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A Spatiotemporal Approach to Measure Impact of Factors of Production on Innovations

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ABSTRACT

Measuring innovations is momentous in research work on industrial location, regional economic planning and industrial profits. However, fewer studies have considered spatiotemporal factors for analysing the impact of factors of production on innovation till this date. Present study is therefore an attempt to fill this void by developing a model relating to factors of production effects on industrial innovation with continuous spatial locations for Pakistan. Our methodology is consistent with the approach espoused by Desmet and Hansberg (2014). The model assumes that labour and capital affects the innovation at each available location during the production process. This model has also incorporated spill over-effects which declines with the upsurge in distance. Migration of labour act as the basic element for the speculation of higher-level of innovation. Successively, simulation of the model for a developing economy like Pakistan, we conclude that the share of capital to innovation is much higher relative to the share of labour, but comparatively spill over-effects of capital is susceptible to the increase in distance. Our study has theoretical contribution in the sense that we have improved the existing work of Desmet and Hansberg (2014), where labour was considered as the only source of innovation and capital, as an endogenous variable, was neglected.

Keywords
Industrial Innovation, Spatiotemporal Approach, Spillover effects, Economy of Pakistan.

JEL Classification
O14, E24, R12, R32

1. Introduction

Economic literature has been systematically employed to evaluate different regional-economic problems pertaining to labour, capital, industrial output and economic structure. According to the complex economic system each region even with different level of development faces competition either from the neighbouring or comparatively developed regions. Consequently, every region is trying to potentially utilize their resources to attain certain level of economic development by innovation to survive in the competitive neighbourhood. Whereas, scarcity of one or more factors of production are susceptible to

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the economic growth and competition with the contra regions. Therefore, economic development mainly depends on the ability of regions to take advantage of their innovation capability by employing the available factors of production more efficiently. Whilst, availability of different factors of production and proximity of concerned regions to the larger markets, adjoining developed regions are considerable makings of the region's economic development through spillover-effects.

Previous literature in this field has either overlooked this important dimension or studies have scantly addressed this aspect. As an example, Desmet and Hansberg (2014), Boucekkine et al. (2009), Dunning and Lundan (2008), Caves (2007), and Hilber & Voicu (2009) had discussed effects of capital on innovation by connecting regional innovation to Foreign Direct Investment (FDI) and concluded that the FDI recipient economies can utilize funds to accelerate their innovation and improve their fiscal and monetary position. However, Ellison et al., (2010) and Henderson et al., (1995) studied innovation effects on geographical locations of industries and found that spillover-effects determine the final location of industries.

Amidst these dynamic problems, this study has made an effort to elaborate the effects of factors of production on innovation. Although, labour and capital are assumed to be the mainstays of producing value addition and innovation, however, incorporating both factors of production in a continuum of locations and their movement is of extreme importance to elicit the phenomenon of spatial innovation, where geographical locations are lined up in a continuous space (Quah, 2002; Brito, 2004). Further, analysing factors of production and its effect on innovation, distance between different locations is an important factor that negatively affect diffusion of technology (spillover-effect) and supply of value-added. But, analysing innovation in a continuous location makes the model intractable for some reasons; for example, distribution of economic activities across space and time to clear both factors market and goods market.[1] The only way to overcome this problem is the supposition put forwarded by Brock and Xepapadeas (2008, 2010); Boucekkine, Camacho: Zou (2009) and Quah (2002) that each location in the space perform as an isolated location. The term isolation still keeps positive trade costs and spillover-effect. The aforementioned studies have assessed either the share of labour or capital for analysing the magnitude of innovation, however, this study has provided a dynamic platform to deal with both the factors of production in a single model and derive the shares of each factor of production to innovation.

The conceptual observation of innovation in terms of location through different factors of production need a dynamic model composed of related endogenous variables that explain patterns (migration and final destination to work) of factor of production which further determine their level of effectiveness on spatial innovation. Observing labour agglomeration

[1] As described by Desmet and Hansberg (2014)

through cost-led circular-casualty, any increase in the level of production of value-added in a location, provides more preferences of value-added at lower cost to the local consumers. While, rational consumers always try to maximize their level of utility by migrating to comparatively cheaper locations. Therefore, low cost-of-living attracts more labours and, consequently, increase the supply of labour in the specific location which further attract producers of value-added to the concerned location, Desmet and Hansberg (2014). Agglomeration of industries to a specific location raise the level of innovation both through investment in innovation and through spillover-effect. Therefore, share of each factor of production to innovation is an essential ingredient for restructuring and development of an economy.

Our study is thus a contribution to the existing literature by incorporating some of the caveats of the previous research work. This analysis is based on time series data for the Economy of Pakistan from 1976-2014. Ostensibly, service sector has higher share to the aggregate value-added production in the country than manufacturing sector, and reasonably service sector utilizes higher number of both factors of production. Furthermore, share of labour to the aggregate growth in value-added production is comparatively higher than capital.

The forthcoming sections are organized as, section 2 deals with the model deliberation to elucidate the effects of factors of production on innovation. Section 3 while shedding lights on the structure of Economy of Pakistan as share of two factors of production to service sector and manufacturing sector, presents the results of ours Spatiotemporal Approach . Final section entails concluding comments about this research work.

2. The Model

This study assumes that each of the isolated location, lined up in a continuous space, is composed of manufacturing sector or service sector; both sectors utilize labour and capital to produce value-added products. Secondly, both factors of production are contributing to innovation in each location where the level of innovations, further, affect the surroundings through spillover-effect. Third, transportation of value-added and spillover-effects are prone to remoteness, where impact of spillover effect will be higher with proximity. Fourth, the innovation draws in each sector are random and are categorized by its level: higher the level of innovation shall spur greater spatial development. Industries face problem of labours ‘wages corresponding to the location of their industry; as supply of labour determines the magnitude of industries at a particular location.

The model presented by Desmet and Hansberg (2014) assumes that labour "L" is the sole maker of value added products and innovation. Nonetheless, our study is an improvement in the sense that we have endeavoured to incorporate capital along with labour as a determinant of innovation. This is evenly distributed across continuous space where the number of locations are limited from 0 to 1. Each location "ℓ_1" is composed of manufacturing sector "M" and service sector "S" while each sector produces value-added commodities by utilizing labour, capital and technology at time"t". Model assumes the amount of land is fixed and immobile, but labour and capital are mobile. Primarily, labour migrate in search of higher level of utility obtained by the consumption of differentiated goods and services. Consumers order instantaneous utility function $U(C_i)$ where "C" denotes consumption and sectors are represented by the subscript "i"$(i = M, S)$. Labor holds time. Mobility of labour towards their desired location, directs capital movements. Consequently, model assumes capital movement as the cause of labour migration.

2.1. Consumer preferences

Consumer across locations are free to migrate in search of comparatively higher level of indirect utility. Whilst, consumers also try to arrange their utility-preferences. Labour supply their unit of time to the factor markets that weigh them relatively higher wages "w". Consumer' preferences are arranged as $U(C_M, C_S)$ and they consume value-added products at cost $P_i C_i = p_M C_M(\ell_1, t) + p_S C_S(\ell_1, t)$. Cost function is assumed to follow constant elasticity of substitution (CES) with homogeneity of degree one. Following market clearing conditions$C_i = X_i$, where aggregate production "X_i" in one of the two sectors $(i = M, S)$ at location "ℓ_1" requires $E(x_i) = w_i L_i(\ell_1, t) + \pi_i K_i(\ell_1, t)$ as production cost function. The second part of the function was missing in Desmet and Hansberg (2014). Hence, we have reformulated the model. Consumer preferences for the two sectors' product in location "ℓ_1" at time "t" are organized as following:

$$\max_{\{C_i(\ell_1,t)\}_0^\infty} \sum_0^\infty \left(\varepsilon_M C_M^\mu + \varepsilon_S C_S^\mu\right)^{1/\mu} \qquad \text{..... (1)}$$

$$s.t. \qquad E\big(X_i(\ell_1, t)\big) = P_i(\ell_1, t) C_i(\ell_1, t)$$

Consumers purchase whatever is produced by the two sectors. Therefore, maximization process of eq.1 will result into consumers' demand for the two sectors' value-added products, wherever, consumption of goods and services is affected by real rewards to two factors of production.

$$C_S(\ell_1, t) = \left[E(X_i(\ell_1, t)) \Big/ (P_S + P_M \lambda^{1/\mu - 1}) \right],$$

$$C_M(\ell_1, t) = \lambda^{1/\mu - 1} \left[E(X_i(\ell_1, t)) \Big/ (P_S + P_M \lambda^{1/\mu - 1}) \right]$$

Where $\lambda = \left(\frac{P_M}{\varepsilon_M} \Big/ \frac{P_S}{\varepsilon_S} \right)$

The comparative price index"λ": that brings the two sectors' prices to quotient, reflecting consumer behaviour of weighing the two sectors' prices that helps consumer in organizing their preferences for both the sectors. If"$\lambda > 1$", means it cost more to the consumer to purchase manufacturing sector produce than service sector, and vice-versa. Function of consumer's demand (as eq.1) can be rearranged to obtain the level of indirect utility. Therefore, $\bar{u} = \sum_0^\infty \left(\varepsilon_M C_M^\mu + \varepsilon_S C_S^\mu\right)^{1/\mu}$, indirect utility is composed of comparative price index and the cost that consumers pay to buy two sectors production,

$$\bar{u} = \left[h_M \lambda^{\mu/\mu-1} + h_M\right]^{1/\mu} \left[E(X_i)\left(P_S + P_M \lambda^{1/\mu-1}\right)\right].$$

2.2. Producers

This is pretty straight forward that an economy at each location is composed of two economic agents, that is, consumers and producers. Consumers are the suppliers of labour and producers consist of owner of capital to produce value-added goods and services in one of the two sectors at each location. Producers obtain the number of labours "L" at the wage[2] "w" and add "K" amount of capital at "π" interest rate and start production in one of the two sectors at location "ℓ_1". Furthermore, both sectors follow imperfect competition, where, goods and services are produced and sold to consumers. Consequently, our model has some prominent features, first, explanation of the role played by capital in the process of production; second, the share of capital to innovation and third, shifting of capital resources with labour migration. Land is free of cost and available to all those who win the bid for labours.

2.2.1. Technology

Furthermore, each sector "i" try to innovate "$0 < \eta < 1$" level of innovation at cost "$\Omega(\eta(\ell_1, t)) > 0$" to stay in the market and produce, while the probability of success in innovation is denoted by "θ" whilst "$1 - \theta$" stands for failure. The cost of current innovation is paid out by the returns generated through the sale of value-added products at time"$t - 1$", i.e. $\Omega(\eta(\ell_1, t)) \big/ P_i(\ell_1, t) X_i(\ell_1, t-1)$. If the producer succeeded in utilizing their investment in innovation today, then the "ith" sector will add innovation to the existing level of technology "$A^-(\ell_1, t)$" through the innovation multiplier "ν" and start production. With the probability $\Pr(\nu < \nu_i) = (1/\nu)^\theta$ firm will be able to add $E(A_i^+(\ell_1, t) \mid A^-(\ell_1, t))$ of technology: which is conditional to the existing level of technology. The probability of success should be Pareto optimal.

$$E\left(A_i^+(\ell_1, t) \middle| A^-(\ell_1, t)\right) = \left[\frac{\eta + \theta - 1}{\theta - 1}\right] \cdot A^-(\ell_1, t) \qquad for\ \theta > 1\ and\ \eta > 0 \qquad \ldots (2)$$

[2] Wage rate is determined by the free mobility of labor, but labor migrate before the realization of innovation.

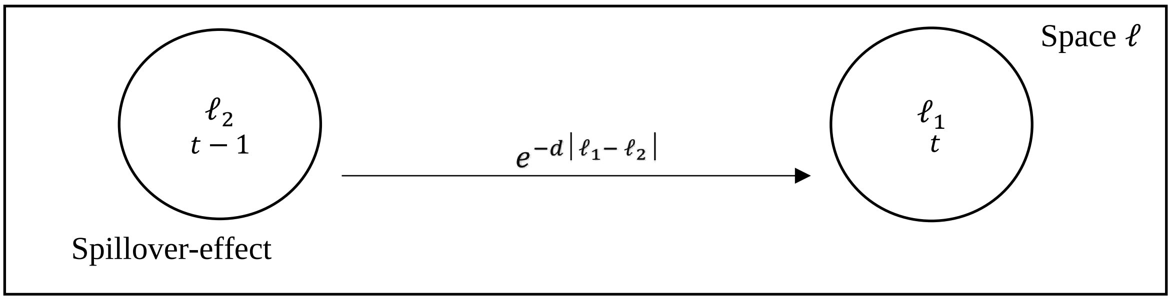
It shows, that how much the particular sector will be able to achieve success in innovation, will add to its existing "A^{-}" level of technology. The negative " $-$ " superscript stand for the level of technology before innovation realization, and the plus " $+$ " denotes level of technology after innovation realization.

2.2.2. Spillover-effects and Timing[3]

As mentioned, the producers are located in a continuous locations$(0\ to\ 1)$. Where, distance negatively affect both spillover-effect and sales of production, while spillover-effect is positively correlated across locations. Let $cr(\ell_1,\ \ell_2) > 0$ represent correlation of spillover-effect, therefore, if the distance between $\ell_1\ and\ \ell_2$ increases or decreases the correlation of spillover-effect is assumed to be positive but it declines with the level of distance. Accordingly, the realization of spillover-effect follows$e^{-d|\ell_1-\ell_2|}A_i^{+}(\ell_2, t-1)$, which means that the realization of spillover-effect is negatively affected by the distance "$-d$" between two locations $\ell_1\ and\ \ell_2$.

$$A_i^{-}(\ell_1, t) = \max_{\ell_2 \epsilon |0,1|} e^{-d|\ell_1-\ell_2|} A_i^{+}(\ell_2, t-1) \qquad \text{…. (3)}$$

The spillover-effects of location ℓ_1 is subject to the level of technology at ℓ_2: means location ℓ_2 at time $t-1$ already attained higher level of technology than $\ell_1$at time t.



2.2.3. Production Function

Amidst production of value-added goods and services in one of the two sectors, producers in the beginning try to acquire moderately higher probability of success in innovation; a unit of land is available to those producers who can compete for labour at the prevailing rate of labour wage. Furthermore, firm add their unit of capital[4] to start production at location"ℓ_1". Combining all the variables in location "ℓ_1" at time"t", the resulting Cobb-Douglas production function for two sectors is as:

$$X_i(\ell_1, t) = A_i^{\gamma}(\ell_1, t)\ K_i^{\alpha}\ (\ell_1, t) L_i^{1-\alpha}(\ell_1, t) \qquad where\ i = M, S \quad and\ \ \alpha + \gamma = 1 \quad \text{…. (4)}$$

$$\max_{\ell_1}\ \ E\big(X_i(\ell_1, t)\big) = P_i(\ell_1, t) C_i(\ell_1, t)$$

[3] Spillover-effect are indirect source of agglomeration and is effected by the length of distance.
[4] Ibid page 7

Production X_i is being determined by the three factors at the right side of the eq. 5. Whatever is produced at cost $E\big(X_i(\ell_1,t)\big)$ are sold at priceP_i. Under the assumption of spillover-effect and probability of success in innovation, model will take "Ω" to denote the difference in cost of innovation[5]. In order to guarantee difference in cost of innovation, we utilized eq.3, that the realization of technology in location "ℓ_1" at time "t" is negatively affected by the distance between the two locations ℓ_1 and ℓ_2. Assuming the cost of innovation as $\Omega(\eta) = \big(w(\ell_1,t) + \pi(\ell_1,t)\big)\left[\Omega_1 + \Omega_2 \cdot \frac{1}{1-\eta}\right]$, $where\ \Omega_2 > 0, \Omega_2' > 0\ and\ \Omega_2'' \leq 0$. The capability of this innovation cost function is that the cost of innovation will increase with the increase in wages and profit. By putting cost of innovation function into the production function (eq.4) will result into

$$P_i(\ell_1,t).X_i(\ell_1,t) \cdot \left[{}^{\eta}/_{\theta-1} + 1\right] - w(\ell_1,t) \cdot L_i(\ell_1,t) - \pi(\ell_1,t) \cdot K_i(\ell_1,t) - \Omega\big(\eta(\ell_1,t)\big) \quad \ldots (5)$$

First order derivative with respect to "η" of eq.5 will result into the share of capital and share of labour that affect the level of innovation. The advantage of eq. 6A and 6B is that these equations have their asymptote at 1. The derivation of one factor of production assumes another factor of production as given and constant.

Under fixed labour amount

$$\hat{\eta}_K = 1 - \left[\left(\frac{\alpha(\theta-1)}{\gamma}\right) \cdot \frac{\Omega_2}{A_i^{-} \cdot P_i^{1/\gamma-1}} \cdot \frac{\pi^{-1/\gamma}}{\bar{L}_i}\right]^{1/2} \quad \ldots (6A)$$

And fixed capital amount

$$\hat{\eta}_L = 1 - \left[\left(\frac{(\theta-1)^{\gamma+1}}{\gamma^{\gamma+1} \cdot (1-\alpha)^{2-\alpha}}\right) \cdot \frac{\Omega_2}{A_i^{-\gamma+1} \cdot P_i^2} \cdot \frac{w^{2-\alpha}}{\bar{K}_i^{\alpha+1}}\right]^{1/2} \quad \ldots (6B)$$

3. Results and discussion

This section is an illustrious elucidation of our reformulated model. However, this necessitates a discussion and depiction of the Economy of Pakistan. Data for this study ranges from the period 1976 to 2014. The data is organized and calibrated as model to observe the outcomes that the economy has faced during this time period[6].

[5] The realization of innovation is still supposed to be the same, and correlation is 1.

[6] Main sources of the data are World Bank and WTO (World Trade Organization).

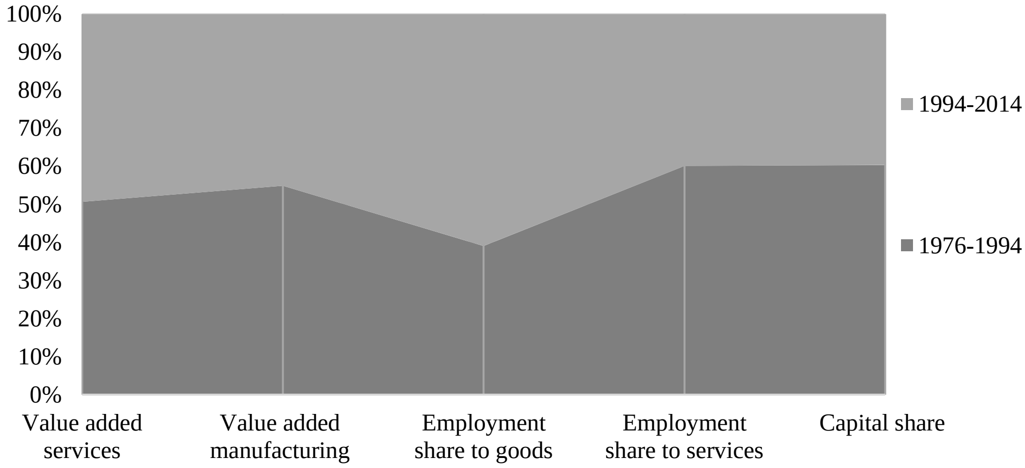


Figure 1. Summary of the economy of Pakistan

Source: World Bank annual census and WTO for trade statistics.

Figure1 extricate the economic history of the country and summarize the relevant variables in percentage points. This is evident that value-added services and employment to goods sector are on the rise while other variables are facing decline[7]. At the outset from the year 1947, country's economy embraced backward manufacturing and service sectors, but comparatively, after 1958 the economy progressed till early 1970's, where growth was evident in almost all the sectors, including services and manufacturing, (see Zaidi and Saeed, 2013; Mahmud, 2000; LaPorte, 1996). The designed model deliberated hitherto in section 2, is composed of two sectors[8], therefore, each variable under discussion will be related to manufacturing or service sector. Throughout the paper, the deep dark lines represent the service sector while the shaded one stands for manufacturing sector.

To start our analyses, we need to find out the share of each factor of production to the value-added sectors, as per eq.4.

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[7] The paper faces some shortcomings of unavailability of separate data on share of capital made to both sectors, therefore, we used gross capital and tried to assess the role played by capital in each sector at a time.

[8] Manufacturing refers to value-added net output of a sector after adding up all outputs and subtracting intermediate inputs. Services include value-added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. Services also included imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling. Value-added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. Both manufacturing and services are calculated without making deductions for depreciation of fabricated assets and their origin is determined by the ISIC (International Standard Industrial Classification). (source: World Bank)

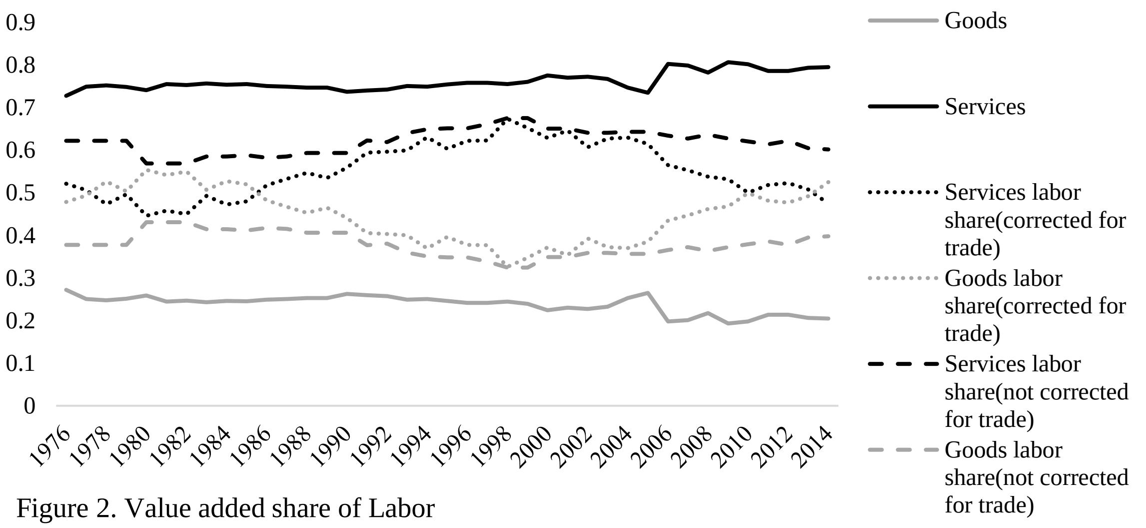


Figure 2. Value added share of Labor

Figure.2 depicts the share of labour to the aggregate value-added produced by each sector. Evidently, share of labour to service sector has increased overtime in comparison to manufacturing sector. Furthermore, this figure also includes share of labour to both the sectors, corrected for trade and otherwise. The first case as the share of labour to value-added sectors when the country chooses not to trade is represented by the second-lap of curves (dashed curves) and third-lap or the middle curves represent the share of labour to value-added sectors as corrected for trade (the dotted curves)[9].

By observing the second lap dashed curves for both the sectors, it appears that the share of labour to service sector (the deep-coloured dashed curve) is higher than to manufacturing sector (the light-shaded dashed curve) but once the data is corrected for trade, the share of labour to manufacturing sector (the light-shaded dotted curve) exceeds the share of labour to service sector (the deep-coloured dotted curve), as is evident from 1977 to 1988. Because of a larger trade volume in recent years, share of labour to manufacturing sector in present time is also greater than the service sector, represented by the dotted line.

Nonetheless, in aggregate terms the share of labour to service sector is more than the share of labour to the manufacturing sector, with and without trade. Being an under developed economy, still service sector employees more labour on a comparative basis.

The share of capital to the value-added production in each sector is portrayed in Figure.3. Service sector is utilizing higher amount of capital than the manufacturing sector[10]. At first, when country start trading, share of capital is equivalent for both the sectors, but with the

[9] The second lap of curves supposes the gross trade and value added ratio as same as the gross output and value added ratio for the economy of Pakistan, whereas the third lap of curves ignores intermediate inputs and trade in the concerned sector. (See Desmet and Hansberg (2014) page no.1224)

[10] Because of unavailability of the separate capital amount that is being utilized in both value-added sectors, we are left with gross capital amount that couldn't be assessed for the factor "not corrected for trade".

passage of times, service sector draw on more capital than the manufacturing sector, except for the year 2002.

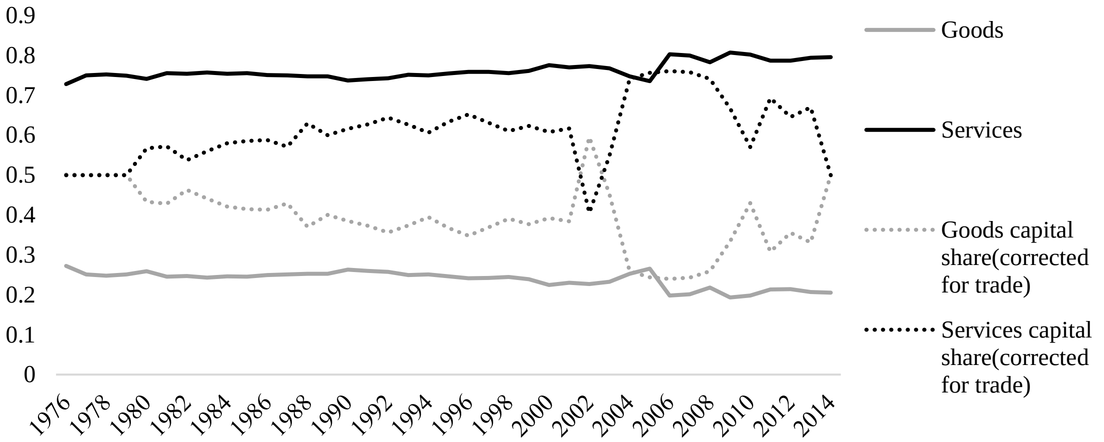


Figure 3. Value added share of Capital

The commonalities between Figure.2 and Figure.3 are, the declining share of input to the goods sector and increased share of service sector. Additionally, both the figures emulate that during the initial years shares of labour and capital were higher for the manufacturing sector[11], while in the mid shares of both the factors were higher for the service sector, and at the end both sectors utilize almost similar shares of both factors[12]. Nevertheless, the share of aggregate capital to innovation in each sector is explained through Figure.5.

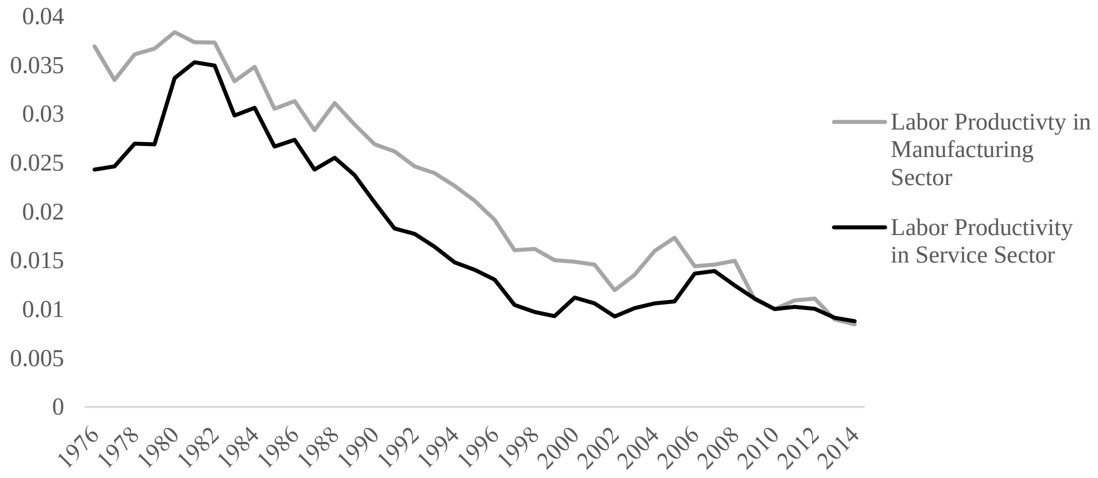


Figure 4: Productivit deflated price index (base year=2010)

[11] See also Imran et al (2020) for detail study on factors productivity while having bilateral economic ties.
[12] See (Callen et al. 2016; Shabbir et al., 2011; Looney, 1997; Seitz and Licht, 1995) for further exposition

As mentioned in section 2, the real cost of innovation is deflated by price index, therefore, Figure.4 (for labour) and Figure.5 (for both aggregate labour and aggregate capital), explicates the relevant factor-productivity deflated by consumer price index (CPI)[13].

Figure.4 holds the share of labour to innovation in each sector, where shares are represented with different colours. Although, value addition by manufacturing sector is comparatively lower (as per Figure.2), but productivity of labour in the manufacturing sector is much higher than the service sector. During the times of economic instability, both curves tend to decline continuously, means the change in prices is much higher than change in labour-productivities, leading to a decline in innovation in both sectors, as innovation is represented by the slope of both the curves in Figure.4. However, both the sectors demonstrate equal size of elasticity (still negatively sloped) to CPI, requiring some measures, for example, a decrease in the level of inflation or an increase in the factors productivity (investment in R&D etc.) to spur innovation in each sector.

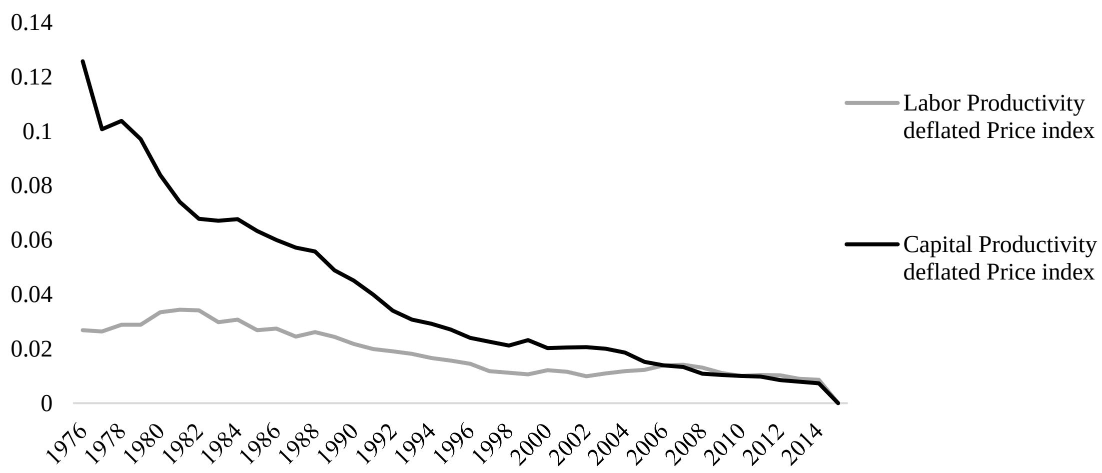


Figure 5. Factor Productivity deflated Price Index (base year=2010)

Figure. 5 explains the aggregate productivity of each factor in both the sectors, where shaded-curve represent share of labour productivity in both the sectors and deep-black-curve represent share of capital productivity[14]. Capital productivity – deflated by CPI – in both sectors is much higher than labour-productivity awaiting 2007. There are several reasons for small segment of labour to innovation; Firstly, because of the low industrial base. Besides, country lacks proper incentives and workable environment for new manufacturers, whereas country has abundant unemployed labour (see Hassan, 2012 and Iqbal, 1986). At the same times, although, capital-productivity is comparatively higher, but capital is further exposed to market fluctuations. Eventually, this also establishes a fact that not only labour

[13] factor-productivity denotes share of each factor of production to innovation which is, further, deflated by CPI to know the real factor-productivity at market price
[14] Data limitation concerning capital spent in both sectors separately, we are not able to assess capital productivity deflated to CPI.

but capital has also an effect on innovation through the level of productivities. This is also evident as of eq.6A and eq.6B.

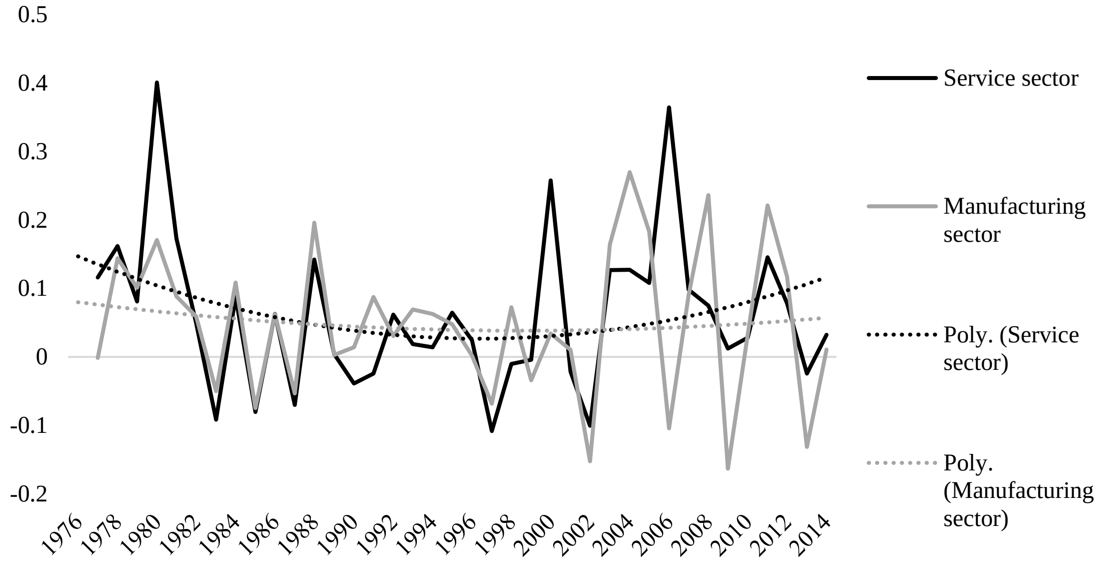


Figure 6: Growth in value added per worker

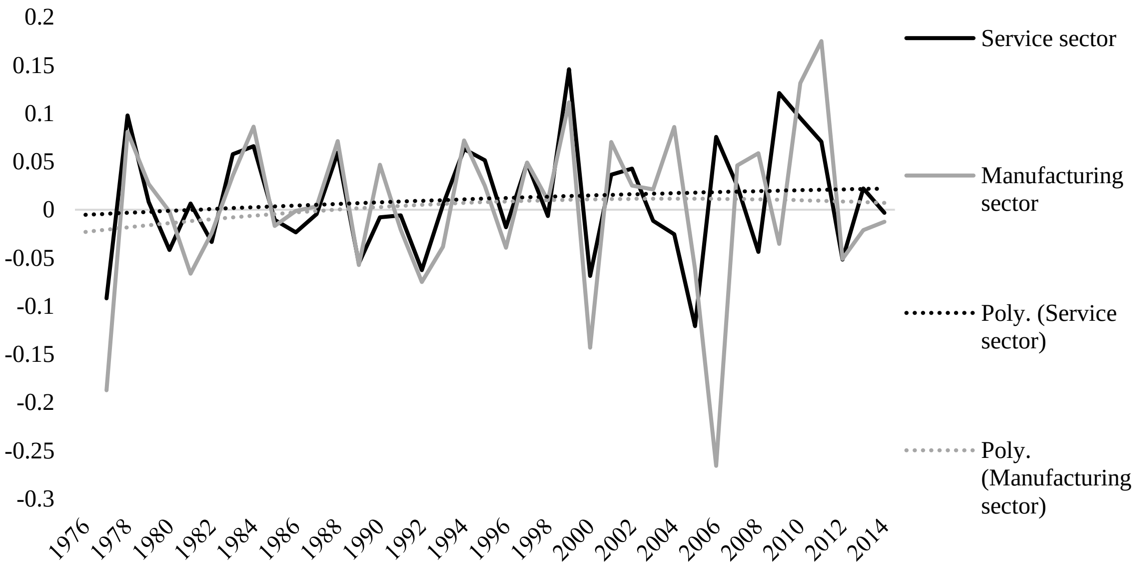


Figure 7. Growth adjusted for gross capital

Subsequent to calculating the level of innovation backed by each factor of production to the concerned sectors, we have also explored the growth being contributed by each of the factors of production, since it is one of the assumption of our model that each location encompassed two sectors and the growth of these sectors represent growth and development of the particular location. Henceforward, Figure.6 presents share of labour and Figure.7

depicts share of capital to the value-added production. The share of labour to the growth of manufacturing sector plus service sector is evident in Figure.6, where labour augments higher growth to service sector initially (explained in Figure.4), amidst the declining trend of the curves. Furthermore, Figure.7 echoes the same pattern for capital, with a conspicuous occurrence of declining trend of capital towards the growth of service sector in year 2006. The polynomial curves (with degree 2) in both figures presents the summary of the direction of growth; growth stimulated by labour to both the sectors are greater (Figure.6) than that of capital (Figure.7). An alternative explanation can be that labour and capital both are comparatively utilized more in service sector than the manufacturing sector which reinforces our corollaries concerning Figure.2 and Figure.3. Finally, concerning our assumption related to correlation of spillover-effects, (as per eq.6A and eq.6B) regarding share of each of the factor of production to innovation at any location, Figure.8 presents the effect of distance on the spillover-effect and investment in innovation.

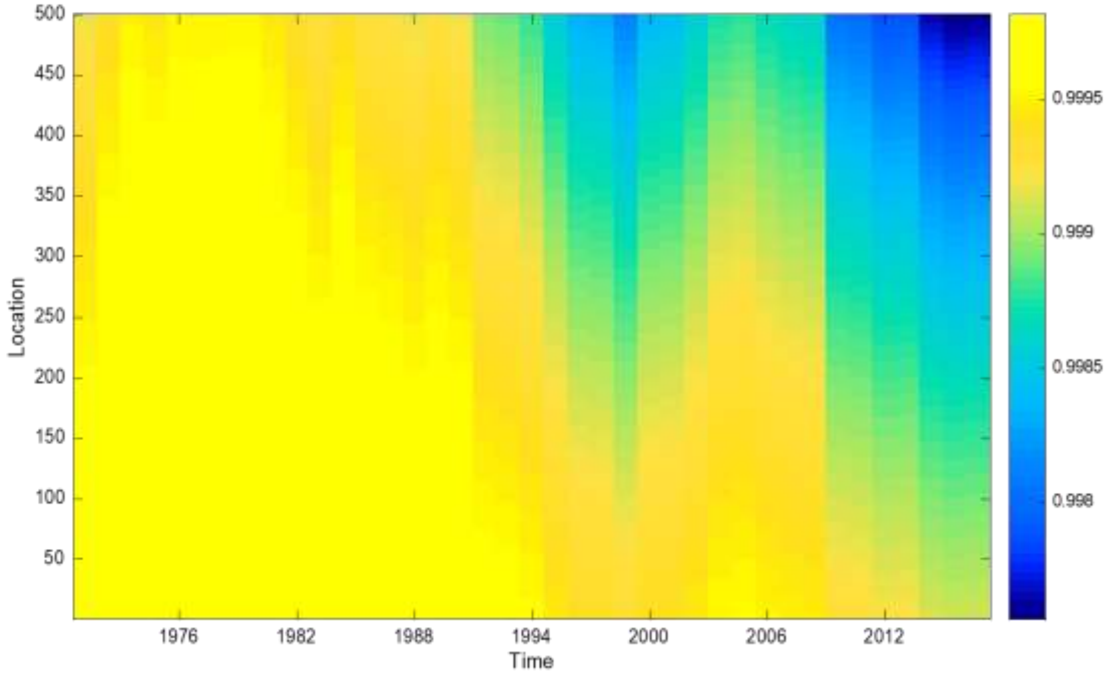
Impacts of spillover-effects and innovation are manifested by the three-dimensional diagram. Data considered for this exercise is of 39 years. Number of locations in a space are expanded to 500, where each location is supposed to be of the same size. Therefore, through benchmark analyses the real cost of innovation is estimated as, $\Omega = 0.0000385$, (see Desmet and Rossi-Hansberg, 2012). Additionally, the parameter of Pareto distribution $a = 35$ and to clearly understand the spillover-effects, distance-term is supposed to be $d = 0.004$ *and* 0.0015. Distance term is measured as per 1000km, which separate the east from the west, (see Ramondo and Rodríguez-Clare, 2013, Desmet and Rossi-Hansberg, 2012). Further, to decide shares of both factors of production to the value-addition in the two sectors, we have followed Valentinyi and Herrendorf (2008) and assumed $\alpha = 0.6$ *and* $\gamma = 0.4$ to ensure that $\alpha + \gamma = 1$, while the elasticity of substitution is assumed to be stable at $\mu = -1.5$, *therefore* $1/_{\mu - 1} = 0.4$ (see Desmet and Hansberg, 2014 and Herrendorf, Rogerson, and Valentinyi, 2013) to ensure the incentive for producers to start production in one of the two sectors.

For Benchmark analysis through the specified and fixed variables mentioned in previous paragraph, we documented the innovation and spillover-effect in each location for the economy of Pakistan throughout the specified time-period. Intensity of yellow-colour represent higher share of concerned factor of production to innovation. Intensity of yellow colour shows higher spillover-effect while accounting distance factor as d.

To begin with the year 1976, higher distance costs have less effect on the share of capital to innovation (Figure.8a) in comparison to the share of labour (Figure.8b), given the distance effect of spillover-effect for the nearby locations. But with the passage of time both effects move in opposite directions and increase the share of labour to innovation visa vie the share of capital. Whilst, lowering the distance effect (d = 0.0015) causes further decline in the share of capital (Figure.8c) to spatial innovation than the share of labour (Figure.8c).

Figure 8. Impact of Capital and labour on Spatial Innovation in Pakistan

Figure 8a (Labour) and 8b (Capital): under *d* = 0.004



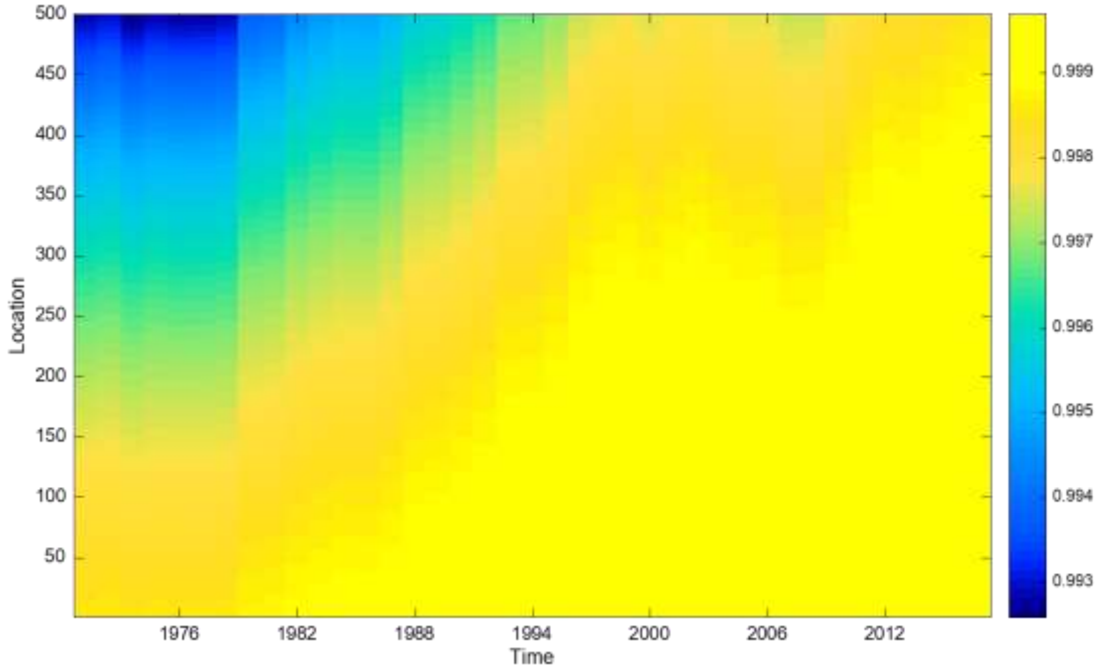
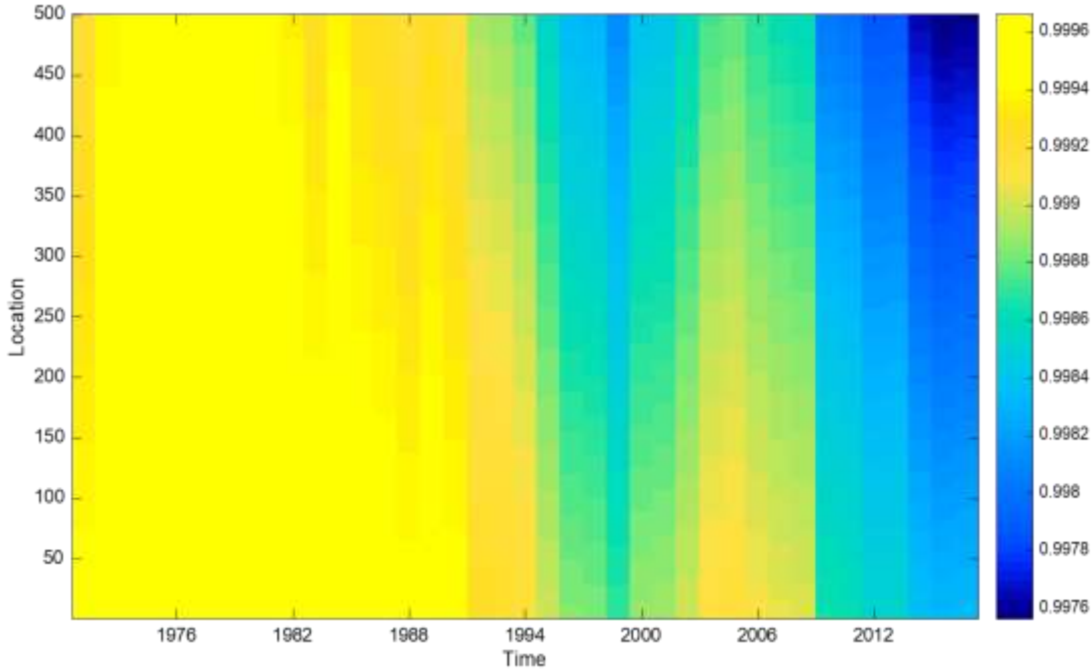
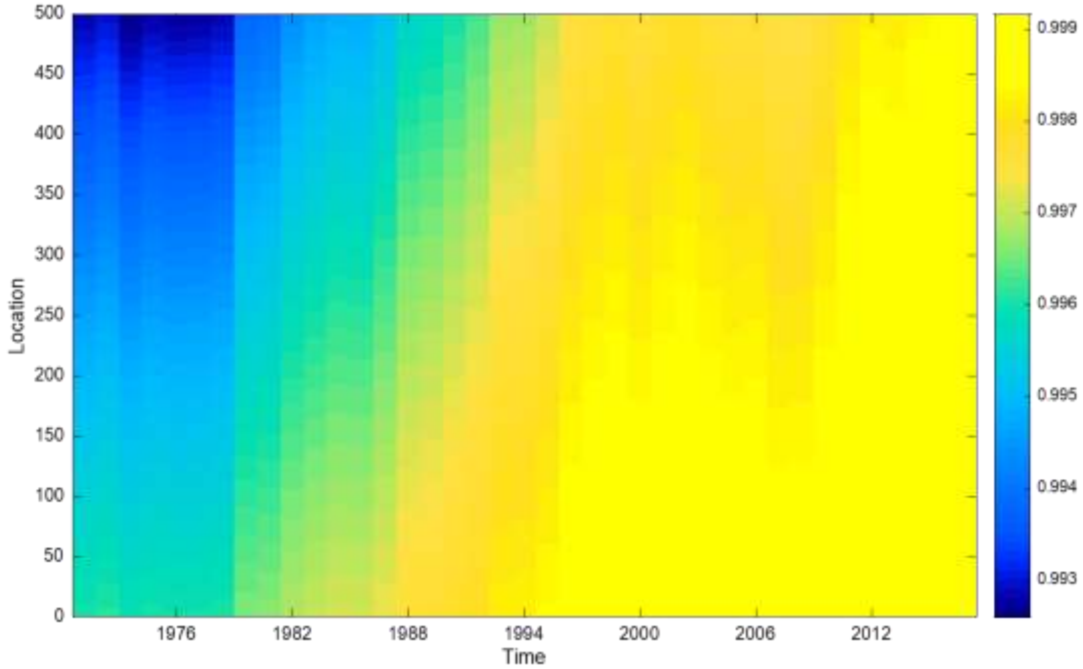


Figure 8c (Labour) and 8d (Capital): *d* = 0.0015





Therefore, higher distance (d = 0.004) is comparatively more beneficial for labour to effect innovation as compared to capital. Figure 8 (a, b, c, d) also represent the factor-productivity and their clustering and a measure of share of innovation that each factor of production adds to innovation.

Overall, the results concerning share of labour and share of capital to innovation proves that share of labour to innovation increases with time and spread out to a larger number of locations. While the share of capital declines and agglomerate in fewer locations with the increase in distance. The following three dimensional figures are worthwhile to identify the monopoly of locations where the particular factor of production is more helpful in innovation and formation of innovation clustering over time.

4. Conclusion

Major objectives of our study is the assessment of the impact of factors of production on innovation in an underdeveloped economy like Pakistan. our analysis is based upon the spatial model concerning the importance of the share of capital and share of labour to innovation. Additionally, we have considered three inputs, that is, labour, capital and level of technology in a location, where migration of labour leads to the transfer of capital (as every producer owns a unit of capital). We infer that in any of the two sectors, producer needs to anticipate the number of labours as the foremost important criterion. Besides, distance negatively affect spillover-effects. Rendering to the designed model, capital-pulled innovations are positively related with profits (eq.6A) and labour-pulled innovations are positively correlated to wages (eq.6B). The application of the model is done for the economy of Pakistan for the time period of 1976 to 2014. Furthermore, it is established that labour and capital both are extensively utilized in service sector than manufacturing sector (as per Figure.2 and Figure.3). But correcting it for trade, the share of both the factors towards manufacturing has increased, while these shares decline for service sector. Therefore, we found that trade is more beneficial for manufacturing sector for the purpose to increasing the shares of both factors of production (Figure.2 and Figure.3 after corrected for trade). Moreover, share of capital to innovation in both sectors is comparatively higher than that of labour. This result is a contribution to the already existing work of Desmet and Hansberg (2014), where labour was only source of innovation and capital, as an endogenous variable, was neglected. Therefore, capital is more important factor to innovate but more exposed to distance factor (Figure.5), because distance leads to agglomeration of the capital resources to limited locations (Figure.8a and Figure.8c), while higher distance leads to higher rate of dispersion (Figure.8b and Figure.8d) of labour resources and increase the share of labour as spillover-effects to innovation. Therefore, share of labour to spillover-effect is directly related to distance, as higher distance brings higher innovation, while share of capital is negatively related to increase in distance.

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