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COVID-19 lockdown, family migration and unemployment in a gendered society



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ABSTRACT

COVID-19 has posed severe challenges not only to researchers in the field of medicines and natural sciences but also to policymakers. Almost all nations of the world lockdown have been chosen as an immediate response to this pandemic crisis. The labour market in developing economies continues to be gendered with gender-based wage differentials besides occupational segregation, women who are the marginalized section in the society, bear the brunt of the unprecedented COVID-19 lockdown. Against this backdrop, a multi-sectoral general equilibrium model has been constructed with heterogeneity in migration (with and without family migration) that has been derived from the intra-household bargaining problem amongst unskilled families to analyse the gendered effect of the pandemic. Lockdown has been conceptualized as a restriction on the physical gathering of labour in the contact-intensive sectors. The results of the paper reflect internal contradictions of developing economies that have a conditional-conditioning relationship with an archaic structure.

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1. Introduction

The ongoing COVID-19 crisis has disproportionately affected not only the health sector but its effects have been spilt over across other sectors and industries. The natural consequence is the global economic crisis. The cause of spillover from the health pandemic to the economic crisis can be attributed to natural causes and political mismanagements. Given the ever-changing nature of the virus and owing to the absence of any appropriate curative medicines or preventive vaccines, the government of various nations had resorted to lockdown as the only immediate measure to curb the spread of the disease or to break the chain of transmission. India, with no exception, adopted a more aggressive lockdown. However, the unplanned and sudden announcement of the lockdown made it the world's strictest lockdown with the worst socio-economic effects. According to a study by the Centre for Monitoring Indian Economy (CMIE), the prevailing rate of unemployment in India increased three folds and reached up to 26 per cent (Singh et al., 2020). Mahmud and Riley (2021) found a large decline of about 60 per cent in household non-farm income and that labour was almost wiped out from the lockdown.

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Professor Sarbajit Chaudhuri was involved in this research, however, a few months before the submission he left the physical world due to a (non-Covid) lung infection on 25th April 2021. The rest of the authors (S. Mahata, R.K. Khan and R.N. Nag) remembers Prof. S. Chaudhuri with great fondness and love.

Besides this, migration has been a major problem in the Indian labour market. India, with a migrant population of about 5.6 crores (Census, 2011), witnessed the worst circular/reverse migration of labour in its history since independence. Around 10.4 million to 10.5 million migrant labourers moved from urban to rural areas of origin in about 30 days of the first phase of lockdown (Singh et al., 2020; Rajan and Bhagat 2022). The labour market in India continues to be gendered with gender-based wage differentials besides occupational segregation. Women who are the marginalized section in society, bear the brunt of the unprecedented COVID-19 lockdown more than men in terms of disproportionate fall in female labour force participation, higher male-female wage disparity and increased labour in unpaid domestic activities. Rukmini (2019) found that in India around 40 per cent of working women lost their jobs which accounts for 17 million women workers, within two months of the lockdown. This is because the share of women in the “contact-intensive sector” is relatively higher than men (Albanesi and Kim, 2021) and women are more often employed in the informal sector or on a casual basis without a job contract in the formal sector (Bahn and Sanchez Cumming, 2020).¹ Around 90 per cent of the female workers were engaged in the informal sector (Agarwal, 2021). It is pertinent to note that women workers who are at the bottom of the informal employment pyramid, account for half the total migrant in India. As per Census India, 2011 report, 67.93 per cent of total migrants are women and 32.07 per cent are men (Kumar and Choudhury, 2021). Women were hard hit during the lockdown period while migrating back to their native places (Rajan and Sumeetha, 2019; Rajan et al., 2020, etc.). Using the data obtained from the Consumer Pyramids Household Surveys (CMIE-CPHS), Abraham et al. (2021) estimated a logit regression model that predicts that women were seven times more likely to lose work during lockdown compared to men, however, education shielded male workers from losing jobs. Besides this, during the unlock phases they are less likely to return to the urban sector to get back their employment. Deshpande (2022) estimated that the likelihood of females being employed was nine per cent lower than that for men, compared to April 2019. Deshpande (2022) used a difference-in-difference model which revealed a lowering of the gender gap in employment probabilities. This result is due to a lower probability of male employment which fell sharply rather than an increase in female employment. All these results commonly indicate that women in the unskilled labour market were hard hit by the lockdown measure compared to their men counterparts. Jadhav (2020) found that this was because women are overrepresented in most precarious jobs in the manufacturing, informal service, construction and agriculture sectors. These industries are mostly contact-intensive industries that were completely or partially restricted by the governments of several developing nations to restrict the spread of the virus. Lockdown had both direct and indirect effects on females’ burden of unpaid domestic work. In a sample survey of different urban centres in India, Chauhan (2021) found that 35 per cent and 25 per cent of women spent more than 28 h/week and 50 h/week on unpaid domestic chores during the lockdown than 21 per cent and 8.8 per cent before the lockdown. On the contrary, a 26.3 per cent decline had been observed for women spending up to 7 h/week. Chauhan (2021) also reported that based on employment status, unemployed women witnessed the highest increase in unpaid household work. The volatility of the foreign capital market during the lockdown phase had also impacted the gendered labour market through various secondary channels in terms of sectoral relocation of unskilled and skilled labour, variation in household income etc. All of this influenced female labour force participation. Thus, in our analysis, we seek to theoretically explore this mixed effect on female effort in domestic work and her participation in the labour market in the backdrop of the pandemic crisis.

In what follows, we undertake a brief review of the extant literature. On the macroeconomic front, there has been an emerging body of literature focusing on several aspects of the pandemic crisis. Sawada and Sumulong (2021) found that the strict lockdown measures and decline in mobility lead to a drop in private consumption by double-digit rates in India. The empirical analysis in the paper also revealed that an adverse supply shock led to a sharp decline in the growth of the manufacturing sector in India (–22.9 per cent), Pakistan (–16.4 per cent), Sri Lanka (–19.2 per cent) and Thailand (–13.2 per cent). Guerrieri et al. (2020) using a Keynesian framework demonstrated how the pandemic-induced adverse supply shock turned into a demand-deficient recession under the conditions of—low substitutability across sectors, incomplete markets and liquidity-constrained consumers. This supply shock-induced demand-deficient recession has been termed the “Keynesian supply shock”. The paper also suggested that loosening monetary policy as well as abundant social insurance could be the first-best policy response. Dasgupta and Rajeev (2020) employed a similar demand-constrained Keynesian model and analysed the transaction cost induced supply and demand shock in terms of fall in consumption, reduced investment and disruption in the supply chain. The paper illustrated how a demand-constrained Keynesian equilibrium turns to an artificially generated supply-constrained equilibrium. Baqaee and Farhi (2022) used a disaggregated Keynesian model in presence of nominal wage rigidities and credit constraints to analyse the supply and demand shocks of the pandemic. The findings reveal that a negative supply shock leads to a stagflationary situation while a negative demand shock leads to a deflationary situation. Faria e Castro (2020) used a calibrated DSGE New Keynesian framework and modelled the pandemic as a large negative shock to the utility of consumption that leads to an adverse demand shock. Fornaro and Wolf (2020) studied the pandemic as a negative shock to the growth rate in productivity and considered endogenous technological change and stagnation traps. The other macroeconomic concern that the literature points out is rising public debt in response to the pandemic crisis. Jorda et al. (2020) obtained that an aggressive counter-pandemic fiscal expansion will boost public debt, and lower national savings rates, however, the rising public debt could be sustained in the long run. Basu et al. (2021) using a dependant economy model conceptualized lockdown in terms of technological regress, fall in consumption expenditure,

¹ Contact-intensive sectors can be classified as sectors in which physical interaction of people is imperative in both the production and consumption process. Usually, labour in the contact-intensive sector has to be physically present to carry out the production activities. The treatment of contact-intensity of sectors has been discussed later in section 2 and 4 of this paper.

and fall in investment expenditure and analysed the effect of an expansionary fiscal policy on debt dynamics. The paper obtained that this could add to the future burden of liabilities of the Government and lower the exchange rate.

On the micro-theoretic front, the literature has not been adequate to the best of our knowledge. Even though there exists a dearth of any trade-theoretic general equilibrium analysis of the pandemic crisis, however, a few exceptions in this regard include [Mandal et al. \(2020\)](#) and [Chaudhuri et al. \(2021\)](#). [Mandal et al. \(2020\)](#) analysed the aspect of restriction on international mobility of skilled labour and restriction on trade of exportable products for a small-open developing economy. It obtained that restriction on international mobility of labour raises unemployment of unskilled labour while the effect on trade restriction remains ambiguous. On the other hand, [Chaudhuri et al. \(2021\)](#) analysed the efficacy of the rural employment generation programme in a less-developed economy to counter the burden of the reverse migrated labour in the backdrop of the pandemic crisis. It obtained that unproductive expenditure on public employment schemes (when no capital is used) could produce a counterproductive outcome in terms of lower social welfare, however, the use of capital that improves land productivity besides increasing employment could lead to a better outcome in terms of lower income-disparity and higher social welfare.

Let us now consider different established theories which dealt with household modelling and migration modelling. However, very little work has been done to integrate both of these. The motivation of the paper is to fill this gap in the literature in the context of COVID-19 in an otherwise general equilibrium model. There is two main strand of literature which dealt with the gendered aspect of household modelling, viz., the unitary household model and the intra-household bargaining model. [Becker \(1973, 1976\)](#) is the pioneering work in the unitary household model. The limitations of the works in this strand are: household is assumed to be one, resources of household are pooled and common preferences of members are usually assumed. The other strand of the balance of power approach (or, intrahousehold bargaining) in which the solution to the household problem is obtained as a Nash bargaining outcome between the male and the female member ([Agarwal 1997](#); [Basu 2006](#); [Quisumbing 2003](#); [Doss 2013](#); [Heath and Tan 2020](#)).

On the other hand, there is much honing of the H-T model that has drawn attention to factors such as the existence of the informal urban sector ([Harberger 1971](#); [Chandra and Khan 1993](#); [Gupta 1993, 1997](#)), relative deprivation ([Stark 1991](#)), capital mobility ([Corden and Findlay 1975](#)), capital market imperfection ([Katz and Stark 1986](#)), asymmetric information ([Esfahani and Salehi-Isfahani 1989](#)) and family migration ([Mincer 1978](#); [Anam and Chaing 2007](#)). [Mincer \(1978\)](#) pioneered the discussion on family migration in a formal setup. The analysis found that net family gain rather than personal gain actuates family migration. However, the limitation of Mincer's analysis is that migration involves the mobility of the entire family. This is not a true feature of migration in many developing countries, particularly, South Asian economies. In large numbers, individual members migrate leaving behind other members of the family. Families in such cases are multi-centred but united ([Shah 1973](#); [Chekki 1974](#)). On the other hand, [Banerjee and Kanbur \(1981\)](#), [Stark \(1984\)](#) and [Anam and Chiang \(2007\)](#) developed a multi-centred migration model where families allocate members in rural and urban regions so as to maximize expected family gain given other economic factors. The majority of these analyses considered heterogeneity of members based on productivity differences. Unfortunately, these strands of literature have brushed aside many complex gender issues.

The extant literature on COVID-19 has identified the facets of consequences caused by this pandemic. However, the post-COVID fall in female labour force participation, higher male-female wage disparity, reverse migration and greater involvement of women in unpaid domestic activities bear testimony to multiple dimensions of gender discrimination. There exists a dearth of any analytical literature dealing comprehensively with family-based migration decisions, pandemic crises and gender-based labour market imperfections. Notably, the literature on theoretical "general equilibrium analysis" in the context of the gendered aspect of the pandemic crisis is scanty. Against this backdrop, this paper contributes to the emerging literature on the incidence of COVID-19 in a gendered society that is not merely a mechanically biological entity but fundamentally socially nurtured. A micro-theoretic dualistic general equilibrium model has been constructed for a distortion-ridden developing economy in the presence of capital market imperfection, open unemployment of male and female unskilled labour and migration of unskilled labour with family and without family. The regional (rural-urban) migration equilibrium has been obtained as a solution to the intra-household bargaining problem between the male and female members of the family. Migration of the male member accompanied by the female member of the unskilled household is classified as "migration with family", whereas, migration of the male member leaving behind the female member in the rural region is classified as "migration without family". The distinguishing feature of the migration equilibrium is that it generalizes the usual [Harris and Todaro \(1970\)](#) and [Chandra and Khan \(1993\)](#) migration equilibrium in terms of family migration equilibrium.

In this paper, the lockdown has been conceptualized as an exogenous policy instrument to restrict human mobility in contact-intensive economic activities which has multi-dimensional effects in the form of adverse-supply shock (high transaction cost) in the production sector, restriction on the physical gathering of labour at their workplace, adverse demand shock and high psychological cost on unskilled labour. Few of the existing theoretical literature had captured the psychological effect of COVID-19 in terms of a fall in consumption demand, ignoring the psychological distress of migrant workers. [Kumar et al. \(2020\)](#) in their primary sample survey of migrant workers during the lockdown phase, found that about 63.3 per cent underwent loneliness, 58.2 per cent experienced frustration and tension and 51 per cent felt anxious ([Jesline et al., 2021](#)). Living far away from their families and native place mounted fear and uncertainty amongst migrants over their regular expenses like food, clothing, medicines, job security and accommodations. They became also worried about their safe return to their native places. Thus, in our analysis, we capture this aspect of psychological distress amongst migrant workers

separately for those who were living with or without their families. The effects are analysed on female labour force participation, her burden on unpaid domestic chores, gender-based wage disparity and unemployment. Probably lockdown was inevitable but it has multidimensional adverse effects. The results of the paper reveal the complexities of gender discrimination and migration dynamics. And accordingly, no facile conclusion is warranted.

The rest of the paper is organized as follows. The structure of the representative developing economy is described in Section 2. In Section 3, the migration equilibrium is derived from the representative household's optimizing behaviour. The general equilibrium implications of lockdown have been analysed in Section 4. Finally, Section 5 concludes the paper.

2. Description of the economy

The stylized economy comprises of $(\bar{L} + \bar{S})$ number of families, where \bar{L} and \bar{S} are the number of unskilled families and skilled families, respectively. A family is composed of one adult male and one adult female member, each endowed with a total of one unit of time. The male member in the unskilled family spends his entire time in wage-earning activities while the female member distributes her time in unpaid household work (l_F^G), labour market (e_F) and enjoys leisure ($1 - l_F^G - e_F$).² Thus, the total supply of unskilled male and unskilled female labour in the economy is \bar{L} and $e_F \bar{L}$, respectively. On the other hand, in the skilled family, both the male and female member is homogenous in terms of skill and devotes their entire time to the labour market. Thus, the total supply of each male and female skilled labour in the economy is \bar{S} . Besides unskilled and skilled labour the other factors of production are capital and land. The supply of land is naturally fixed at \bar{T} and total capital endowment is composed of domestic capital that is exogenously given by \bar{K}_D and foreign capital K_F that depends positively on the domestic and foreign interest rate differential.³

The economy is segregated into two broad regions, rural region (R) and urban region (U). The agriculture sector (sector 1) is concentrated only in the rural region whereas the urban sector consists of the formal manufacturing sector (sector 2), informal sector (sector N) and a high-skilled sector (sector 3). Sector 1, sector 2 and sector 3 produces an internationally traded commodity X_1 , X_2 and X_3 , respectively while sector N produces a non-traded commodity, X_N .⁴ In the rural region, sector 1 employs unskilled male and female labour besides a specific input land. In the urban region, unskilled male labour and capital are used in the production of X_2 , while X_N is produced using unskilled male labour, unskilled female labour and informal capital.⁵ Finally, sector 3 employs male and female skilled labour besides capital.⁶

Unskilled male workers in the rural region (sector 1) earns a competitive wage, W_M , while its counterpart in the urban region earns institutionally determined high wage rate, \bar{W}_M in sector 2 while in sector 3 it earns a competitively determined urban informal wage rate \hat{W}_M , where, $\bar{W}_M > W_M > \hat{W}_M$. Unskilled female workers earn a competitive wage, W_F in the rural region and earn a higher wage rate, $\hat{W}_F (= \vartheta W_F)$ in the urban region, where $\vartheta (> 1)$ is the urban wage premium.⁷ The specific input land in the rural region is rented at rate R . Capital is mobile only in the urban region across sector 2, sector 3 and sector N. In the domestic market, sector 2 and sector 3 employs capital at a formal interest rate r while capital earns an informal interest rate η in sector N. In the international market, capital earns interest rate r^* which is exogenous to this economy. All skilled workers in sector 3 earn a high-skilled wage rate W_S (see footnote 4). Because of intersectoral (interregional) wage differential, some of the rural workers migrate to the urban region (with or without family) hingeing on the decision taken by the male member of the rural household.⁸ Migration of the male member accompanied by the female member of the unskilled household is classified as “migration with family”, whereas, migration of the male member leaving behind the female member in the rural region is classified as “migration without family”.

The representative firm in each of these industries maximizes profit in the competitive market and each representative family in both rural and urban regions maximizes utility. Production technology is characterized by constant returns to scale and factors exhibit positive but diminishing marginal productivity. This is a small open developing economy in which the prices of the traded commodity are given exogenously, which is determined in the international market whereas the price

² In the Time Use Survey (TUS), 2019, conducted by the NSSO (MOSPI, Govt. of India) it was found that women spend 300 more minutes on unpaid household chores than men and 480 minutes of women work relative to men are not counted as work and thus remain unpaid (Mitra and Sinha, 2021).

³ Chaudhary, Sodani and Das (2020) found that Indian capital markets are envisaging funds flow to the western economies, owing to a fall in the rate of returns to capital in the domestic capital market. A sharp decline in FPIs in India had been observed—₹ 247.76 billion withdrawals from the equity market and ₹ 140.50 billion from the debt market in 13 days. To capture this effect of foreign capital outflow endogenously in our model, we assume that $K_F = K_F(r - r^*)$; $K'_F > 0$.

⁴ The qualitative results of the theoretical model are invariant to the pattern of trade provided there is no trade distortion in the final commodity producing sectors of the economy.

⁵ Around 88 per cent of total female labour are employed in the informal sector (Mitra and Sinha, 2021).

⁶ Although, in developing nations including India, discrimination persists even in education and other skill-acquisition activities, the extent of disparities that exists in the unskilled labour market is much more significant compared to that prevailing in the skilled labour market. This makes the unskilled labour relatively much vulnerable than the skilled families. This is why we assume away wage disparity in the skilled sector.

⁷ Lewis (1954) adduces reasons for the existence of such wage gap in terms of high cost of living in the urban region which is invariably higher than the rural region and the psychological cost to face the regimented urban environment.

⁸ The migration decision has been derived in section 3.1. Although the decision making of the unskilled family is initially homogenous in nature, however, heterogeneity arises endogenously with respect to migration decision. Research indicates that poorer women from landless families are more likely to migrate than those having ancestral assets or own land. For example, Afsar (2006, 2011) found that in Bangladesh 80 per cent of female domestic workers in the urban region came from landless families while only 54 per cent came from land owning homes. On the contrary, Shaw (2010) found that Sri Lankan women migrant workers belong to poor families and not poorest.

of the non-traded commodity is locally determined by the market forces of demand and supply. Thus, the stylized economic structure assumed resembles a typical developing economy that is characterized by the presence of regional duality, labour and capital market imperfection, gender disparity, skill-heterogeneity and an informal sector.

The most severely affected sectors owing to COVID-19-induced lockdown are those which are “*contact-intensive*” in nature (i.e., sector 2 and sectorN) that can be classified as sectors in which physical interaction of people is imperative in both the production and consumption process. Lockdown is conceptualized in terms of the parameter “ Ψ ” which is defined in the interval $[0, 1]$ as the policy instrument of the government to restrict human mobility in contact-intensive economic activities.⁹ $\Psi = 1$ implies complete lockdown in the economy, i.e., no one is allowed to engage in any economic activity associated with the contact-intensive sectors, while $\Psi = 0$ implies no restriction on human mobility (no lockdown) and any $\Psi \in (0, 1)$ implies a partially imposed lockdown.

3. Household

In this section, the optimizing behaviour of the unskilled and skilled household is analysed to derive the migration equilibrium condition (with or without family), time allocation of unskilled females and the demand for final commodities. The first sub-section (Section 3.1) deals with the unskilled family and their migration decision, while the latter sub-section (Section 3.2) deals with the optimal decision-making of the representative skilled family.¹⁰

3.1. Unskilled families and the migration decision

Each representative household of the \bar{L} number of unskilled families maximize the weighted aggregate utility in a collective household bargaining setup: $(1 - \omega)V_F + \omega V_M$, where, V_F and V_M are the respective utility function of the female and male member of the household and ‘ ω ’ represents the bargaining strength of the male member defined exogenously on the interval $[0, 1]$.¹¹ Each female member derives positive utility from the consumption of x_{1F} and x_{2F} that are produced in sector 1 and 2, respectively beside a household public good (G) and her leisure $(1 - l_F^G - e_F)$. In a similar fashion, each male member enjoys utility from x_{1M} , x_{2M} and G , however, female participation in the labour market (e_F) leads to decrement in the utility level of the male member.¹² The household public good is produced using the female’s effort in unpaid household work (l_F^G) and the monetary contribution of the male member. The male member in the household has the final say in the migration decision, juxtaposing his indirect utility from residing in the rural region with family (Rwf) and staying in the urban region with family (Uwf) or without family ($Uwof$).¹³

3.1.1. The rural region with family (Rwf)

The utility of the unskilled female member assumes the following form

$$V_F^{(Rwf)} = \alpha_{1F} \ln(x_{1F}) + \alpha_{2F} \ln(x_{2F}) + \beta_F \ln(G) + \gamma_F \ln(1 - l_F^G - e_F); \alpha_{1F}, \alpha_{2F}, \beta_F, \gamma_F > 0 \tag{1}$$

The unskilled male member’s utility takes the analogous form

$$V_M^{(Rwf)} = \alpha_{1M} \ln(x_{1M}) + \alpha_{2M} \ln(x_{2M}) + \beta_M \ln(G) + \gamma_M \ln(1 - e_F); \alpha_{1M}, \alpha_{2M}, \beta_M, \gamma_M > 0 \tag{2}$$

The production of the household public good is defined by the following technology

$$G = l_F^G \phi W_M \tag{3}$$

where, $\phi \in (0, 1)$ is the fraction of the unskilled male income that is contributed towards the production of the household public good.

The household optimization problem then becomes

$$\text{Max}_{\{e_F, l_F^G, x_{1F}, x_{2F}, x_{1M}, x_{2M}\}} (1 - \omega)V_F^{(Rwf)} + \omega V_M^{(Rwf)}; \omega \in [0, 1]$$

subject to, $(x_{1M} + x_{1F}) + P_2(x_{2M} + x_{2F}) = (1 - \phi)W_M + W_F e_F$ where, P_2 is the relative price of commodity 2 and the price of commodity 1 is normalized to unity.

The following assumptions are made to determine the interior solution to the optimization problem:

Assumption 1. $\frac{W_F}{W_M} > \frac{(1 - \phi)A_1}{|A_2|}$

⁹ See Indian Economic Survey 2020-21 that highlights the severity of lockdown on the contact-intensive sectors.

¹⁰ This analytical family structure of the household bears a close resemblance to the Heath and Tan (2020).

¹¹ There exists sufficient evidence that reveals household decision making as intra-household bargaining problem unlike the unitary household models. These includes Lundberg, Pollak and Wales (1997), Duflo (2003), Duflo and Christopher (2004), Luke and Munshi (2011), Heath and Tan (2020) etc.

¹² This is due to cultural barriers and social norms towards women engaging in paid work outside the home that hurts the “pride” of the family or male counterpart in specific. This has been discussed in Basu (2006), Dewan (2019), Rukmini (2019) etc.

¹³ If the male and female member of the household stays together then it is classified as “with family”, while, if they stay apart then it is classified as “without family”.

Assumption 2.
$$\frac{\frac{\{(1-\phi)W_M+W_F\}A_4A_1}{\{A_4+(1-\omega)\gamma_F\}} + \{W_F|A_2| - (1-\phi)W_MA_1\}}{W_FA_3} < 1$$

where,

$$A_1 = \{(1-\omega)(\gamma_F + \beta_F) + \omega(\gamma_M + \beta_M)\} > 0$$

$$A_2 = \{-(1-\omega)(\alpha_{1F} + \alpha_{2F}) - \omega(\alpha_{1M} + \alpha_{2M})\} < 0$$

$$A_3 = \{\omega(1 + \gamma_M) + (1-\omega)(1 + \gamma_F)\} > 0$$

$$A_4 = \{\omega\beta_M + (1-\omega)\beta_F\} > 0$$

Assumption 1 ensures that the female member of the household always puts a positive level of effort in wage-earning activities (i.e., $e_F^{(Rwf)} > 0$) whereas assumption 2 guarantees female leisure to be always positive (i.e., $e_F^{(Rwf)} + I_F^{G(Rwf)} < 1$). Given assumptions 1 and 2, the Nash bargaining interior solution to the household’s optimization problem is given by the following

$$I_F^{G(Rwf)} = \frac{\{(1-\phi)W_M + W_F\}A_1A_4}{W_F\{A_4 + (1-\omega)\gamma_F\}A_3} \tag{4}$$

$$e_F^{(Rwf)} = \frac{W_F|A_2| - (1-\phi)W_MA_1}{W_FA_3} \tag{5}$$

The partial equilibrium values of female time in household work ($I_F^{G(Rwf)}$) and in the labour market ($e_F^{(Rwf)}$) have the following properties:

- (i) $\frac{\partial I_F^{G(Rwf)}}{\partial W_M} = \frac{(1-\phi)A_1A_4}{W_F\{A_4 + (1-\omega)\gamma_F\}A_3} > 0$
- (ii) $\frac{\partial I_F^{G(Rwf)}}{\partial W_F} = -\frac{(1-\phi)A_1A_4W_M}{W_F^2\{A_4 + (1-\omega)\gamma_F\}A_3} < 0$
- (iii) $\frac{\partial e_F^{(Rwf)}}{\partial W_M} = -\frac{(1-\phi)A_1}{W_FA_3} < 0$
- (iv) $\frac{\partial e_F^{(Rwf)}}{\partial W_F} = \frac{(1-\phi)W_MA_1}{W_F^2A_3} > 0$

The intuition behind the properties (i)-(iv) are elucidated as follows. An increase in the male wage rate increases the production of household public goods that raises the marginal benefit from female household work, thus, $I_F^{G(Rwf)}$ increases such that the parity between marginal benefit and marginal loss gets restored at the new equilibrium level, while for a high W_M the household can afford to spend more time in non-labour market activities of the female member. On the other hand, an increase in the female wage rate raises the opportunity cost of unpaid household work, thus, family substitute $I_F^{G(Rwf)}$ by $e_F^{(Rwf)}$ that leads to a fall in $I_F^{G(Rwf)}$ and an increase in $e_F^{(Rwf)}$.

Substituting the optimal values in Eq. (2) leads to the following indirect utility function of the male member

$$V_M^{(Rwf)}(W_M, W_F) = \alpha_{1M} \ln \left(\frac{\alpha_{1M}\omega((1-\phi)W_M + W_F)}{A_3} \right) + \alpha_{2M} \ln \left(\frac{\alpha_{2M}\omega((1-\phi)W_M + W_F)}{A_3P_2} \right) + \beta_M \ln \left(\frac{\phi W_M((1-\phi)W_M + W_F)A_1A_4}{W_FA_3(A_4 + (1-\omega)\gamma_F)} \right) + \gamma_M \ln \left(1 - \frac{W_F|A_2| - (1-\phi)W_MA_1}{W_FA_3} \right) \tag{6}$$

The indirect utility function ($V_M^{(Rwf)}(W_M, W_F)$) has the following properties:

- (v) $\frac{\partial V_M^{(Rwf)}}{\partial W_F} = \frac{W_F(1-\beta_M) - (1-\phi)(\gamma_M + \beta_M)W_M}{\{(1-\phi)W_M + W_F\}W_F}$
- (vi) $\frac{\partial V_M^{(Rwf)}}{\partial W_M} = \frac{(1-\phi)(1 + \beta_M + \gamma_M)W_M + \beta_MW_F}{\{(1-\phi)W_M + W_F\}W_M} > 0$

An increase in W_F raises the consumption of both the final product that positively influences the level of indirect utility, while, properties (ii) and (iv) imply a fall in I_F^G and an increase in $e_F^{(Rwf)}$ that negatively affects the indirect utility. Thus, the change in $V_M^{(Rwf)}$ due to the change in W_F hinges on the relative strength of the above two effects. On the other hand, an increase in W_M raises the consumption of both the final product and also escalate the production of household public good that unambiguously improves the indirect utility of the male member.

3.1.2. The urban region with family (Uwf)

The utility of the unskilled female and male members in the urban region assumes the following form

$$V_F^{(Uwf)} = \alpha_{1F} \ln(x_{1F}) + \alpha_{2F} \ln(x_{2F}) + \beta_F \ln(G) + \gamma_F \ln(1 - I_F^G - e_F); \alpha_{1F}, \alpha_{2F}, \beta_F, \gamma_F > 0 \tag{7}$$

$$V_M^{(Uwf)} = \alpha_{1M} \ln(x_{1M}) + \alpha_{2M} \ln(x_{2M}) + \beta_M \ln(G) + \gamma_M \ln(1 - e_F); \alpha_{1M}, \alpha_{2M}, \beta_M, \gamma_M > 0 \tag{8}$$

In the urban region, the unskilled male member has two options for employment, i.e., to engage either in the high-wage paying urban formal sector (sector 2) with probability $(\frac{a_{M2}x_2}{L - a_{M1}x_1})$ or in the low-wage paying urban informal sector (sector N) with probability $(\frac{a_{MN}x_N}{L - a_{M1}x_1})$, where, a_{ji} s are the unit factor demand in sector i for factor j . Those male workers who fail to secure a job in sector 2 at formal wage rate, \bar{W}_M , are absorbed into sector N at urban informal wage rate $\tilde{W}_M (< \bar{W}_M)$. Thus, the average earning of the male worker in the urban region is $\{\bar{W}_M(\frac{a_{M2}x_2}{L - a_{M1}x_1}) + \tilde{W}_M(\frac{a_{MN}x_N}{L - a_{M1}x_1})\}$, that is denoted by, μ_M . The role of the urban informal sector in providing temporary relief to urban workers has been discussed by Chandra and Khan (1993). On the other hand, the female member in the urban region earns ϑW_F , where $\vartheta (> 1)$ is the urban wage premium (see footnote 5).

The production of the household public good is defined by the following technology.

$$G = I_F^G (1 - \zeta(\Psi)) \phi \mu_M \tag{9}$$

The urban household optimization problem then becomes

$$\text{Max}_{\{e_F, I_F^G, x_{1F}, x_{2F}, x_{1M}, x_{2M}\}} (1 - \omega)V_F^{(Uwf)} + \omega V_M^{(Uwf)}; \omega \in [0, 1]$$

subject to, $(x_{1M} + x_{1F}) + P_2(x_{2M} + x_{2F}) = (1 - \zeta(\Psi))[(1 - \phi)\mu_M + \vartheta W_F e_F]$

The possibility of contracting the disease has created enormous fear amongst the migrant workers consisting of a perceived high cost of healthcare associated with participation in the labour market, high job search cost and lack of availability of daily basic services etc. This leads to a high unprecedented psychological cost amongst unskilled workers which is denoted by, $\zeta(\Psi)$ that causes a fall in expected urban unskilled wage rate, where, $\zeta(0) = \bar{\zeta}$, $\bar{\zeta} \in (0, 1)$ and $\zeta(1) = 1$.¹⁴

The following restrictions on the parameters are assumed:

Assumption 3. $\frac{W_F}{\mu_M} > \frac{A_1(1 - \phi)}{|A_2|}$

Assumption 4. $\left(\frac{1}{A_3 \vartheta W_F}\right) \left[\frac{A_1 A_4 \{(1 - \phi)\mu_M + \vartheta W_F\}}{A_5} + \vartheta W_F |A_2| - (1 - \phi)\mu_M A_1\right] < 1$

where, $A_5 = \{\omega \beta_M + (1 - \omega)(\gamma_F + \beta_F)\} > 0$.

The Nash bargaining solution to the household's optimization problem is given by the following:

$$I_F^G(Uwf) = \frac{A_1 A_4 \{(1 - \phi)\mu_M + \vartheta W_F\}}{A_3 A_5 \vartheta W_F} \tag{10}$$

$$e_F(Uwf) = \frac{\vartheta W_F |A_2| - (1 - \phi)\mu_M A_1}{\vartheta W_F A_3} \tag{11}$$

Assumptions 3 and 4 ensure that $e_F^{(Uwf)} > 0$ and $(e_F^{(Uwf)} + I_F^G(Uwf)) < 1$.

The following properties describe the properties of $I_F^G(Uwf)$ and $e_F^{(Uwf)}$:

(vii) $\frac{\partial I_F^G(Uwf)}{\partial W_F} = -\frac{(1 - \phi)\mu_M A_1 A_4}{\vartheta W_F^2 A_3 A_5} < 0$

(viii) $\frac{\partial I_F^G(Uwf)}{\partial \mu_M} = \frac{(1 - \phi)A_1 A_4}{\vartheta W_F A_3 A_5} > 0$

(ix) $\frac{\partial e_F^{(Uwf)}}{\partial W_F} = \frac{(1 - \phi)\mu_M A_1}{\vartheta W_F^2 A_3} > 0$

(x) $\frac{\partial e_F^{(Uwf)}}{\partial \mu_M} = \frac{-(1 - \phi)A_1}{\vartheta W_F A_3} < 0$

¹⁴ Even if no lockdown is imposed there will always be a positive cost of migration (or, relocation cost) that is denoted by “ $\bar{\zeta}$ ”. In both Harris and Todaro (1970) and Chandra and Khan (1993) this migration cost is absent. However, such similar treatment in a different context could be found in Datta Chaudhuri (1989) and Gupta (1997).

Substituting the optimal values of the instrumental variables in Eq. (8) the following male indirect utility function is obtained

$$V_M^{(UwF)}(\mu_M, W_F) = \alpha_{1M} \ln \left(\frac{\alpha_{1M} \omega (1 - \zeta) ((1 - \phi) \mu_M + \vartheta W_F)}{A_3} \right) + \alpha_{2M} \ln \left(\frac{\alpha_{2M} \omega (1 - \zeta) ((1 - \phi) \mu_M + \vartheta W_F)}{A_3 P_2} \right) + \beta_M \ln \left(\frac{A_1 A_4 \phi (1 - \zeta) \mu_M ((1 - \phi) \mu_M + \vartheta W_F)}{A_3 A_5 \vartheta W_F} \right) + \gamma_M \ln \left(1 - \frac{\vartheta W_F |A_2| - (1 - \phi) \mu_M A_1}{\vartheta W_F A_3} \right) \quad (12)$$

$V_M^{(UwF)}$ has the following properties:

- (xi) $\frac{\partial V_M^{(UwF)}}{\partial \mu_M} = \frac{(1 - \phi)(1 + \gamma_M + \beta_M) \mu_M + \beta_M \vartheta W_F}{\{(1 - \phi) \mu_M + \vartheta W_F\} \mu_M} > 0$
- (xii) $\frac{\partial V_M^{(UwF)}}{\partial W_F} = \frac{\vartheta W_F (1 - \beta_M) - (1 - \phi)(\gamma_M + \beta_M) \mu_M}{\{(1 - \phi) \mu_M + \vartheta W_F\} W_F}$
- (xiii) $\frac{\partial V_M^{(UwF)}}{\partial \Psi} = - \left(\frac{\zeta'(\Psi)}{1 - \zeta} \right) < 0$

The imposition of a more stringent lockdown raises the urban living cost for the migrant workers in the urban area (i.e., a high value of ζ) that causes a fall in family income of the urban households, this leads to a fall in the level of indirect utility of the male member (property (xiii)).

3.1.3. The urban region without family (Uwof)

The utility of the unskilled female member in the rural region and unskilled male member in the urban region assumes the following form.

$$V_F^{(Rwof)} = \alpha_{1F} \ln(x_{1F}) + \alpha_{2F} \ln(x_{2F}) + \beta_F \ln(G) + \gamma_F \ln(1 - I_F^G - e_F); \quad \alpha_{1F}, \alpha_{2F}, \beta_F, \gamma_F > 0 \quad (13)$$

$$V_M^{(Uwof)} = \alpha_{1M} \ln(x_{1M}) + \alpha_{2M} \ln(x_{2M}) + \beta_M \ln(G) + \gamma_M \ln(1 - e_F); \quad \alpha_{1M}, \alpha_{2M}, \beta_M, \gamma_M > 0 \quad (14)$$

The production of the household public good is defined by the following technology

$$G = I_F^G \phi (1 - \zeta(\Psi)) \mu_M \quad (15)$$

The female member stays back in the rural region and earns W_F in the rural labour market, while the male member of the family migrates to the urban region and earns μ_M . Given that both the members of the household are staying apart in two different regions, they can make money transfers to each other depending on the shortfall of income over expenditure. Thus, the budget constraint of both the male and female members are given by

$$(x_{1F} + P_2 x_{2F}) - (1 - \phi) W_F e_F = \bar{\phi} \{ (1 - \zeta(\Psi))(1 - \phi) \mu_M \} \quad (16)$$

$$(x_{1M} + P_2 x_{2M}) - (1 - \zeta(\Psi)) \{ (1 - \bar{\phi})(1 - \phi) \mu_M \} = \underline{\phi} W_F e_F \quad (17)$$

where, $\underline{\phi}$ and $\bar{\phi}$ defined on the interval $[0, 1]$ are the respective share of income transferred from the female to male member and vice versa, respectively. In this case, the migration cost incurred by the male member is $\zeta (= \zeta(0))$, where, $\zeta \in (0, \bar{\zeta})$. Thus, the household collectively solves the following optimization problem:

$$\text{Max}_{\{e_F, I_F^G, x_{1F}, x_{2F}, x_{1M}, x_{2M}\}} (1 - \omega) V_F^{(Rwof)} + \omega V_M^{(Uwof)}; \quad \omega \in [0, 1]$$

subject to, $(x_{1M} + x_{1F}) + P_2(x_{2M} + x_{2F}) = (1 - \zeta(\Psi))[(1 - \phi) \mu_M] + W_F e_F$

The following partial equilibrium values of the instrumental variables solve the household's optimization problem

$$I_F^{G(Rwof)} = \frac{A_1 A_4 \{ (1 - \zeta)(1 - \phi) \mu_M + W_F \}}{A_3 A_5 W_F} \quad (18)$$

$$e_F^{(Rwof)} = \frac{W_F |A_2| - A_1 (1 - \zeta)(1 - \phi) \mu_M}{A_3 W_F} \quad (19)$$

Properties of $e_F^{(Rwof)}$ and $I_F^{G(Rwof)}$ are follows:

- (xiv) $\frac{\partial I_F^{G(Rwof)}}{\partial \mu_M} = \frac{A_1 A_4 (1 - \zeta)(1 - \phi)}{A_3 A_5 W_F} > 0$
- (xv) $\frac{\partial I_F^{G(Rwof)}}{\partial W_F} = - \frac{A_1 A_4 (1 - \zeta)(1 - \phi) \mu_M}{A_3 A_5 W_F^2} < 0$

$$\begin{aligned}
 \text{(xvi)} \quad \frac{\partial I_F^{G(Rwof)}}{\partial \Psi} &= -\frac{A_1 A_4 (1 - \phi) \mu_M \zeta'(\Psi)}{A_3 A_5 W_F} < 0 \\
 \text{(xvii)} \quad \frac{\partial e_F^{(Rwof)}}{\partial \mu_M} &= -\frac{A_1 (1 - \zeta)(1 - \phi)}{A_3 W_F} < 0 \\
 \text{(xviii)} \quad \frac{\partial e_F^{(Rwof)}}{\partial W_F} &= \frac{A_1 (1 - \zeta)(1 - \phi) \mu_M}{A_3 W_F^2} > 0 \\
 \text{(xix)} \quad \frac{\partial e_F^{(Rwof)}}{\partial \Psi} &= \frac{A_1 \zeta'(\Psi)(1 - \phi) \mu_M}{A_3 W_F} > 0
 \end{aligned}$$

Substituting Eq. (18) and (19) in Eq. (14) gives the following male indirect utility function:

$$\begin{aligned}
 V_M^{(Uwof)}(\mu_M, W_F) &= \alpha_{1M} \ln \left(\frac{\alpha_{1M} \omega ((1 - \zeta)(1 - \phi) \mu_M + W_F)}{A_3} \right) + \alpha_{2M} \ln \left(\frac{\alpha_{2M} \omega ((1 - \zeta)(1 - \phi) \mu_M + W_F)}{A_3 P_2} \right) \\
 &\quad + \beta_M \ln \left(\frac{A_1 A_4 \phi (1 - \zeta) \mu_M \{ (1 - \zeta)(1 - \phi) \mu_M + W_F \}}{A_3 A_5 W_F} \right) \\
 &\quad + \gamma_M \ln \left(1 - \frac{W_F |A_2| - A_1 (1 - \zeta)(1 - \phi) \mu_M}{A_3 W_F} \right)
 \end{aligned} \tag{20}$$

The indirect utility function of the male member has the following properties

$$\begin{aligned}
 \frac{\partial V_M^{(Uwof)}}{\partial \mu_M} &= \frac{(1 - \zeta)(1 - \phi)(1 + \gamma_M + \beta_M) \mu_M + \beta_M W_F}{\{(1 - \zeta)(1 - \phi) \mu_M + W_F\} \mu_M} > 0 \\
 \frac{\partial V_M^{(Uwof)}}{\partial W_F} &= \frac{W_F (1 - \beta_M) - (1 - \zeta)(1 - \phi)(\gamma_M + \beta_M) \mu_M}{\{(1 - \phi)(1 - \zeta) \mu_M + W_F\} W_F} \\
 \frac{\partial V_M^{(Uwof)}}{\partial \Psi} &= -\zeta'(\Psi) \left[\frac{(1 - \zeta)(1 - \phi)(1 + \gamma_M + \beta_M) \mu_M + \beta_M W_F}{\{(1 - \zeta)(1 - \phi) \mu_M + W_F\} (1 - \zeta)} \right] < 0
 \end{aligned}$$

3.1.4. Migration decision

The decision to migrate from the rural to the urban region (with or without family) is taken solely by the male member of the family, which, however, is conditional on both male and female earnings besides the other household parameters.¹⁵ In this paper, the distinguishing features of the migration model that generalizes the usual Harris and Todaro (1970) (hereafter, H-T (1970)) and Chandra and Khan (1993) (hereafter, C-K (1993)) migration equilibrium are as follows:

- (a) The households are bifurcated based on their nature of migration i.e., with or without family (see footnote 11). Thus, the households in the economy are heterogeneous based on their migration decision which is absent in both H-T (1970) and C-K (1993).
- (b) Unlike H-T (1970) and C-K (1993), the migration decision is influenced by the degree of male social stigma associated with female labour market participation (denoted by γ_M). Basu (2006) describes this stigma as the “pride hurt” of the male member of a conservative society.
- (c) The direction of migration depends on the aggregate family earnings in both the urban and the rural regions rather than the expected wage differential of the male member as in the case of H-T (1970). Thus, migration from rural to the urban region could take place even if the expected urban wage falls short of the rural wage for male labour.
- (d) Migration to the urban region involves a positive migration cost that is proportional to the expected urban income of the family which is absent in both H-T (1970) and C-K (1993). The scholarly works of Todaro (1969), Chaudhuri (1989) and Gupta (1997) have considered a lumpsum fixed migration cost in a different context contrary to which migration cost in this model hinges on the migration decision with or without family.
- (e) Open unemployment exists even in the presence of the urban informal sector which is conditional on the economy-wide lockdown.

This implies that both H-T (1970) and C-K (1993) are special cases of the migration equilibrium developed in this model. The migration equilibrium with family is obtained by equating Eq. (6) and (12) which is as follows:

$$(1 - \phi) W_M + W_F = \frac{(1 - \zeta)}{\vartheta^{\beta_M + \gamma_M}} \{ (1 - \phi) \mu_M + \vartheta W_F \} \left(\frac{\mu_M}{W_M} \right)^{\beta_M} \left\{ \frac{\vartheta A_3 W_F + A_1 (1 - \phi) \mu_M - |A_2| \vartheta W_F}{A_3 W_F + A_1 (1 - \phi) W_M - |A_2| W_F} \right\}^{\gamma_M}$$

¹⁵ The household parameters include $\alpha_{tk}, \beta_k, \gamma_k$ for $t = \{1, 2\}$ and $k = \{M, F\}, \omega$ and ϕ .

and, the migration equilibrium without family is obtained by equating Eqs. (6) and (20) that lead to the following equilibrium condition:

$$(1 - \phi)W_M + W_F = \{(1 - \phi)(1 - \zeta)\mu_M + W_F\} \left(\frac{(1 - \zeta)\mu_M}{W_M} \right)^{\beta_M} \left\{ \frac{A_3W_F + A_1(1 - \phi)(1 - \phi)\mu_M - |A_2|W_F}{A_3W_F + A_1(1 - \phi)W_M - |A_2|W_F} \right\}^{\gamma_M}$$

For $\zeta(0) = 0$ (no migration cost), $W_F = 0$ and $\vartheta = 1$ (no rural-urban wage gap for female), both the migration equilibrium boils down to the usual C-K (1993) migration equilibrium which is itself a generalised case of H-T (1970).

3.2. Skilled family and the demand function

In this economy, there are \bar{S} number of homogenous skilled families each consisting of one skilled male member and one skilled female member, both supplying their entire labour hours and earning the same skilled wage rate, W_S . Each skilled family is an equiproportionate owner of domestic capital (\bar{K}_D). The family consumes various types of traded final commodities besides the consumption of a non-traded final commodity.

The utility of the skilled female and male members of the family assumes the following form

$$V_F^{(S)} = \alpha_{1F}^{(S)} \ln(x_{1F}^{(S)}) + \alpha_{2F}^{(S)} \ln(x_{2F}^{(S)}) + \alpha_{3F}^{(S)} \ln(x_{3F}^{(S)}) + \kappa(\Psi)\beta_F^{(S)} \ln(x_N^G) \tag{21}$$

$$V_M^{(S)} = \alpha_{1M}^{(S)} \ln(x_{1M}^{(S)}) + \alpha_{2M}^{(S)} \ln(x_{2M}^{(S)}) + \alpha_{3M}^{(S)} \ln(x_{3M}^{(S)}) + \kappa(\Psi)\beta_M^{(S)} \ln(x_N^G) \tag{22}$$

Lockdown induced restriction of market access and negative expectation that the future will continue to be uncertain which Keynes referred to as the “state of confidence effect” that leads to an adverse demand shock.¹⁶ This has been parameterized by $\kappa(\Psi)$ where, $0 \leq \kappa(\Psi) \leq 1$; $\kappa'(\Psi) < 0$; $\kappa(1) = 0$ and $\kappa(0) = 1$.

Thus, each representative skilled household maximizes the following weighted utility function.¹⁷

$$\text{Max}_{\{x_{1M}^{(S)}, x_{2M}^{(S)}, x_{3M}^{(S)}, x_{1F}^{(S)}, x_{2F}^{(S)}, x_{3F}^{(S)}, x_N^G\}} \quad \frac{1}{2}V_F^{(S)} + \frac{1}{2}V_M^{(S)}$$

subject to, $(x_{1M}^{(S)} + x_{1F}^{(S)}) + P_2(x_{2M}^{(S)} + x_{2F}^{(S)}) + P_3(x_{3M}^{(S)} + x_{3F}^{(S)}) + P_N x_N^G = 2W_S + \frac{r\bar{K}_D}{S}$

Optimization yields the demand for the non-traded commodity by each skilled family:

$$x_N^G = \frac{\kappa(\Psi)(\beta_F^{(S)} + \beta_M^{(S)}) \left(2W_S + \frac{r\bar{K}_D}{S} \right)}{(\alpha_{1M}^{(S)} + \alpha_{2M}^{(S)} + \alpha_{3M}^{(S)} + \alpha_{1F}^{(S)} + \alpha_{2F}^{(S)} + \alpha_{3F}^{(S)} + \kappa(\Psi)\beta_F^{(S)} + \kappa(\Psi)\beta_M^{(S)})P_N} \tag{23}$$

The effect of lockdown on x_N^G is given by

$$\frac{\partial x_N^G}{\partial \Psi} = \frac{\kappa'(\Psi)(\beta_F^{(S)} + \beta_M^{(S)})(\alpha_{1M}^{(S)} + \alpha_{2M}^{(S)} + \alpha_{3M}^{(S)} + \alpha_{1F}^{(S)} + \alpha_{2F}^{(S)} + \alpha_{3F}^{(S)}) \left(2W_S + \frac{r\bar{K}_D}{S} \right)}{(\alpha_{1M}^{(S)} + \alpha_{2M}^{(S)} + \alpha_{3M}^{(S)} + \alpha_{1F}^{(S)} + \alpha_{2F}^{(S)} + \alpha_{3F}^{(S)} + \kappa(\Psi)\beta_F^{(S)} + \kappa(\Psi)\beta_M^{(S)})^2 P_N} < 0$$

Thus, the aggregate demand for the non-traded commodity is

$$X_N^D = \bar{S} x_N^G(P_N, 2W_S, r, \Psi), \quad \frac{\partial X_N^D}{\partial P_N} < 0; \quad \frac{\partial X_N^D}{\partial W_S} > 0; \quad \frac{\partial X_N^D}{\partial r} > 0; \quad \frac{\partial X_N^D}{\partial \Psi} < 0; \quad X_N^D(\dots, 1) = 0 \tag{24}$$

4. General equilibrium analogue and the implications of lockdown

In this section, the general equilibrium implication of lockdown has been analysed in two alternative scenarios, viz. migration with family and migration without family.

4.1. Migration with family

The price-average cost parity condition in the agriculture sector is given by the following expression:

$$W_M a_{M1} + W_F a_{F1} + R a_{T1} = 1 \tag{25}$$

¹⁶ See Dasgupta and Rajeev (2020) for a theoretical exposition in a demand constrained macroeconomic framework. However, in this paper the adverse demand shock has no direct effect on the prices of the traded commodities that are internationally determined, while it affects the demand for the non-traded services produced by sector N such as hospitality, motor repair services, beauty and wellness, transport, tourism etc.

¹⁷ For the skilled families the bargaining strength of the male and female member is assumed to be equal unlike the unskilled families where the bargaining strength of each member is denoted by ω and $1 - \omega$, respectively.

The price of the commodity produced by sector 1 is normalized to unity such that terms of trade in the other sectors and the real income of each economic agent are measured relative to the agriculture price.

The profit-maximizing condition in sector 2 is given by

$$\bar{W}_M a_{M2} + r a_{K2} = P_2 - T(\Psi); \quad T'(\Psi) > 0, \quad T(0) = 0 \text{ and } T(1) \geq P_2 \tag{26}$$

$T(\Psi)$ is the lockdown-induced transaction cost borne directly by the contact-intensive sector 2 that is defined as a positive function of the lockdown parameter. This can be looked upon as a higher cost of bringing labour to the workplace in absence of general public transport, cost of maintaining (installing) health and sanitization infrastructure, high transportation cost etc. In case, there is a complete lockdown, i.e., $\Psi = 1$, the transaction cost in this contact-intensive sector, T may exceed the unit price level such that the net unit price falls short of its average cost. This may cause the sector to vanish.

The profit-maximizing conditions of sector N , sector 3 and imperfection in the female labour market are given by the following equations, respectively,

$$a_{MN} \bar{W}_M + a_{FN} \bar{W}_F + a_{KN} \eta = P_N \tag{27}$$

$$W_5 a_{S3} + r a_{K3} = P_3 \tag{28}$$

$$\bar{W}_F = \vartheta W_F \tag{29}$$

The capital market imperfection in sector 1 can be represented by the following relationship between informal interest rate (η) and formal interest rate (r),¹⁸

$$\eta = q + \Gamma(r); \quad q > 0, \quad \Gamma'(r) > 1, \quad \Gamma''(r) > 0, \quad \Gamma(0) = 0 \quad \forall r \geq 0 \tag{30}$$

The migration equilibrium during the lockdown period is given by the following equation:

$$(1 - \phi)W_M + W_F = \frac{(1 - \zeta)}{\vartheta^{\beta_M + \gamma_M}} \{ (1 - \phi)\mu_M + \vartheta W_F \} \left(\frac{\mu_M}{W_M} \right)^{\beta_M} \left\{ \frac{\vartheta A_3 W_F + A_1 (1 - \phi)\mu_M - |A_2| \vartheta W_F}{A_3 W_F + A_1 (1 - \phi)W_M - |A_2| W_F} \right\}^{\gamma_M} \tag{31}$$

The full employment condition of capital and land is represented by the following equations, respectively,

$$a_{K2} X_2 + a_{K3} X_3 + a_{KN} X_N = K = \bar{K}_D + K_F(r - r^*); \quad K'_F(\cdot) > 0 \quad \forall r > r^* \tag{32}$$

$$a_{T1} X_1 = \bar{T} \tag{33}$$

The total availability of labour for the production of sector 2 and N output is $(\bar{L} - a_{M1} X_1)$. The imposition of lockdown in the contact-intensive sector 2 and sector N restricts the physical presence and use of ‘ Ψ ’ proportion of unskilled labour. As a result, post-lockdown availability of unskilled labour endowment in sector 2 and sector N is given by $(1 - \Psi)(\bar{L} - a_{M1} X_1)$. Thus, the level of lockdown-induced unemployment of unskilled labour is given by:

$$\Omega_M = \Psi(\bar{L} - a_{M1} X_1) \tag{34}$$

The utilization of unskilled labour in the contact-intensive sectors (sector 2 and sector N) conditional on the degree of lockdown is given by the following equation:

$$a_{M1} X_1 + a_{M2} X_2 + a_{MN} X_N + \Omega_M = \bar{L} \tag{35}$$

The female member in the rural labour market exerts effort $e_F^{(Rwf)}$ while its counterpart in the urban labour market exerts $e_F^{(Uwf)}$ (Eqs. 5 and 11, respectively). Given that each family comprises of unit male and female member and female migrates with the male member, thus, the total supply of female labour in the rural and urban regions is $e_F^{(Rwf)} a_{M1} X_1$ and $e_F^{(Uwf)} (a_{MN} X_N + a_{M2} X_2)$, respectively. The equilibrium in the female labour market is given by:

$$a_{F1} = e_F^{(Rwf)} a_{M1} \tag{36}$$

$$a_{FN} X_N = e_F^{(Uwf)} (a_{MN} X_N + a_{M2} X_2) \tag{37}$$

Female unemployment is given by the following equation:

$$\Omega_F = \Psi e_F^{(Uwf)} \left(\bar{L} - \frac{a_{F1} X_1}{e_F^{(Rwf)}} \right) \tag{38}$$

¹⁸ For an endogenous determination of the capital market imperfection see Gupta (1993), Marjit and Acharyya (2003), Chaudhuri and Gupta (2014). For a similar treatment of capital market imperfection see Mahata, Khan and Nag (2020).

The market-clearing condition for skilled labour is given by:

$$a_{S3}X_3 = \bar{S} \quad (39)$$

The equilibrium condition for the non-traded commodity is as follows:

$$X_N = X_N^D \quad (40)$$

In this general equilibrium system, there are eighteen main endogenous variables, $W_M, \bar{W}_M, W_F, \bar{W}_F, \vartheta, R, \eta, r, W_S, P_N, X_1, X_2, X_3, X_N, \Omega_M, \Omega_F, e_F^{(Rwf)}$ and $e_F^{(Uwf)}$ beside the ten a_{ji} s, with the same number of independent equations (i.e., Eqs. (5), (11) and (25)-(40)). Eqs. (26) and (30) determine r and η , respectively. Eq. (28) determines W_S . X_3 is determined from Eq. (39). From Eqs. (33) and (34), X_1 and Ω_M is obtained in terms of W_M, W_F and R , respectively. Solving simultaneous Eqs. (32), (35) and (38), X_2, X_N and Ω_F are obtained in terms of $W_M, W_F, R, \bar{W}_F, \bar{W}_M, P_N$ and ϑ . Thus, Eqs. (31), (36), (37) and (40) are reduced in terms of the remaining unknown variables which together with Eq. (25), (27) and (29) solves for the final equilibrium values of $W_M, W_F, R, \bar{W}_F, \bar{W}_M, P_N$ and ϑ . Once factor prices are obtained, the factor coefficients get determined and $e_F^{(Rwf)}$ and $e_F^{(Uwf)}$ are solved from Eqs. (5) and (11), respectively. Sector 2 and sector N form a *sub-system* where sector 2 is assumed to be capital-intensive relative to unskilled male labour compared to sector N . Non-reversibility of factor-intensity ranking and Walrasian stability for the non-traded commodity ensures the stability of the general equilibrium model. This completes the determination of general equilibrium values and description of the working of the model.

4.2. Implications of lockdown

Lockdown has been conceptualized as a government-controlled exogenous policy instrument to restrict human mobility in the contact-intensive economic activities in terms of an increase in $\Psi \in [0,1]$ which has multi-dimensional effects in the form of reduced labour supply of proportion Ψ , adverse supply shock in terms of a high transaction cost in the production sector ($T(\Psi)$), high urban cost of living ($\zeta(\Psi)$) and an adverse demand shock ($\kappa(\Psi)$), respectively. These effects penetrate through different channels that have both primary and secondary effects on the endogenous variables, however, it is reasonable to assume that the primary effect dominates the secondary effect under certain sufficient conditions.¹⁹

Lockdown has inflicted high **transaction costs** which tends to reduce the profitability of sector 2 and hence its average cost is higher than the average revenue Eq. (26)). The natural outcome is the contraction of sector 2, thus the demand for capital falls which leads to a fall in r . It follows from Eq. (30) that a fall in formal interest rate (r) lowers the informal interest rate η . This reduces the cost of production in sector 3 which leads to the substitution of skilled labour by capital, hence, a_{S3} falls which leads to expansion of this sector (Eq. (39)). Profit maximization in this sector leads to an increase in W_S (Eq. (28)). Fall in domestic interest rate relative to world interest rate (i.e., fall in $(r - r^*)$) results in an outflow of foreign capital (K_F) that lowers the endowment of capital availability in the domestic market. Owing to the Rybczynski-type effect (RTE), this leads to an expansion of the unskilled male labour-intensive sector N while the capital-intensive sector 2 contracts.²⁰ The demand for unskilled female labour in the urban region accentuates that escalates the urban wage premium (ϑ) of the unskilled female labour. On one hand, the high wage-paying sector (sector 2) contracts which lead to a fall in the average unskilled male wage rate in the urban region (μ_M). On the other hand, an increase in ϑ raises the urban unskilled family income. If the latter effect dominates the former effect, the male's indirect utility ($V_M^{(Uwf)}$) in the urban region improves which leads to migration with family from the rural region to the urban region despite a fall in μ_M (property (xi) and (xii)).²¹ In the rural region, the supply of both unskilled male and female labour falls causing a rise in respective rural unskilled wage rate (W_M and W_F). The demand for the specific factor land falls in the rural region which leads to a fall in its return (R). The inflow of migrants in the urban region leads to an increase in urban unemployment of both male and female labour (Eqs. (34) and (38)). It follows from property (iii), (iv), (ix) and (x) that female labour force participation in the rural region ($e_F^{(Rwf)}$) remains ambiguous while it increases in the urban region ($e_F^{(Uwf)}$). The following proposition is immediate.

Proposition 1. Lockdown inflicted high transaction cost leads to, (a) an increase in urban unemployment of both unskilled male and female labour, (b) rural to urban migration of unskilled labour with family, (c) accentuates the urban informalization, (d) escalates female participation in the urban informal labour market and (e) an outflow of foreign capital.²²

A **physical restriction** imposed on labour gathering in the contact-intensive sector leads to an immediate increase in the urban unemployment of unskilled male labour Eq. (34)), thus, the unskilled male labour supply falls in the urban region.

¹⁹ See Appendix for mathematical derivations.

²⁰ The Rybczynski type effect (RTE) has been discussed in details in footnote 12-14 in Chaudhuri and Biswas (2016). In brief, RTE is different from RE (Rybczynski effect) in the sense that in the former output adjustment following factor-intensity ranking occurs through changes in factor relocation owing to variation in factor prices without actual changes in factor endowment level, while the latter involves output adjustment due to direct change in factor endowment. Literature of trade and development that have discussed RTE includes Chaudhuri and Biswas (2016), Chaudhuri (2018) etc. among others.

²¹ In the usual H-T (1970) migration model, a decrease in expected urban wage causes reverse migration (urban to rural). However, in this case labour migrates from the rural to the urban region despite a fall in μ_M which contradicts the H-T (1970) result. This is because migration decision hinges on the family income rather than the male's own average income.

²² Urban informalization implies an expansion of the urban informal sector (sector N) and a higher engagement of unskilled male and female labour in this sector.

This leads to a Rybczynski effect which leads to an expansion of sector 2 and contraction of sector N (Eq. (25)). The other immediate effect of a physical restriction imposed on labour gathering is an increase in unskilled female unemployment in the urban region (Eq. (38)). On one hand, contraction of the urban non-traded sector leads to a fall in demand for female labour that lowers the unskilled female's urban wage premium and hence unskilled female urban wage plummets. On the other hand, the expected urban unskilled male wage increases owing to an expansion of the high-wage paying sector. If the former effect dominates the latter then it will lead to reverse migration (urban to rural) of unskilled male labour with families. This increases the supply of unskilled labour of either type in the rural region which causes a reduction in both male and female unskilled wage rates. Land becomes relatively costlier in the rural region, thus, a_{T1} falls which leads to an expansion of output in the rural region (Eq. (33)). It follows from Eq. (25) that R increases. It follows from Eqs. (5) and ((11) that female labour force participation in the rural region ($e_F^{(Rwf)}$) remains ambiguous while it plunges in the urban region ($e_F^{(Uwf)}$), respectively. The following proposition summarizes the result.

Proposition 2. *An imposition of partial lockdown in terms of physical restriction on labour gathering might lead to, (a) an increase in unskilled male and female urban unemployment, (b) an exodus of urban unskilled migrant workers, (c) a high informalization of the rural sector and (d) female labour force participation in the urban region deteriorates while in the rural region it remains ambiguous.*

The possibility of contracting the disease has created enormous fear and anxiety amongst the migrant workers consisting of a perceived high cost of healthcare associated with participation in the labour market, high job search costs and lack of availability of daily basic services (Kumar and Choudhury 2021). This leads to a high **unprecedented psychological cost** amongst unskilled workers which is implied by an increase in the value of ζ in Eq. (31) that causes a fall in expected urban unskilled family income. Unskilled male workers with families migrate back to the rural region which creates downward pressure on the rural male and female unskilled wage rate. It follows from Eq. (25) that R increases which leads to a fall in a_{T1} and an expansion of sector 1. As a consequence of reverse migration, urban unemployment of unskilled male and female labour falls. Labour scarcity in the urban area leads to an RTE, thus sector 2 expands and sector N contracts. Contraction of the urban non-traded sector leads to a fall in demand for female labour that lowers the unskilled female's urban wage premium (ϑ). It follows from Eqs. (5) and (11) that female labour force participation in the rural region ($e_F^{(Rwf)}$) remains ambiguous while it plunges in the urban region ($e_F^{(Uwf)}$), respectively. The following proposition is immediate.

Proposition 3. *Lockdown induced high unprecedented psychological cost amongst unskilled workers leads to, (a) a fall in unskilled urban unemployment of male and female labour, (b) an exodus of urban unskilled migrant workers, (c) a high informalization of the rural economy and (d) female labour force participation in the urban region deteriorates while in the rural region it remains ambiguous.*

On the consumption side, lockdown-induced restriction of market access and negative expectation that the future will continue to be uncertain which Keynes referred to as the “state of confidence effect”, leads to an **adverse demand shock**. This is captured by a fall in κ in Eq (23) . This lowers the domestic price of non-traded services (P_N) to equilibrate the market. This leads to a fall in urban informal wage rate for both male and female unskilled labour causing reverse migration. Unskilled labour supply increases in the rural region which creates downward pressure on the rural male and female unskilled wage rate and an increase in R . Thus, sector 1 expands. Due to reverse migration, urban unemployment of unskilled male and female labour falls. A fall in labour endowment in the urban region leads to an RTE effect that causes an expansion of sector 2 and contraction of sector N . Given properties (iii), (iv), (ix) and (x) it is obtained that female labour force participation in the rural region ($e_F^{(Rwf)}$) and in the urban region ($e_F^{(Uwf)}$) remains ambiguous. This leads to the following proposition.

Proposition 4. *Unprecedented adverse demand shock leads to, (a) a fall in the urban unemployment of unskilled male and female labour, (b) reverse migration of unskilled families, (c) a high informalization of the rural economy and (d) an ambiguous effect on female labour force participation in both rural and urban region.*

4.3. Migration without family

In this scenario, the male unskilled labour migrates to the urban region without their family, i.e., male member regional migration is unaccompanied by their female counterpart under certain circumstances as discussed in Section 4. This leads to certain adjustments to the general equilibrium analogue as follows. First, the urban informal sector (sector N) employs only male unskilled labour and informal capital. Second, the migration equilibrium is obtained by comparing the indirect utility of the male member from staying in the rural region with family and urban region without family. Finally, unlike the preceding case where families in the rural region were homogenous in terms of the presence of both male and female members in the rural household, in this case, the rural families are heterogeneous. Heterogeneity means that families with only female members and families with both male and female members coexist. The remaining structure of the general equilibrium are unchanged. The modified equations are represented as follows:

$$a_{MN}\tilde{W}_M + a_{KN}\eta = P_N \quad (41)$$

Table 1
Summarization of economic impacts of COVID-19 lockdown.

COVID-19 induced shocks	Migration with families(Case 1)				Migration without families(Case 2)			
	Urban-unemp	R-U migration	Inform.	FLFP	Urban-unemp	R-U migration	Inform.	FLFP
Adverse supply shock (Transaction cost, $T(\Psi)$)	(↑)	(↑)	(↑) in urban inform.	e_F^{Uwf} (↑) & e_F^{Rwf} ambg	(↓)	(↓)	(↑) in urban inform.	e_F^{Rwf} (↑) & e_F^{Rwof} (↑)
Physical restriction on labour gathering (Ψ)	(↑)	(↓)	(↑) in rural inform.	e_F^{Uwf} (↓) & e_F^{Rwf} ambg	(↑)	(↓)	(↓) in urban inform.	e_F^{Rwf} (↓) & e_F^{Rwof} ambg
High urban cost of living ($\zeta(\Psi)$)	(↓)	(↓)	(↑) in rural inform.	e_F^{Uwf} (↓) & e_F^{Rwf} ambg	(↓)	(↓)	(↑) in rural inform.	e_F^{Rwf} (↓) & e_F^{Rwof} (↓)
Adverse demand shock ($\kappa(\Psi)$)	(↓)	(↓)	(↑) in rural inform.	e_F^{Uwf} & e_F^{Rwf} ambg	(↓)	(↓)	(↓) in urban inform.	e_F^{Rwf} (↑) & e_F^{Rwof} (↑)

Symbols – Urban-unemp: urban unemployment of unskilled male (female) labour; R-U migration: rural-urban migration; Inform.: informalization of unskilled labour; FLFP: female labour force participation (rural and urban); (↑): increase; (↓): decrease; e_F^{Uwf} (e_F^{Uwf}): female labour time in the rural (urban) region while staying with family; e_F^{Rwof} : female labour time in the rural region while staying apart from (without) family; ambg: ambiguous.

$$(1 - \phi)W_M + W_F = \{(1 - \phi)(1 - \zeta)\mu_M + W_F\} \left(\frac{(1 - \zeta)\mu_M}{W_M} \right)^{\beta_M} \left\{ \frac{A_3W_F + A_1(1 - \zeta)(1 - \phi)\mu_M - |A_2|W_F}{A_3W_F + A_1(1 - \phi)W_M - |A_2|W_F} \right\}^{\gamma_M} \quad (42)$$

$$a_{F1}X_1 = a_{M1}X_1 e_F^{(Rwf)} + (\bar{L} - a_{M1}X_1) e_F^{(Rwof)} \quad (43)$$

In this general equilibrium system, there are fifteen main endogenous variables, $W_M, \tilde{W}_M, W_F, R, \eta, r, W_S, P_N, X_1, X_2, X_3, X_N, \Omega_M, e_F^{(Rwf)}$ and $e_F^{(Rwof)}$ beside the nine a_{ji} s, with the same number of independent equations (i.e., Eqs. (5),(19), (25),(26),(28),(30),(32)-(35) and (39)- (43)).

Implications of lockdown

Following the similar logic as in section 5.1, the following propositions are obtained.

Proposition 5. Lockdown inflicted high transaction cost leads to, (a) a fall in urban unemployment of unskilled male labour, (b) urban to rural migration of unskilled male labour without family, (c) accentuates the urban informalization and (d) escalates female participation in the rural labour market and (e) an outflow of foreign capital.

Proposition 6. An imposition of partial lockdown in terms of physical restriction on labour gathering might lead to, (a) an increase in unskilled male urban unemployment, (b) an exodus of urban unskilled male migrant workers, (c) a fall in informalization of the urban region and (d) female labour force participation in the rural region deteriorates for those staying with families while it remains ambiguous for those staying without families.

Proposition 7. Lockdown induced high unprecedented psychological cost amongst unskilled workers leads to, (a) a fall in unskilled urban unemployment of male labour, (b) an exodus of urban unskilled migrant male workers, (c) a high informalization of the rural economy and (d) female labour force participation in the rural region deteriorates. .

Proposition 8. Unprecedented adverse demand shock leads to, (a) a fall in the urban unemployment of unskilled male labour, (b) reverse migration of unskilled male labour, (c) a lower informalization of the urban economy and (d) an increase in female labour force participation in the rural region.

The following table (Table 1) summarizes the results that compare the economic impact of lockdown on female labour force participation in both rural and urban region for those females who stays with family and those staying apart in the rural region without family.

5. Conclusion

The COVID-19 pandemic in the developing economies has had an uneven and disproportionate impact on female labour in terms of labour force participation, gender-based wage disparity, unemployment and migration. There has been copious of empirical and case-study-based literature on the gendered effect of the pandemic, however, no theoretical explanation has been provided so far in a formal structure. This paper attempted to fill the theoretical space in the literature by providing an analytically tractable model that can explain the gendered effect of the pandemic in presence of family ties and migration. In so doing, we constructed a general equilibrium model for a distortion-ridden developing economy. A generalized version of the H-T (1970) and C-K (1993) has been derived from the intra-household bargaining problem of unskilled families. The effect of the pandemic has been conceptualized in terms of an adverse supply shock leading to high transaction costs in

the contact-intensive manufacturing sector, restriction on the physical gathering of labour, high urban cost of living and an adverse demand shock. The effect of the pandemic-inflicted shocks is heterogenous for workers migrating with families and those without families, for instance, an imposition of partial lockdown in terms of physical restriction on labour gathering leads to a lower female labour force participation in the rural region for those staying with families while it might increase for those staying without families. The results of the paper reflect internal contradictions of an emerging and less-developed economy that has a conditional-conditioning relationship with an archaic structure.

Conflict of interest statement

The authors declare no potential conflict of interest.

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Appendix

Mathematical Appendix

The proportionate change in the varibales/parameters is denoted by ‘^’, θ_{ji} and λ_{ji} denote the distributive share and physical share of the j th factor in the i th sector, respectively.

Taking total derivative of equations (26), (28) and (30) yields the following results

$$\hat{r} = -\frac{\theta_{T2}}{\theta_{K2}} \hat{\Psi} \tag{A.1}$$

$$\hat{W}_S = \frac{\theta_{K3}\theta_{T2}}{\theta_{S3}\theta_{K2}} \hat{\Psi} \tag{A.2}$$

$$\hat{\eta} = -\varepsilon_{\Gamma r} \frac{\theta_{T2}}{\theta_{K2}} \hat{\Psi} \tag{A.3}$$

where, $\varepsilon_{\Gamma r} = \frac{\Gamma'(r)\Gamma}{\eta} (> 0)$ is the elasticity of informal interest with respect to formal interest.

The following equations are obtained from differentiating Eqs. (25), (27) and (29), respectively

$$\hat{W}_M = -\frac{\theta_{F1}}{\theta_{M1}} \hat{W}_F - \frac{\theta_{T1}}{\theta_{M1}} \hat{R} \tag{A.4}$$

$$\hat{W}_M = \left(\frac{1}{\theta_{MN}}\right) \hat{P}_N - \left(\frac{\theta_{FN}}{\theta_{MN}}\right) \hat{v} - \left(\frac{\theta_{FN}}{\theta_{MN}}\right) \hat{W}_F + B_T \hat{\Psi} \tag{A.5}$$

$$\hat{W}_F = \hat{v} + \hat{W}_F \tag{A.6}$$

where, $B_T = \frac{\varepsilon_{\Gamma r}\theta_{KN}\theta_{T2}}{\theta_{MN}\theta_{K2}} > 0$.

From Eq. (33) we obtained output of sector 1 (X_1) independnt of the parameter Ψ , thus,

$$\hat{X}_1 = 0 \tag{A.7}$$

The effect on male unemployment is obtained by taking total derivative of Eq. (34) that leads to the following result

$$\hat{\Omega}_M = \hat{\Psi} - B_1 \hat{W}_F - B_2 \hat{R} \tag{A.8}$$

where,

$$B_1 = \lambda_{L(-1)} \left(S_{MF}^1 - \frac{S_{MM}^1 \theta_{F1}}{\theta_{M1}} \right) > 0$$

$$B_2 = \lambda_{L(-1)} \left(S_{MT}^1 - \frac{S_{MM}^1 \theta_{T1}}{\theta_{M1}} \right) > 0$$

$$\lambda_{L(-1)} = \left(\frac{a_{M1} X_1}{\bar{L} - a_{M1} X_1} \right)$$

Differentiating Eq. (36) and (39), respectively and using equations (5), (A.4) and (A.6)

$$\hat{R} = -\frac{A_4}{A_3} \hat{W}_F \tag{A.9}$$

$$\hat{X}_3 = A_5 \hat{\Psi} \tag{A.10}$$

where,

$$B_3 = (S_{FT}^1 - S_{MT}^1) - \frac{\theta_{T1}}{\theta_{M1}} (S_{FM}^1 - \varepsilon_{FM}^{Rwf} - S_{MM}^1)$$

$$B_4 = (S_{FF}^1 - \varepsilon_{FF}^{Rwf} - S_{MF}^1) - \frac{\theta_{F1}}{\theta_{M1}} (S_{FM}^1 - \varepsilon_{FM}^{Rwf} - S_{MM}^1) < 0$$

$$B_5 = \frac{S_{SK}^3 \theta_{T2}}{\theta_{S3} \theta_{K2}} > 0$$

Taking total derivative of Eqs. (32) and (35) and arranging in matrix form

$$\begin{pmatrix} \lambda_{K2} & \lambda_{KN} \\ \lambda_{M2} & \lambda_{MN} \end{pmatrix} \begin{pmatrix} \hat{X}_2 \\ \hat{X}_N \end{pmatrix} = \begin{pmatrix} B_6 \hat{\Psi} + B_7 \hat{\vartheta} + B_8 \hat{W}_F - B_9 \hat{P}_N \\ B_{10} \hat{W}_F - B_{11} \hat{P}_N + B_{12} \hat{\vartheta} + B_{13} \hat{\Psi} \end{pmatrix}$$

Using Cramer’s rule, the following results are obtained

$$\hat{X}_2 = \frac{(\lambda_{MN} B_6 - \lambda_{KN} B_{13}) \hat{\Psi} + (\lambda_{MN} B_7 - \lambda_{KN} B_{12}) \hat{\vartheta} + (\lambda_{MN} B_8 - \lambda_{KN} B_{10}) \hat{W}_F + (\lambda_{KN} B_{11} - \lambda_{MN} B_9) \hat{P}_N}{|\lambda|_{2N}^{MK}} \tag{A.11}$$

$$\hat{X}_N = \frac{(\lambda_{K2} B_{13} - \lambda_{M2} B_6) \hat{\Psi} + (\lambda_{K2} B_{12} - \lambda_{M2} B_7) \hat{\vartheta} + (\lambda_{K2} B_{10} - \lambda_{M2} B_8) \hat{W}_F + (\lambda_{M2} B_9 - \lambda_{K2} B_{11}) \hat{P}_N}{|\lambda|_{2N}^{MK}} \tag{A.12}$$

where,

$$|\lambda|_{2N}^{MK} = \lambda_{K2} \lambda_{MN} - \lambda_{KN} \lambda_{M2}$$

$$B_6 = -\frac{\theta_{T2}}{\theta_{K2}} (\varepsilon_{KF} \lambda_{KF} - \lambda_{K2} S_{KK}^2 - \lambda_{KN} S_{KK}^N \varepsilon_{\Gamma r} + \lambda_{K3} S_{KS}^3) - \lambda_{KN} S_{KM}^N B_T - \frac{\lambda_{K3} S_{KS}^3 \theta_{K3} \theta_{T2}}{\theta_{S3} \theta_{K2}} < 0$$

$$B_7 = \frac{\lambda_{KN} S_{KM}^N \theta_{FN}}{\theta_{MN}} - \lambda_{KN} S_{KK}^N > 0$$

$$B_8 = \frac{\lambda_{KN} S_{KM}^N \theta_{FN}}{\theta_{MN}} - \lambda_{KN} S_{KF}^N$$

$$B_9 = \frac{\lambda_{KN} S_{KM}^N}{\theta_{MN}} > 0$$

$$B_{11} = \frac{\lambda_{MN} S_{MM}^N}{\theta_{MN}} < 0$$

$$B_{12} = \frac{\lambda_{MN} S_{MM}^N \theta_{FN}}{\theta_{MN}} - \lambda_{MN} S_{MF}^N < 0$$

$$B_{13} = \frac{\theta_{T2}}{\theta_{K2}} (\lambda_{M2} S_{MK}^2 + \lambda_{MN} S_{MK}^N \varepsilon_{\Gamma r}) - \lambda_{MN} S_{MM}^N B_T + \frac{\theta_{T2}}{\theta_{K2}} S_{MK}^N \varepsilon_{\Gamma r} \lambda_{MN} - \lambda_{\Omega M} \bar{L}$$

$$\lambda_{\Omega M} \bar{L} = \frac{\Omega_M}{\bar{L}}$$

On taking total derivative of Eq. (40) the following value is obtained

$$\hat{P}_N = B_{14}\hat{\Psi} + B_{15}\hat{W}_F + B_{16}\hat{\vartheta} \tag{A.13}$$

where,

$$B_{14} = \frac{\frac{|\lambda|_{2N}^{MK}}{\theta_{K2}} \left(\frac{\varepsilon_{NS}\theta_{K3}\theta_{T2}}{\theta_{S3}} - \varepsilon_{NK}\theta_{T2} \right) - (\lambda_{K2}B_{13} - \lambda_{M2}B_{12}) + \varepsilon_{N\Psi}|\lambda|_{2N}^{MK}}{\lambda_{M2}B_9 - \lambda_{K2}B_{11} - \varepsilon_{NP_N}|\lambda|_{2N}^{MK}}$$

$$B_{15} = \frac{(\lambda_{M2}B_8 - \lambda_{K2}B_{10})}{\lambda_{M2}B_9 - \lambda_{K2}B_{11} - \varepsilon_{NP_N}|\lambda|_{2N}^{MK}}$$

$$B_{16} = \frac{(\lambda_{M2}B_7 - \lambda_{K2}B_{12})}{\lambda_{M2}B_9 - \lambda_{K2}B_{11} - \varepsilon_{NP_N}|\lambda|_{2N}^{MK}}$$

and ε_{Nj} is the elasticity of demand for commodity N with respect to $j = \{P_N, S, K, \Psi\}$ where S and K implies skilled labour income and capital income, respectively.

Main results

The primary effects of lockdown are obtained as follows.

- Adverse supply shock – High transaction cost

It follows from equation (A.1), (A.2), (A.3), (A.7) and (A.10) that $\frac{\hat{r}}{\hat{\Psi}} < 0$, $\frac{\hat{\eta}}{\hat{\Psi}} < 0$, $\frac{\hat{W}_S}{\hat{\Psi}} > 0$, $\frac{\hat{X}_1}{\hat{\Psi}} = 0$ and $\frac{\hat{X}_3}{\hat{\Psi}} = B_5 > 0$.

From (A.11) and (A.12) the following effects are obtained provided the sufficient condition that sector 2 is more capital-intensive than male labour compared to sector N , i.e., $|\lambda|_{2N}^{MK} > 0$.

$$\frac{\hat{X}_2}{\hat{\Psi}} = \frac{(\lambda_{MN}B_6 - \lambda_{KN}B_{13})}{|\lambda|_{2N}^{MK}} < 0$$

$$\frac{\hat{X}_N}{\hat{\Psi}} = \frac{(\lambda_{K2}B_{13} - \lambda_{M2}B_6)}{|\lambda|_{2N}^{MK}} > 0$$

where, $B_{13} = \frac{\theta_{T2}}{\theta_{K2}} (\lambda_{M2}S_{MK}^2 + \lambda_{MN}S_{MK}^N \varepsilon_{\Gamma r}) - \lambda_{MN}S_{MM}^N B_T + \frac{\theta_{T2}}{\theta_{K2}} S_{MK}^N \varepsilon_{\Gamma r} \lambda_{MN} > 0$.

From (A.13) the following result is obtained provided $\varepsilon_{NS}\theta_{K3} < \varepsilon_{NK}\theta_{S3}$ and $\lambda_{M2}B_9 - \lambda_{K2}B_{11} > \varepsilon_{NP_N}|\lambda|_{2N}^{MK}$

$$\frac{\hat{P}_N}{\hat{\Psi}} = B_{14} < 0$$

- Physical restriction on labour

From (A.8) the primary effect on unemployment is obtained as $\hat{\Omega}_M > 0$. It follows from equation (A.1), (A.2), (A.3), (A.7) and (A.10) that $\frac{\hat{r}}{\hat{\Psi}} = \frac{\hat{\eta}}{\hat{\Psi}} = \frac{\hat{W}_S}{\hat{\Psi}} = \frac{\hat{X}_1}{\hat{\Psi}} = \frac{\hat{X}_3}{\hat{\Psi}} = 0$.

From (A.11) and (A.12) and given the factor-intensity ranking, the following results are obtained such that $B_{13} = -\lambda_{\Omega M \bar{L}} < 0$

$$\hat{X}_2 = \frac{-\lambda_{KN}B_{13}\hat{\Psi}}{|\lambda|_{2N}^{MK}} > 0$$

$$\hat{X}_N = \frac{\lambda_{K2}B_{13}\hat{\Psi}}{|\lambda|_{2N}^{MK}} < 0$$

Finally, from (A.13) it is obtained that

$$\frac{\hat{P}_N}{\hat{\Psi}} = -\frac{\lambda_{K2}B_{13}}{(\lambda_{M2}B_9 - \lambda_{K2}B_{11}) - \varepsilon_{NP_N}|\lambda|_{2N}^{MK}} > 0$$

- Adverse demand shock

It follows from (A.13) that $\frac{\hat{P}_N}{\hat{\Psi}} = \frac{\varepsilon_{N\Psi}}{(\lambda_{M2}B_9 - \lambda_{K2}B_{11}) - \varepsilon_{NP_N}|\lambda|_{2N}^{MK}} < 0$.

The effect on output is obtained as follows:

$$\frac{\hat{X}_2}{\hat{\Psi}} = \frac{(\lambda_{KN}B_{11} - \lambda_{MN}B_9)\varepsilon_{N\Psi}}{|\lambda|_{2N}^{MK} \{ (\lambda_{M2}B_9 - \lambda_{K2}B_{11}) - \varepsilon_{NP_N}|\lambda|_{2N}^{MK} \}} > 0$$

$$\frac{\hat{X}_N}{\hat{\Psi}} = \frac{(\lambda_{M2}B_9 - \lambda_{K2}B_{11})\varepsilon_{N\Psi}}{|\lambda|_{2N}^{MK} \{ (\lambda_{M2}B_9 - \lambda_{K2}B_{11}) - \varepsilon_{NP_N}|\lambda|_{2N}^{MK} \}} < 0$$

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