.4 [5.81]	19.66 [5.97]	20.71 [5.96]	23.57 [7.69]	25.22 [8.21]	27.09 [8.72]	21.62 [7.66]
Unemployment rate, %	5.47 [3.24]	5.65 [3.28]	5.25 [3.05]	4.61 [2.79]	4.03 [2.45]	5.30 [2.63]	3.11 [1.60]	4.79 [2.91]
Urban population, %	44.18 [31.04]	43.73 [31.00]	44.1 [31.02]	44.37 [30.87]	45.52 [31.49]	42.17 [29.34]	42.07 [29.23]	43.79 [30.61]
Population density	441.67 [1049.14]	439.93 [1048.84]	441.84 [1049.34]	442.99 [1051.48]	442.84 [1007.71]	402.9 [990.72]	393.9 [979.16]	430.33 [1025.86]
Prison	0.22 [0.41]	0.21 [0.41]	0.21 [0.41]	0.22 [0.41]	0.21 [0.41]	0.19 [0.40]	0.20 [0.40]	0.21 [0.41]
N obs	493	530	529	519	541	472	471	3555

Note: Standard deviations in brackets.

Table 2: Estimated Effect of TB-incidence and TB-prevalence on Weighted Average Regional TFP Growth and Average Regional Wage Growth

	Log Regional Wage		Residual Log Regional TFP		Residual Log Regional TFP - FE		
	OLS	FE	OLS	FE	Agr	Man	Serv
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log of TB incidence	0.0438*	0.0548**	0.0423*	0.0506**	0.034	-0.0021	0.1338
	(0.0171)	(0.0095)	(0.0185)	(0.0148)	-0.0755	(0.1298)	-0.359
Log of TB prevalence	-0.0098	-0.0333*	-0.0467+	-0.0893**	0.0991	-0.0122	-0.0811
	(0.0260)	(0.0148)	(0.0272)	(0.0187)	-0.1273	(0.1760)	-0.2945
Log of Death Rate	-0.1212*	0.6259**	-0.0675	0.0846	-0.9345**	0.5343	1.7950+
	(0.0512)	(0.0490)	(0.0502)	(0.0695)	(0.3020)	(0.6631)	(0.9206)
% Emp with HE	0.0073**	0.0071*	0.0018	-0.0017	0.0110	-0.0139	-0.0638
	(0.0024)	(0.0034)	(0.0027)	(0.0029)	(0.0131)	(0.0298)	(0.0494)
% Emp with HE, squared	-0.0001**	-0.0001**	-0.0000	0.0001	-0.0001	-0.0000	0.0008+
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0001)	(0.0005)	(0.0005)
Unemployment	-0.0191**	0.0074**	-0.0051	0.0006	0.0001	0.0151	-0.0933
	(0.0027)	(0.0017)	(0.0033)	(0.0026)	(0.0124)	(0.0242)	(0.0640)
Urban Population	0.0040**	0.0008	-0.0013*	0.0009	-0.0057	-0.0015	0.5173*
	(0.0004)	(0.0008)	(0.0006)	(0.0015)	(0.0046)	(0.0043)	(0.2072)
Population density	0.0000	0.0001	0.0000	0.0003	0.0021*	0.0001	-0.0008**
	(0.0000)	(0.0001)	(0.0000)	(0.0003)	(0.0009)	(0.0004)	(0.0002)
Export share			-0.0221	-0.0130	-0.1677	0.4197	-0.5503
			(0.0593)	(0.0629)	(0.2200)	(0.3021)	(0.8000)
Import share			0.0083	-0.0404	-0.1239	0.2805*	0.5834
			(0.0504)	(0.0363)	(0.1049)	(0.1385)	(0.6492)
Prison*year	0.0008	-0.0181**	0.0062+	-0.0194**	-0.0665*	0.0445	0.1141
	(0.0033)	(0.0036)	(0.0037)	(0.0046)	(0.0285)	(0.0385)	(0.0699)
Year	0.1235**	0.1408**	0.0771**	0.0810**	0.3137**	0.1621**	0.0111
	(0.0036)	(0.0039)	(0.0042)	(0.0032)	(0.0179)	(0.0253)	(0.0736)
Constant	-241.6447**	-278.4420**	-154.2850**	-162.4863**	-629.3732**	-328.3743**	-58.5966
	(7.3674)	(7.9130)	(8.3469)	(6.4620)	(36.0297)	(51.0530)	(141.9271)
Number of Observations	3,555	3,555	3,555	3,555	2,340	1,745	817
R-squared/F-stat	0.6922	941.49	0.2825	179.62	62.72	8.14	6.13
Number of id		609		609	562	504	311

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 3: Estimated Own and Spatial Effects of TB-incidence and TB-prevalence on Productivity

	Log Regional Wage		Residual Log Regional TFP	
	SLX (1)	SAR (2)	SLX (3)	SAR (4)
Spatial lag of dependent variable		0.5326** (0.0442)		1.1652** (0.1765)
Log of TB incidence	0.0397** (0.0086)	0.0143+ (0.0081)	0.0401** (0.0124)	-0.0094 (0.0150)
Spatial lag (Log of TB incidence)	0.1221** (0.0127)	0.0613** (0.0126)	0.0838** (0.0182)	-0.0330 (0.0260)
Log of TB prevalence	-0.0216+ (0.0122)	0.0135 (0.0115)	-0.0757** (0.0175)	0.0564* (0.0272)
Spatial lag (Log of TB prevalence)	-0.0491** (0.0108)	-0.0446** (0.0098)	-0.0608** (0.0154)	0.0446* (0.0227)
Prison*year	-0.0184** (0.0025)	-0.0187** (0.0022)	-0.0192** (0.0035)	-0.0076+ (0.0041)
Prison*year in neighbouring rajons	-0.0128** (0.0043)	-0.0041 (0.0040)	-0.0246** (0.0062)	-0.0056 (0.0071)
Number of Observations	3,555	3,555	3,555	3,555
Number of id	609	609	609	609

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 4: Sensitivity Analysis with Regards to Specification

	Main	Specification	
		Main + industry	Main - education
	(1)	(2)	(3)
Regional Wage - FE			
Log of TB incidence	0.0548** (0.0095)	0.0419* (0.0173)	0.0545** (0.0096)
Log of TB prevalence	-0.0333* (0.0148)	-0.0451+ (0.0256)	-0.0353* (0.0147)
Residual Regional TFP - FE			
Log of TB incidence	0.0507** (0.0148)	0.0513** (0.0148)	0.0494** (0.0151)
Log of TB prevalence	-0.0895** (0.0187)	-0.0896** (0.0188)	-0.0867** (0.0188)

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 5: Sensitivity Analysis with Different Approaches to TFP Measurement

	Residual Regional TFP - FE				
	rtfp	rtfp_op1	rtfp_op1_acf	rtfp_lp	rtfp_lp_acf
	(1)	(2)	(3)	(4)	(5)
Log of TB incidence	0.0506** (0.0148)	0.0504** (0.0140)	0.0493** (0.0138)	0.0517** (0.0145)	0.0484** (0.0141)
Log of TB prevalence	-0.0892** (0.0187)	-0.0971** (0.0177)	-0.0986** (0.0174)	-0.0932** (0.0188)	-0.0886** (0.0178)

Note: Robust standard errors in parentheses ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$

Table 6: Comparison of current expenditures on TB-related programs from all sources and individual productivity losses associated with a 10% increase in TB prevalence

	2014	2009
Gross Domestic Product (UAH)	1,586,900,000,000	947,042,000,000
Employment (persons)	18,073,300	20,191,500
Average monthly wage	3368	1906
Considered decrease in TB prevalence (%)	-10	-10
TFP elasticity with respect to TB prevalence	-0.0893	-0.0893
Wage elasticity with respect to TB prevalence	-0.0333	-0.0333
Total national wage bill	730,450,492,800	461,819,988,000
Gain from fighting TB in terms of wages (UAH)	2,432,400,141	1,537,860,560
Gain from Fighting TB in terms of wages (% of GDP)	0.15	0.16
Gain from fighting TB in terms of TFP (% of GDP)	0.89	0.89
Total gain from fighting TB (% of GDP)	1.05	1.06
TB-related expenditure (UAH)	568,836,440	n/a
TB-related expenditure (% of GDP)	0.04	

Table A1: Descriptive Statistics without education variable

	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Average regional wage, 2001 UAH	275.85 [119.84]	314.57 [128.11]	359.47 [137.94]	453.40 [150.79]	524.44 [162.01]	586.03 [165.91]	656.82 [178.71]	614.68 [153.34]	666.67 [163.75]	499.78 [206.49]
Average regional TFP (weighted)	-0.36 [0.28]	-0.31 [0.31]	-0.06 [0.28]	-0.02 [0.27]	0.06 [0.26]	0.1 [0.26]	0.17 [0.24]	0.24 [0.25]	0.28 [0.24]	0.02 [0.34]
Lagged values:										
TB prevalence (per 100,000)	266.4 [76.99]	284.44 [85.71]	300.61 [98.77]	243.98 [83.78]	237.09 [81.57]	229.79 [73.65]	217.79 [71.92]	214.84 [72.32]	207.52 [69.00]	243.98 [85.28]
TB incidence (per 100,000)	65.46 [25.61]	69.23 [27.84]	72.25 [29.09]	76.12 [32.98]	80.71 [31.33]	80.82 [31.81]	78.32 [30.67]	76.43 [30.89]	71.99 [27.10]	74.88 [30.29]
Death rate (per 1,000)	17.83 [3.88]	18.32 [3.90]	18.75 [3.99]	18.51 [4.22]	19.26 [4.35]	18.92 [3.98]	18.94 [4.14]	18.75 [4.29]	17.82 [4.07]	18.59 [4.12]
Unemployment rate	5.23 [2.72]	5.66 [3.32]	5.50 [3.23]	5.63 [3.26]	5.25 [3.06]	4.62 [2.80]	3.99 [2.44]	5.20 [2.61]	3.02 [1.59]	4.89 [2.95]
Share of urban population	43.92 [31.23]	44.11 [30.93]	43.82 [30.77]	43.41 [30.76]	43.75 [30.79]	44 [30.65]	44.91 [31.35]	41.8 [29.32]	41.72 [29.22]	43.51 [30.57]
Population density	449.84 [1052.08]	434.14 [1033.44]	434.29 [1039.31]	433.07 [1039.65]	434.71 [1040.02]	435.55 [1041.76]	448.73 [1034.18]	413.73 [1024.03]	406.08 [1015.33]	432.38 [1034.81]
Prison	0.22 [0.41]	0.21 [0.41]	0.21 [0.41]	0.20 [0.40]	0.20 [0.40]	0.21 [0.41]	0.20 [0.40]	0.19 [0.39]	0.19 [0.40]	0.20 [0.40]
N obs	476	506	539	576	575	565	591	522	521	4871

Note: Standard deviations in brackets.