Linkages and changing factor use in Indian economy: Implications of emerging trade pattern

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Abstract

Globally, a greater component of trade in intermediates – parts and components – is a characteristic of the changing paradigm of international trade. Consequently, alongside the increasing trade openness of the Indian economy, the access to international factors of production has increased through their embodied use during the production of intermediates that are imported. Thus, the emerging trade pattern has the potential to impact the use factors of production of domestic origin through leakages in the internal economy. This paper makes an assessment of the changing intensity of use of the two factors of production, viz. labor and capital, in the economy. The analysis aims to provide an estimate of the impact of import utilization on the use of labor and capital.

In the backdrop of generally declining employment intensity, the employment foregone effect from the use of imported intermediate inputs is observed to have worsened over the period of study. Ironically, this has contributed to lower domestic employment, even in the traditionally labor-intensive sectors. The employment effect of import utilizations is also reflected in the declining share of labor income. The use of capital embodied in imported intermediates has contributed to increasing the capital intensity of the economy despite the low domestic capital investment. This underscores a greater dependency on capital-intensive imports. While import reliance has increased for both employment and capital goods through their embodied use in the imported inputs, the dependency on imported capital has been stronger. A higher relative use of capital (K-to-L) indicates that the production method is relatively capital-intensive, thus requiring more capital goods and investment. The findings resolve the puzzle on India's increasing relative use of capital alongside a slowdown of domestic investments in productive capital. The deficit on domestic investment has been compensated through import utilizations of capital goods.

Keywords: factor intensity; linkages; import utilization; labor; capital; India

JEL codes: C67; D57; F66; J24; O24

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1. Backdrop

The transformation of the Indian economy from a primarily agrarian structure to a service led expansion has often been debated for its job creation effects. This leapfrogging in the economic structure has bypassed a domestic manufacturing revolution, which has the potential to absorb a vast labor force displaced from the agriculture sector. The lower significance of domestic manufacturing activity is also attributed to the emergence of global production networks that have resulted in a rapid division of labor-intensive activities in the backdrop of globalization. The consequent fragmentation of the production process across countries of the world has changed the paradigm of international trade with a greater share of the trade in intermediate inputs. The intermediate inputs – parts and materials – are imported to make products for consumption domestically as well as abroad. In fact, the trade in intermediates is recognized as a growing force in world trade. In India, the exports of intermediate goods account for 52% of non-fuel exports, while intermediate imports have a much higher corresponding share of 73% (WTO-IDE-JETRO 2013). The contribution of intermediates in the non-fuel imports is much stronger than the world average of 51%, underscoring their importance for economic activity.

A predominance of trade in intermediates also supports access to the factors of production – labor and capital – as the inputs for production, even though the factor of production itself may be non-transportable between the trading partners. In effect, this is expected to relax the domestic shortages on certain factors of production (e.g. capital in the Indian context) leveraging from the changing composition of trade which is increasingly dominated by intermediates. At the same time, a labor displacing effect of import utilization cannot be ruled-out due to the cost competitiveness of labor-intensive imports from low-wage countries. Thus, the emerging pattern of trade has the potential to impact the use of domestic production factors in the economy.

It is not incidental that the job creation concerns in the Indian economy have increased over time. The declining use of labor has received much attention in the recent policy debate, due to its impact on income inequalities despite overall economic growth. In fact, issues related to increasing unemployment and low employment generation have existed even prior to the outbreak of the recent pandemic, hinting towards an underlying structural

problem. This is reflected in the fact that despite being the fastest growing economy and abundant endowments of labor, India has not been able to make a headway in the labor-intensive manufacturing which has huge employment potential (Das and Kailta 2010). Measures such as easier FDI norms, trade openness, and the introduction of a market determined exchange rate regime are observed to have limited effects through employment opportunities in the past, particularly in the labor-intensive sectors. Also, the use of capital-intensive inputs has increased, which are sourced through imports. Thus, benefitting from the greater use of capital in the increasingly mechanized methods of production, the structural transformation is also expected to have impacted the factor-mix in the economy in favour of capital use. Further, the rising wage-rental ratio in the economy, which reflects upon the changing relative use of the factors of production, is a prime reason for declining employment intensity (Sen and Das 2015).

With increasing wage rates relative to the change in the price for capital, it just might be the case that factor proportions (i.e. the relative use of factors) have transformed, if not reallocated completely, contributing to changes in the production structure and the income shares of labor and capital. A secular decline in the income share of labor has been substantiated across developed and developing economies challenging the Kaldor thesis of constant shares of the factor incomes (Diwan, 2001). In India, a greater emphasis on investment is evident from the capital formation, in proportionate terms, that has remained above the world level since 1994.[3] However, despite a low domestic capacity utilization of 60-70%, the import dependency of capital goods is estimated high between 40-45% (GOI, 2016). Thus, taking into account the impact of the trade channel, through easier access to capital (goods) in the process of industrial upgradation, is important for an open economy as advocated by Ju et al. (2009). The increasing cross-border mobility of capital (goods) ensures access to international technology through the use of imported inputs (even though at an intermediate level). Trade in intermediates can potentially equalise technology between countries even though technology transfer does not occur.

The use of imported capital compensates for the domestic deficit on indigenous technology and innovation, reflecting upon the inadequate national R&D ecosystem. On the labor front, the utilization of imports often gets criticized for an employment displacing effect, although the improved availability of (imported) inputs may also support domestic

[3] India's GFCF (as % of GDP) has increased from 23.4% during 1994 to 28.8% during 2019 (World Bank 2021). It has continued to be higher than the comparable figure for the world during the period. The world GFCF (as % GDP) for the world has been lower at 23.8% during 2019.

production in the material using industry. The net effects of the domestic policy as well as the emerging pattern of trade on the changing price and technology, however, are realized through changes in the intensity of the use of a factor of production.

Even more, the high-tech imports contributing to automation of the production process embody higher level of skills during the production process. The access to technology and skills as embodied in the imported intermediate inputs advantages from better quality, with implications for the importing country, like India. While the labor substituting effect of capital is well noted (Pollin 2000), capital-skill complementarities have been suggested by Acemoglue (1998). Therefore, the job creation challenge is of greater concern for the low-skilled workers that constitute a significant proportion of labor as a key factor of production. Although labor-intensive activities have existed traditionally in the Indian economy, the proportionate use of capital (relative to labor) remains underestimated (Tandon 2020). This suggests for a more inclusive assessment by taking the intersectoral relationships into account. In fact, the proportionate use of capital has increased even in the not so capital-intensive sectors, such as textiles, due to the technology upgradation drive, one-time capital subsidy and reduced credit rates (Gulhane and Turukmane 2017).

In the backdrop of India's emerging pattern of trade, this paper makes an assessment of the changing intensity of use of the two key factors of production, viz. labor and capital, in the economy. The analysis aims to provide an estimate of the impact of import utilization on the use of labor and capital. Incidentally, the existing studies on India have a constricted view of the economy on at least three key aspects. First, most studies have a partial equilibrium approach that confines to select sector(s) and/or a specific factor of production. While employment related studies are more common in literature, capital as a factor of production has remained under-researched due to the measurement related difficulties. Although the declining share of labor, representing lower use of labor, has been registered across regions of the world, there is a void with regard to studies that simultaneously analyze both – labor and capital – income shares. Second, the existing studies also fall short in their accounting of factor usage due to the intermediate inputs required in preceding stage(s) of production. It is pertinent to note that sectors (or activities) do not only use factors of production for self, but also have an induced effect on other sectors due to their input and supply relationships. With growing trade in intermediate goods, as compared with the trade contribution of finished goods, the factor demand is affected in industries that use imported intermediates, in addition to the import-competing industries. Thus, a net effect on factor use that is manifested through the changes in factor intensity is difficult to

predict ex-ante due to the difference in production technology of the trading partners. More particularly, the sector-level differences in employment, nature of employment and trade exposure are likely to have a differentiated effect across sectors of the economy. Given the difference in employment sensitivity of the sectors, it becomes important to empirically test for the effect of trade on factors of production through a study of the changing use over time. Third, among the already scarce literature, studies on India overlook a differentiated factor use between the domestically produced and imported inputs. For instance, imports from advanced countries are likely to be more capital-intensive than if produced using domestically available technology, thus inducing a (likely) downward bias in the estimated capital-intensity of the economy. It would be interesting to note the effect of capital imports on capital use and also on the use of capital relative to labor. Since imports are mainly intermediates, which are also more capital-intensive than final goods, this amounts to weakening of linkages within domestic production. The present paper, addresses these shortcomings through improving the scope of measurement for the two factors of production, namely labor and capital.

Considering the coexistence of labor- and capital-intensive activities in the Indian economy, and their interactions with each other further strengthens the need for a comprehensive assessment of factor use in the Indian economy. In the backdrop of the expected change in the use of factors of production, and also their changing relative use, the present research findings will be of significance for the policy makers in understanding the differential impact of import utilization across sectors of the economy.[4]

Remaining part of the paper is structured into five sections. Section 2 presents the framework of analysis. The following section elaborates the methodological formulation. Section 4 covers the scope of analysis, data sources and reference period. Results are discussed in Section 5. The final section concludes with policy implications. The appendices are arranged at the end after the list of references.

2. Framework of analysis

In this paper, the assessment of factor use is based on intensity of the factor use, measured as amount of the factor of production required to produce one unit of output in a given sector.

[4] It may be noted that productivity studies tend to discuss the use of raw material, energy and services as additional factors of production. In the present context, these have been accounted through the measurement of direct and indirect use within an I-O framework. Another factor of production, namely innovation and entrepreneurship, is often dealt in qualitative analysis due to unavailability of data in an economy-wide framework.

An economy-wide analysis is best suited to study the factor use at a sector-level while simultaneously accounting for the demand and supply relationships with other sectors in the economy. An Input-Output (I-O) based methodology is used in the paper. The I-O model permits to quantify the intersectoral relationships, factor intensity (of labor and capital) in the production structure, and the output disposition inclusive of the trade flows for imports and exports. However, most existing applications of the widely used Leontief's (1956) conventional I-O model formulations for factor intensity measurement tend to be silent on the technological effect of imported intermediates on the factor use in the economy. The differences between the realized (through the consumption of traded intermediate inputs while also recognizing their differentiated factor intensity) and the conventionally measured (that tend to discount for the differential factor intensity of the domestically produced and imported inputs) estimates of factor intensity cannot be disregarded for an increasingly open economy, like India. Since the overall imports are sourced from multiple countries; the lack of explicit details on commodity-wise procurement from each import partner, makes it practically impossible to differentiate the intensity, separately for every factor of production, and in comparison to the import partner.

Recognizing difference in factor use between the domestic production and imported inputs, and the data constraints, Riedel (1975) proposed a formulation arguing that factor imports (embodied in importations) are essentially procured through payments from the export earnings of an equivalent amount. Therefore, under the condition of constant trade balance, imports can be expressed as a function of export. Since exports make use of the domestically available factor(s) of production, a corresponding equivalent of the values of import provides a measurement of the factor use in the importations. This is referred to as the export equivalence of imports. Thus, an imported commodity, that intensively uses a specific production factor, is purchased through foreign exchange earned by exporting an amount equivalent. Given the domestic origin of exports, an equivalent (value of) the factor use is thus computed from the technology matrix of the home country (in this case India). Additionally, the import requirements for export production as incorporated into the framework suggested by Riedel, are also adopted in the present paper.[5] Even more, the relatively factor-intensive imports sourced from a country 'A' of a commodity in

[5] While certain sectors such as construction and power utilities can be argued as non-tradable due to a predominantly domestic disposition of output, their input structure is nevertheless dependent on the use of imported inputs. For instance, construction machinery is largely imported and coal for electricity generation is sourced from abroad. Therefore, even the non-tradable sectors are implicitly impacted from the channels of trade.

comparison to a source country 'B' will have a higher export equivalent; adequately captured in the measurement thus also reflecting on differential use of factors across countries of origin.

In view of the key objective of the paper to assess the changes in sector-wise factor intensity owing to the emerging trade patterns (both exports and imports), it is important to distinguish between the domestically produced and imported intermediates. This separation of domestic and imported intermediates is necessary due to the rising trade in intermediate inputs, an outcome of global fragmentation of production also referred to as the global value chains (GVCs).[6] Since the focus here is economy-wide rather than on an individual sector (where the imported intermediate inputs can be tracked from the respective countries of origin), the present paper utilizes separate matrices of domestic and imported intermediates.

3. Methodological formulation

The measurement of factor intensity if only based on the direct factor requirement makes the assessment partial in nature due to exclusion of the interactive effects with other sectors of the economy. An approach to expand the scope of measurement is to include the indirect effects so that the factor requirements, both explicit and implicit, of the additional activity are quantified. While the direct factor requirements are measured proportionate to the capacity expansion of the sector, the indirect effects account for factor usage in the sectors that supply inputs to be used in the given sector. The I-O methodology is relevant to- and also competent in addressing the before stated measurement issues related to account for factor use in the – domestically produced inputs, imported inputs, and the countries of import origin.

The conventional formulation of the I-O model as suggested by Leontief (1956) has been suitably developed by Riedel (1975) to separate the domestic resource use from the use of imported inputs. A key component of the modification is related to the use of separate matrices of intermediate inputs that are produced domestically and imported. The technique to construct an import matrix varies across countries. The most common

[6] The impact of differentiated imports by the country of origin is recognized through the substitution possibilities (Armington 1969) and the Multi-Region Input-Output tables (MRIOs) that track country-specific imports. Overtime, many MRIOs have been compiled e.g. those available from the GTAP, ADB, European Commission and UNCTAD. Their application is more suited through contribution to a Computable General Equilibrium based study, where the sector-level effects for each country are captured through changes in commodity and factor prices. However, in the present context it suffices to obtain separate matrices for the domestically produced and imported inputs at the country-level.

approach is the use of import proportionality assumption where the industry use of imports of a particular product is proportionate to the total use of the industry. This is a prevalent approach and is also used by most OECD countries. However, some countries, e.g Japan, carry a limited survey of the use of intermediate inputs use to supplement the assumption (OECD). In countries such as the UK, additional details available for specific commodities are used to improve upon the assumption of linearity. Some researchers have improvized the proportionality assumption by reserving exports from domestic production, thus ruling out the re-exports of imports (Horridge, et al. 2008).[7] This paper uses the latter method to derive the matrix of intermediate use of imports. The matrix of domestically sourced intermediate inputs is obtained using the residual approach by differencing the imported intermediates from total intermediates. The detailed mathematical representation of the model is presented in the Appendix 1, where Eqs (1)-(7) explain Leontief's formulations, followed by Eqs. (8)-(22) elaborating the improvization suggested by Riedel for analyzing the factor use implications of the changing trade patterns. The approach to measurement of factor use is based on the factor intensity.

3.1 Assessing the effect of import utilization on factor use

The expressions F_j^k and $\tilde{F}_j^k$ (refer Eqs. (14) and (22), respectively) represent factor intensity under the – (i) hypothetical conditions of import substitution, and (ii) actual conditions that recognize a differentiated factor intensity of imported inputs. The effect of import utilization is assessed from the difference in factor intensity estimated from the two measurements. A comparison of F_j^k and $\tilde{F}_j^k$ reveals the net factor creating (using)/ saving effect from the utilization of imports per unit of output. Thus, a sector exhibiting $F_j^k < \tilde{F}_j^k$ (the expression $(F_j^k - \tilde{F}_j^k)$ will have a negative sign) would imply that the importation of intermediate inputs leads to saving effect on the use of the domestic factor than would be the case if all intermediates were domestically produced under import substitution. Similarly, $F_j^k > \tilde{F}_j^k$ implies a positive sign of the expression $(F_j^k - \tilde{F}_j^k)$, indicating a factor using (or creating) effect of importations due to net additional demand for the factor. It needs to be borne in mind that the results essentially reflect upon the interdependence of sectors in the economy.[8]

[7] However, the results may not be significantly different for countries with minimal proportion of re-exports.

[8] Therefore, summation of the shares of labor and capital income may not add up to 1 for a given sector, as would be expected in a Cobb-Douglas production function under constant returns to scale. In that sense it may not be necessary that a capital using effect is noted alongside a labor saving effect, as in the paper.

For an inference at the macro-level, it is technically inappropriate to add-up the effects of the individual sectors in the economy. However, an output-weighted aggregate of the sector-wise factor intensities is reflective of the overall impact of import utilization on the production factors.

The results are interpreted as the effect of imports on the use of factors of production. Changes over time indicate the impact of emerging pattern of trade through the embeddedness of factor use in the imported intermediate inputs. In view of the growing job distress during the period that marks a liberalized import regime and a more welcoming environment for investment goods, the possibility of an adverse impact of imports on both the production factors cannot be dismissed. Further, a comparison of the displacement effect from the use of imports can be telling through the relative import dependency for labor and capital as the two factors of production.

4. Scope of analysis and data sources

Labor and Capital are two key factors of production that I choose to study here. Factor intensity (factor coefficient) is the amount of a productive factor used in one unit of output. The use of labor in an activity refers to the persons employed, also termed as employment required for a unit of output produced in the sector. The employment intensity is commonly measured as the number of persons required per unit of output.[9] However, in view of differential wage rates (due to education, skills and experience), labor intensity is alternately assessed based on labor payment for a unit of output produced, and is essentially the share of labor income in output. Likewise, it is required to measure the capital intensity. The use of capital refers to the capital deployed in an economic activity. The measurement of capital is challenged with difficulties due to issues related to depreciation and obscelence.[10] Since capital use varies across the type of assets (e.g. transport equipment obsolete faster than building and structures, but slower than computers), it becomes difficult to work-out the replacement values of the existing capital stock with an acceptable degree of precision within an I-O framework. The problem is more severe if the range/ classification of capital assets undergoes a change over time, thus making inter-temporal comparisons less appropriate. However, the problem can be addressed by using capital income as a proxy to capital use. The use of capital is closely related to technology of

[9] Some studies also measure employment through the time duration in man-hours/days/years.
[10] For instance, the estimation of capital stock requires strong assumptions related to aging structure of fixed assets across industries and over different times (ILO 2009).

production, which is reflected in capital income.[11] The relationship between capital use and capital income is bi-directional. Greater capital use improves labor productivity thus improving the capital share of income. Conversely, greater capital income facilitates the entrepreneur to maintain a large capital stock. Since capital use is related to profitability of capital (i.e. returns to capital or profit), which in turn determines the income share of capital, the former can be proxied by the latter. The use of capital income (as a share of output) also provides a way to integrate capital use into the I-O framework in a manner compatible to labor income.

The relative use of factors is measured from the ratio of the capital intensity to the labor intensity (K-to-L).

4.1 Reference period of study

Factor intensity has been worked for two time periods – 2015-16 and 1993-94. The year 2015-16 is selected due to the availability of the latest India Input-Output Transaction Table (IOTT) from a published source.[12] The year 1993-94 is chosen for a comparison over a significant period of time. The India IOTT for 1993-94 is also representative of the economic structure at the time when the privatization, delicensing and liberalization reforms were formally initiated in 1991. Since structural transition is a gradual process, an inter-temporal comparison over a period of two decades is adequate to capture the effect of economic and structural reforms.

4.2 Data and sources

The present analysis has data intensive requirements that are obtained from multiple sources. The IOTT for 1993-94 is sourced from Central Statistics Organization (2000) and provides detailed value flows of economic transactions across 115 sectors. The IOTT for a latest period of 2015-16, is available with reported transactions for 131 sectors (Chadha et al. 2020).

The KLEMS (K-capital, L-labor, E-energy, M-material, S-services) database (Das et al. 2019) of the Reserve Bank of India (RBI) is used to source the values for (computations of) direct factor coefficients separately for each of the sectors required for the analysis (f_j^k) (refer sub-section A1.3 of Appendix 1 for details). The database provides productivity

[11] Generally, richer countries are technologically advanced and have higher stocks of capital.

[12] Even though trading partners and the basket of trade is expected to have changed over time due to the participation in global production chains, the combined effect of all the changes is adequately captured in the production technology (reflected in demand and supply relations of the I-O data) and the transformation of the economic structure (reflected through output and the factor use). Since structural transformation is gradual over time, the underlying structure of the economy is considered valid during the medium-run period of upto 5-7 years.

indicators for 27 economy-wide sectors which are in turn mapped to sectors of the I-O sectors. Each of the 27 sectors is retained in the analysis to prevent any loss of information by aggregating the economy into 27 sectors (Appendix 2 presents description of sectors). Additionally, sectors are broadly grouped into agriculture, mining, manufacturing and service categories (also shown in Appendix 2).

The labor income share in sector output as available from the KLEMS database is used as the direct labor coefficient. A similar approach is adopted to compute direct capital coefficient for all sectors.

An important requirement for an inter-temporal analysis is the use of indicators based on real values, as opposed to nominal values, in order to account for inflation. In this paper, instead of using an aggregate GDP or WPI deflator for all sectors of the economy, adequate care is taken to compute sector-level deflators using the KLEMS sector data. These KLEMS sector-wise deflators are used to convert the nominal values into real values at the base year 1993-94.

5. Results – Factor use in Indian economy

5.1 Employment requirements and the effect of import utilization

The overall intensity of measurement is found to have reduced by 28.1%, from 39.9 persons employed per million Rs. of output during 1993-94 to 11.2 persons employed per million Rs. of output during 2015-16 (Table 1). Among the broad activity groups, highest employment intensity is noted for agriculture, followed by services, manufacturing and mining in that order. However, the decline in employment intensity has been larger for the broad manufacturing that employs only 8 persons per million Rs of output in the recent period as compared to previously employing 31.1 persons per million Rs of output. In fact, the decline in aggregate employment intensity of the economy is essentially attributed to the falling employment intensity of the broad manufacturing that accounts for 37.8% of total output.

At the sector-level, highest employment intensity has been observed for agriculture & allied activities; hotels & restaurants; food products, beverages &tobacco; wood & wood products, and construction during 2015-16. On other end, employment intensity is found lowest for post & telecommunication; electrical & optical equipment; rubber & plastic products; machinery, nec., and financial services. The observed decline in employment intensity of the manufacturing sub-sectors is attributed to technological upgradation as the production gets increasingly mechanized over time; a finding in corroboration with the existing studies by Goldar (2009), Sen and Das (2015) and Sen (2014). The findings are

also consistent with the declining number of jobs per unit exports as observed by Veeramani (2016).

Specifically, the impact of importations on the employment intensity is measured from the percentage difference between the estimate of actual employment intensity and the hypothetical employment intensity under the assumed conditions of import substitution in the domestic economy. The negative sign (in columns (4) and (7)) is indicative of the employment foregone (saving) per unit output due to consumption of imported intermediates. During 1993-94, the utilization of imported inputs had an employment foregone effect of 7.1% for the aggregate economy. A greater employment intensity through realization of imports is on account of the employment use embodied in imported inputs. In fact, the employment foregone effect of the imports is observed to have increased to 9% during 2015-16 indicating that over time a greater proportion of employment is embodied in the imported inputs. This has a displacing effect on the use of domestic employment. The increasing use of imports has been validated in the study by Goldar (2009) attributing the adverse effect of imports on manufacturing employment to the changing factor prices. This is suggestive of the underlying eroding price competiveness of Indian manufacturing sector, which has consequently become increasingly dependent on imported intermediates to advantage from their better price and quality. Also, import competition can force the inefficient domestic firms to quit, thus increasing import utilization to meet supply shortages.

The observation on the employment displacing effect of imports needs to be viewed in the background of an overall declining intensity of employment due to the changing technology choices and production patterns in the post reform period; as also noted in the ILO (2009) strategy paper on India. At the same time, increasing contractualization of jobs (a consequence of outsourcing) in the informal economy and unorganized sector has raised concerns due to the associated low levels of labor productivity and the returns to labor. Therefore, it becomes pertinent to study the effect of import utilization on the share of labor income due to its comprehensiveness from the inclusion of income aspects. The relevant results are reported in sub-section 5.2.

Continuing with the discussion on sector-level effects, the impact of intermediate imports is observed to have varied despite a generally employment displacing behaviour. The impact of importations varies from being relatively insignificant for agriculture to being strongest for the coke & petroleum product sector. Other sectors with higher employment displacement (for a unit of output produced) from the use of imported inputs

include transport equipment; basic metal products, and machinery nec. Thus, the stronger employment foregone impact has been largely noted for the core manufacturing sectors that are recognized for the potential to absorb a large number of factory workers. Also noted is the relatively high value of the difference for the utility sector (power generation) among other sectors. This is attributed to its high indirect employment use essentially due to the resource-intensive nature of the activity and also due to use of imported coal (embodying the employment use during mining) to meet growing energy demands. On the other extreme, relatively muted employment displacement impact is observed for other sectors such as hotels & restaurants; food products, beverages & tobacco; education; trade, and other services. Most of these sectors belong to primary and service activities in the economy. Over the period, the employment foregone effect is observed to have worsened for as many as 10 sectors.[13] This has contributed through the leakages in domestic employment. Ironically, employment displacement is noted even for the traditionally labor-intensive sectors, including the industries where India is expected to exhibit a 'comparative advantage' position given the labor advantage from low wage rates.

[13] Henceforth, public administration & defense is excluded from the discussion due to the non-comparability in the compilation of the sector as reported in IOTTs for the two time periods.

Table 1: Total employment requirements and effect of import utilization

Group/ Sector	1993-94 Employment intensity^			2015-16 Employment intensity		
	Actual&	Import substitution scenario#	Effect of import utilization@ $	Actual	Import substitution scenario	Effect of import utilization
(1)	(2)	(3)	(4)	(5)	(6)	(7)
All	39.856	37.202	-7.13	11.209	10.282	-9.02
Agriculture	90.344	89.406	-1.05	42.117	41.672	-1.07
Mining	15.075	12.925	-16.63	7.209	5.555	-29.77
Manufacturing	31.068	26.641	-16.62	8.028	6.763	-18.71
Services	23.111	20.810	-11.05	9.105	8.363	-8.88
Agriculture, hunting, forestry & fishing	90.344	89.406	-1.049	42.117	41.672	-1.069
Mining & quarrying	15.075	12.925	-16.633	7.209	5.555	-29.771
Food products, beverages & tobacco	61.900	60.053	-3.076	24.468	23.833	-2.663
Textiles, textile products, leather & footwear	43.969	41.258	-6.570	9.471	8.795	-7.690
Wood & products of wood	75.717	74.184	-2.066	18.942	17.198	-10.141
Pulp, paper, paper products, printing & publishing	24.776	20.444	-21.194	9.445	8.281	-14.050
Coke, refined petroleum products & nuclear fuel	20.184	8.755	-130.534	4.882	2.708	-80.302
Chemicals & chemical products	21.997	17.034	-29.131	9.314	7.493	-24.303
Rubber & plastic products	22.018	17.734	-24.157	4.137	3.449	-19.949
Other non-metallic mineral products	33.739	27.988	-20.548	8.359	7.110	-17.564
Basic metals & fabricated metal products	19.135	13.489	-41.854	5.126	3.787	-35.365
Machinery, nec.	16.866	11.909	-41.628	4.240	3.233	-31.129
Electrical & optical equipment	17.117	12.655	-35.261	3.033	2.380	-27.440
Transport equipment	16.026	11.389	-40.713	4.744	3.035	-56.312
Manufacturing, nec; recycling	30.124	26.115	-15.348	12.471	10.882	-14.604
Electricity, gas & water supply	14.567	9.721	-49.847	5.219	4.184	-24.740
Construction	30.007	26.011	-15.365	14.621	13.422	-8.930
Trade	24.986	23.919	-4.460	12.644	11.854	-6.665
Hotels & restaurants	57.823	56.409	-2.506	25.376	24.971	-1.622
Transport & storage	21.027	17.323	-21.379	8.604	7.696	-11.793
Post & telecommunication	9.886	9.061	-9.104	1.522	1.175	-29.556
Financial services	6.696	6.226	-7.540	4.385	3.951	-10.964
Business service	17.597	14.558	-20.875	5.049	4.379	-15.308
Education	25.670	25.118	-2.196	11.349	10.730	-5.771
Health & social work	24.751	21.320	-16.094	8.273	7.416	-11.561
Other services	25.219	24.075	-4.754	8.805	8.184	-7.587

^ Total employment requirements per unit output measured in number of persons engaged per million Rs. output
& Estimates reflect actual conditions that also recognize differentiated employment intensity of imported inputs
# Hypothetical conditions of import substitution
@ difference expressed as %
$ Negative (positive) sign indicates an employment foregone (creating) effect of import utilization
Source: Author computations

5.2 Labor income share and the effect of import utilization

Table 2 presents the share of labor income for the broad groups and sectors. Despite the potential to employ a large proportion of unskilled labor, the broad manufacturing trails

after all other groups, with a lowest share of labor income at 0.286 during 2015-16. The inter-temporal comparisons show a decline in the share of labor income share for the aggregate economy, manufacturing and services. The observed decline in the proportion of labor income is natural in view of technological improvements and the declining employment-intensity noted in the preceding section. Particularly for the broad manufacturing group, the decline is also linked to the associated low value addition nature of activities. Within the broad services, although services such as business services are recognized for higher value addition due to the skilled nature of employment, their share in output is low in comparison to the construction activities that employ a large workforce primarily with low skill-levels and without a significant value addition. The labor income shares for agriculture and mining increased during the period. At the sector-level, a comparison over time shows a mixed pattern of change. Labor income shares have increased for most services while the opposite is noted for most manufacturing sectors.

For each of the broad groups, the utilization of imported inputs is found to adversely impact the income shares of labor in the production, thus reinforcing the earlier finding on declining intensity of employment. This also reflects upon lower returns to labor. It is not very encouraging to note that the effect of import utilization on labor income share has further turned adverse over the period of time, for all broad activity groups. At an aggregate level, the use of importations affected labor income shares by 7.9% during 1993-94. The impact further worsened to 12.1% with a decline in labor income share from 0.455 to 0.403 during the period. This shows that progressively lower labor income shares have been realized over the time, and that the utilization of imported inputs has a restricting effect of 12.1%, at an aggregate level. This in turn hints towards the increasing capital-intensity of inputs, domestic and imported; and the greater embeddedness of capital in imported inputs (discussed in the following sub-section 5.3) that has a net displacing effect on the labor.

Similarly, at the sector-level, the effect of importations shows a further decline in the shares of labor income observed for as many as 18 sectors. These sectors cover both manufacturing and services. While lower share of labor income is often interpreted to imply declining employment-intensity leading to fewer jobs, the possibility of increased employment opportunities for the skilled workers have been proposed due to the skill-complementarity with capital (Abraham and Sasikumar 2019).[14]

[14] While the analysis of employment-intensity in the preceding section does confirm the decline in job intensity, the analysis of a skill-based employment effect is beyond the present scope. Nevertheless, the composite effect for all skill-types can be seen in the impact on labor income share.

Table 2: Labor use and effect of import utilization

Group/ Sector	1993-94			2015-16		
	Labor intensity^			Labor intensity		
	Actual[&]	Import substitution scenario[#]	Effect of import utilization[@ $]	Actual	Import substitution scenario	Effect of import utilization
(1)	(2)	(3)	(4)	(5)	(6)	(7)
All	0.455	0.422	-7.87	0.403	0.359	-12.14
Agriculture	0.545	0.534	-2.20	0.589	0.568	-3.69
Mining	0.291	0.264	-10.20	0.378	0.300	-25.90
Manufacturing	0.386	0.331	-16.75	0.286	0.227	-26.26
Services	0.466	0.437	-6.59	0.459	0.424	-8.23
Agriculture, hunting, forestry & fishing	0.545	0.534	-2.200	0.589	0.568	-3.688
Mining & quarrying	0.291	0.264	-10.203	0.378	0.300	-25.898
Food products, beverages & tobacco	0.477	0.454	-5.092	0.447	0.417	-7.162
Textiles, textile products, leather & footwear	0.430	0.396	-8.569	0.300	0.268	-11.856
Wood & products of wood	0.359	0.340	-5.641	0.427	0.345	-23.773
Pulp, paper, paper products, printing & publishing	0.405	0.350	-15.475	0.277	0.222	-24.608
Coke, refined petroleum products & nuclear fuel	0.320	0.177	-80.889	0.243	0.141	-72.437
Chemicals & chemical products	0.367	0.305	-20.370	0.345	0.259	-33.014
Rubber & plastic products	0.314	0.261	-20.579	0.211	0.179	-18.085
Other non-metallic mineral products	0.355	0.283	-25.436	0.274	0.215	-27.331
Basic metals & fabricated metal products	0.348	0.277	-25.515	0.251	0.188	-33.492
Machinery, nec.	0.338	0.276	-22.459	0.267	0.220	-21.558
Electrical & optical equipment	0.386	0.330	-16.940	0.196	0.165	-18.602
Transport equipment	0.320	0.262	-22.148	0.276	0.196	-41.038
Manufacturing, nec; recycling	0.458	0.408	-12.296	0.318	0.243	-30.725
Electricity, gas & water supply	0.304	0.243	-24.917	0.341	0.293	-16.642
Construction	0.517	0.467	-10.713	0.542	0.485	-11.619
Trade	0.466	0.453	-2.949	0.510	0.473	-7.856
Hotels & restaurants	0.443	0.425	-4.161	0.489	0.470	-4.050
Transport & storage	0.431	0.385	-12.039	0.418	0.375	-11.378
Post & telecommunication	0.177	0.167	-6.195	0.227	0.210	-7.771
Financial services	0.342	0.336	-1.751	0.353	0.332	-6.135
Business service	0.452	0.414	-9.197	0.389	0.358	-8.810
Education	0.651	0.644	-1.072	0.679	0.650	-4.480
Health & social work	0.503	0.460	-9.333	0.543	0.503	-8.017
Other services	0.579	0.564	-2.538	0.496	0.467	-6.250

^ share of labor income per unit output
& Estimates reflect actual conditions that also recognize differentiated labor intensity of imported inputs
# Hypothetical conditions of import substitution
@ difference expressed as %
$ Negative (positive) sign indicates a labor saving (creating) effect of import utilization
Source: Author computations

5.3 Capital use and the effect of import utilization

During 1993-94, among the broad groups, the manufacturing was registered as the most capital-intensive activity. Over time, it has been displaced to the bottom by other

broad groups. The capital-intensity of manufacturing has been the lowest at 0.477 during 2015-16, indicating lowest returns to capital in a sector that has the potential to create economic activity on the ground, build assets, create jobs and expand national output.

Interestingly, capital intensity has increased for each of the other broad activity groups, except for in the manufacturing.[15] The distinguishably lower capital use in the manufacturing during 2015-16 deserves elaboration. First, the change is attributed to the effect of intersectoral linkages. The use of inputs from relatively less capital-intensive manufacturing sub-sectors into other sectors results in a lower capital intensity of the overall manufacturing. Second, a partial reasoning is attributed to the use of specific data. The share of capital in output, as computed for use in the analysis, is sourced from the KLEMS database of the RBI, which acknowledges the possibility of overestimation of compensation to employees in specific cases owing to the methodology adopted (Das et al. 2015). Accordingly, the (direct) share of capital income of the sector is likely to be underestimated, which can further have a cascading effect due to intersectoral interactions. Last but not the least, it is important to note that the decline in capital proportion, as noted here, is not directly comparable with the findings of existing studies which infer growing capital intensity of manufacturing output. There are definitional issues to be recognized for a fair comparison. For instance, the study by Kapoor (2014) measures capital intensity as the ratio of fixed capital to total persons engaged, thus referring to capital proportion relative to labor proportion.[16]

At the sector-level, a number of sectors are observed to have registered a higher proportionate use of capital during 2015-16 as compared with the year 1993-94. These sectors predominantly belong to the service group, while the manufacturing sectors that register higher capital proportions have been fewer in count viz. wood & wood products; chemical & chemical products, and transport equipment.

[15] Capital intensity here refers to the share of capital income (refer Section 4).
[16] A similar analysis on relative use of factors is undertaken in the following sub-section 5.4.

Table 3: Capital use and effect of import utilization

Group/ Sector	1993-94			2015-16		
	Capital intensity^			Capital intensity		
	Actual[&]	Import substitution scenario[#]	Effect of import utilization[@ $]	Actual	Import substitution scenario	Effect of import utilization
(1)	(2)	(3)	(4)	(5)	(6)	(7)
All	0.517	0.473	-9.24	0.500	0.434	-15.22
Agriculture	0.467	0.451	-3.42	0.540	0.509	-6.24
Mining	0.582	0.547	-6.47	0.783	0.665	-17.71
Manufacturing	0.604	0.531	-13.73	0.477	0.387	-23.27
Services	0.480	0.442	-8.57	0.504	0.451	-11.72
Agriculture, hunting, forestry & fishing	0.467	0.451	-3.421	0.540	0.509	-6.238
Mining & quarrying	0.582	0.547	-6.470	0.783	0.665	-17.708
Food products, beverages & tobacco	0.524	0.494	-6.155	0.502	0.457	-9.885
Textiles, textile products, leather & footwear	0.611	0.567	-7.873	0.381	0.333	-14.485
Wood & products of wood	0.620	0.595	-4.242	0.685	0.561	-22.152
Pulp, paper, paper products, printing & publishing	0.626	0.554	-12.862	0.418	0.335	-24.707
Coke, refined petroleum products & nuclear fuel	0.623	0.434	-43.290	0.586	0.431	-35.890
Chemicals & chemical products	0.626	0.545	-14.995	0.707	0.577	-22.457
Rubber & plastic products	0.650	0.579	-12.174	0.375	0.326	-15.035
Other non-metallic mineral products	0.643	0.549	-17.253	0.512	0.423	-21.012
Basic metals & fabricated metal products	0.655	0.562	-16.520	0.398	0.303	-31.490
Machinery, nec.	0.657	0.575	-14.185	0.412	0.340	-21.048
Electrical & optical equipment	0.546	0.472	-15.544	0.299	0.252	-18.428
Transport equipment	0.532	0.455	-16.757	0.543	0.421	-28.871
Manufacturing, nec; recycling	0.574	0.508	-12.994	0.471	0.358	-31.599
Electricity, gas & water supply	0.615	0.535	-14.898	0.566	0.492	-14.980
Construction	0.411	0.345	-19.058	0.452	0.367	-23.274
Trade	0.527	0.509	-3.448	0.613	0.556	-10.113
Hotels & restaurants	0.406	0.382	-6.083	0.442	0.414	-6.972
Transport & storage	0.500	0.439	-13.872	0.510	0.445	-14.509
Post & telecommunication	0.366	0.353	-3.850	0.401	0.376	-6.580
Financial services	0.605	0.597	-1.295	0.673	0.642	-4.806
Business service	0.648	0.598	-8.361	0.559	0.511	-9.337
Education	0.321	0.312	-2.907	0.431	0.387	-11.385
Health & social work	0.473	0.417	-13.550	0.399	0.338	-18.055
Other services	0.476	0.457	-4.118	0.588	0.544	-8.125

^ share of capital income per unit output
& Estimates reflect actual conditions that also recognize differentiated capital intensity of imported inputs
# Hypothetical conditions of import substitution
@ difference expressed as %
$ Negative (positive) sign indicates a capital saving (creating) effect of import utilization
Source: Author computations

The effect of importations on capital use has interesting revelations. The utilization of capital imports leads to capital cost saving for the economy. In fact, the capital cost savings are observed to have further increased over time. At an aggregate level, the use of imported

inputs has been helpful in saving an equivalent of 15.2% of the capital requirement during 2015-16. In other words, imported intermediates of capital goods served to meet the corresponding requirements. Despite the lowest capital-intensity, the effect has been strongest for the manufacturing as a group where the capital saving effect of requirements has increased by almost 10 percentage points from 13.7% during 1993-94 to 23.3% during 2015-16 due to importations of capital embodied in intermediate inputs. This has an important implication through reduced demand for domestic capital investment. The liberalization of foreign investment regime, easier capital imports, and lower tariff barriers on capital goods have made capital inflows easier and cheaper through the imports of machinery, equipment and investment. This enabled domestic upgradations and modernization with growing imports, thus increasing import dependence for capital inputs. However, the import dependency has continued over the period time. The imports of capital goods contribute to 8% of the import bill, next only to imports of crude oil, electronics and gold (EXIM Bank 2014; AIAI 2020; McKinsey 2016). The imports of capital goods include heavy electrical equipment; process plant equipment; earth moving and mining equipment; textile machinery; agricultural machinery; mining & construction machinery, engines & turbines, among others. Alongside the improving access to capital goods, the indigenous development through investment in domestic R&D was neglected in the absence of specific policy incentives. The resulting low levels of R&D, both private and public, further made domestic industry heavily reliant on imported capital-intensive inputs to maintain export competiveness in a more open economic setting with a stronger export orientation.

In fact, the trailing performance of the capital goods sector is evident from international comparisons. For instance, contribution of capital goods to GDP is insignificantly low at 0.6% in India when compared with 3.4% and 4.1% in Germany and China, respectively. The R&D investment of Indian capital goods manufacturers is also low at 0.5% of their turnover. This in sharp contrast to 6% of the revenue being ploughed back into R&D by German manufacturers of capital goods. The role of public policy (e.g. mandating domestic procurements) has also been instrumental in development and strengthening of a strong capital base in countries such as China. Such conscious attempts have been absent in India. The slowdown in domestic investment has also been partially attributed to the uncertainties arising from retrospective taxation, indecisions surrounding business; and the exacerbated bottlenecks such as the financial, labor market and

environmental regulations, and the difficultly in land acquisitions (Patnaik and Pundit, 2014).[17]

Sector-wise impact utilization of the imports of capital goods as intermediate inputs, shows a stronger effect over the period, with coke & petroleum products as an exception. Nevertheless, the coke & petroleum product sector continues to top the chart with highest capital-intensity during 2015-16. This shows that the import dependency has generally increased for the capital goods. The reasons can be linked to changes in productivity, labor substitution policies in businesses, requirements to use advanced technological imports to maintain competitiveness, and inadequacy of domestic R&D, among others. In conclusion, the pattern of trade confirms a capital use that increasingly depends on utilization of imports of capital-goods or the capital embodied in imports.

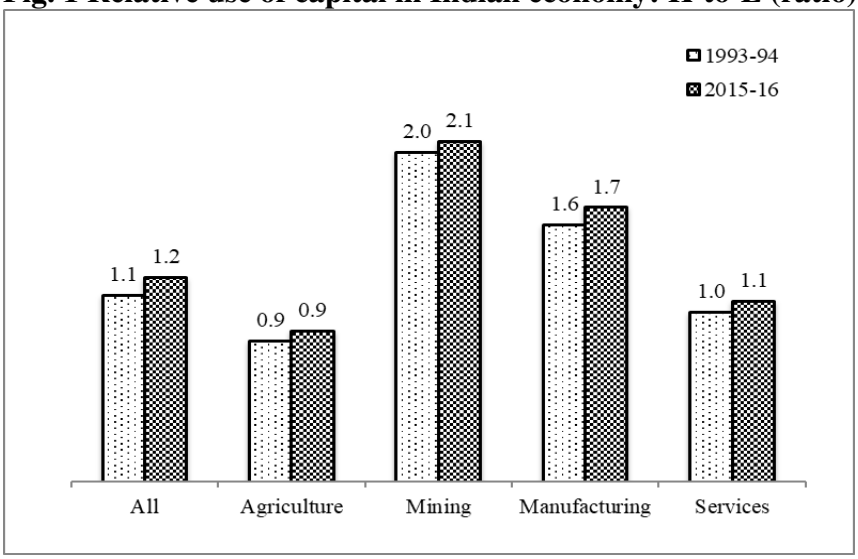
5.4 Capital-to-Labor ratio

The separate measurement of the sector-wise labor-intensity and capital-intensity can be combined into a ratio referred as the capital-to-labor ratio (K-to-L). A higher value of the K-to-L indicates that the production method is relatively capital-intensive requiring more capital goods and investment. The use of capital relative to labor (K-to-L) has invariably increased across the broad activity groups and the overall economy (Fig. 1)[18] These results conform to the findings in an earlier study by Kanan and Raveendran (2009).[19] At the aggregate level, the relative use of capital is observed to have increased by 9.4% during the period or an equivalent 0.45% annual growth in K-to-L, which is inclusive of the resource saving effect from the utilization of imported intermediate inputs. Thus, import substitution of capital goods requires domestic output of capital goods to expand at a higher annual rate. However, the annual growth in gross output of the capital goods sector is observed to have expanded at the matching annual growth of 0.4% (McKinsey 2016) indicating a continued dependence on imports for increasing capital use.[20] Viewed alongside the capital saving effect from import utilization, an increasing dependency on imported capital (as embodied in imported inputs) is recognized. While on one hand this hints on lower domestic capital investments, particularly in manufacturing; this also

[17] Although the retrospective tax law has been recently scrapped in 2021, its effect would be seen in the future.
[18] K-to-L ratio for 1993-94 is computed from the factor use reported in column (2) of Tables 2 and 3 for the broad activity groups. Similarly, K-to-L ratio for 2015-16 is based on values reported in column (5) of the tables. A separate table is avoided for reasons of repetitiveness.
[19] Kanan and Raveendran (2009) focus on organized manufacturing sector.
[20] Gross output of capital goods increased by 2% between 2010 and 2015.

reflects on the low indigenous R&D activity thus encouraging the continued use of imported inputs due their qualitative and advanced features.

Fig. 1 Relative use of capital in Indian economy: K-to-L (ratio)



Source: Author computations

To sum up the entire discussion, the relative use of capital has intensified for the aggregate economy and the broad groups. A resource saving effect of import utilization is observed in general. The capital saving effect of imports has strengthened over time.

6. Conclusion and policy implications

The intensity of factor use is an important consideration for industrial policy design. Factor intensity of an economy reflects upon the underlying factor endowments. In order to be growth supporting, the structural transformation in an economy should reflect the endowment fundamentals. However, with the changing paradigm of international trade characterized by a greater component of trade in the intermediates – parts and components, the access to international production factors (labor and capital) has increased for the domestic economy. The emerging pattern of trade has the potential to impact the use of domestic production factors through leakages in the internal economy. Hence, a country, e.g. India, can experience an increase in the intensity of use for a given factor despite domestic shortages, defying the comparative advantage in labor-intensive production. Consequently, the growth in real per capita is expected to slow down contributing to lower labor income, in turn leading to wider income inequalities as argued by Lin (2003). Thus, it is important to consider the impact of imports on the use of domestic factors of production.

The present paper makes an assessment of the changing use of the two production factors – labor and capital, in the Indian economy and the impact of import utilization on their respective use. The paper broadly notes that the use of imported inputs has a displacing effect on domestic employment. The capital embodied in imported intermediates has contributed to increasing the capital intensity of the economy despite the low domestic capital investment, underscoring a greater dependency on capital-intensive imports. While import reliance has increased for both employment and capital through their embodied use in the imported inputs, the dependency on imported capital has been stronger. Since the industrial structure is expected to align with factor-intensive sectors, an increasing use of capital relative to labor, explains the capital-intensive production structure despite India's abundant endowments of labor. Considering the coexistence of labor- and capital-intensive activities in the Indian economy, their interactions with each other, and a general increase in the relative use of capital even in the not so capital-intensive sectors, further strengthens the relevance of a comprehensive assessment of the factor use as in the present work.

The findings also show a general decline in employment intensity across the broad activity groups and sectors of the economy. The decline in aggregate employment intensity is attributed to the falling employment intensity of the broad manufacturing that has registered the strongest reduction in employment intensity during the period. Utilization of imported intermediates is observed to have an employment forgone effect that has further increased over time. This is suggestive of the eroding wage rate competiveness of the Indian manufacturing sector that has become increasingly dependent on imported intermediates to advantage from their better price and quality. Ironically, employment displacement is noted even for the traditionally labor-intensive sectors. The utilization of imported inputs is found to adversely impact the income shares of labor in the production, reinforcing the declining intensity of employment. The relatively stronger contraction in the labor income share of the manufacturing sector, is further indicative that a larger proportion of the labor income share is embedded in imported goods.

A distinguishably lower capital intensity of the manufacturing sector highlights the need to incentivise productive investment by addressing the concerns of the industry. The utilization of imported capital intermediates leads to savings on the use of capital of domestic origin within the economy. The capital saving impact of imports is notably stronger for the broad manufacturing sector than for other activities. The findings resolve the puzzle on India's increasing relative use of capital alongside a slowdown of domestic

investments in productive capital. The deficit on domestic investment has been compensated through import utilizations of capital goods.

Apart from lower domestic investment, greater use of imported capital goods has implications through the widening gap in demand and supply of skills. The use of capital imports, that generally embody innovation and technology of a higher order, forbids anticipating the spectrum of skills required for operationalization of the machinery. This results in a mismatch of the available skill-set vis-à-vis the technology in use. The pattern, if continued, is likely to have implications through lesser jobs and lower labor incomes in the future. In the absence of indigenous R&D activity, the continued dependency on imported capital intermediates, has a constraining effect on the workers' access to the technological know-how for future R&D activity, effectively limiting the increase in labor income through high-value added jobs.

The use of capital relative to that of labor is observed to have intensified in the aggregate economy corroborating the findings of earlier studies. A higher K-to-L ratio raises concern on the domestic capacity to absorb labor in the economy, particularly in the unskilled and semi-skilled category of workers. The adverse effect of imports, however, should not be interpreted as advocating protectionism. While supporting the opinion that globalization tends to support the access to factors of production that are more mobile, e.g. capital, the analysis also suggests that the domestically abundant endowments of labor need to be more compliant with technological advances incorporated in imported capital.

Extending the findings on lower labor intensity, higher capital intensity and a greater relative use of capital; the present study further contributes through quantifying the effect of import utilization on the use of factors of production in the economy. At the same time, the use of composite intermediate import flows, as in the present paper, has a limitation to distinguish imports by the country of origin, which can be the pursued as a follow-up to the present research. The results also open-up a couple of issues for future research. The greater labor embodied in intermediate imports needs to be studied for the effects on different skill-based categories of labor in order to inform on the likely differential returns to skilled vis-a-vis unskilled labor. Also, the relative dependence on the embodied imports of capital inspires to study if the results are sensitive to alternate measures of capital.

In view of the fast changing technological norms, such as the advancement in the fields of AI and the internet of things, a reversal of the higher (relative) capital use appears infeasible. This creates a Catch-22 situation necessitating to concentrate on the labor implications of capital use. Thus, it becomes prudent to devise future policy with a two-

pronged strategy so as to simultaneously correct for import dependency on capital goods and the demand-supply mis-match in the labor market. Engaging the domestic industry for indigenous R&D will also serve as an important signal on the nature of skill-set required. Also, the domestic R&D activity will be most helpful in providing inputs for design of a modern curriculum through vocational trainings and technical trainings, thus generating job opportunities. Establishing the connect between domestic innovative practices and the response of the labor market will be beneficial for both capital and labor and should be of utmost priority in policy.

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Appendix 1 Model formulation

A1.1 Basics of the Input-Output Model

The I-O model represents intersectoral linkages through demand and supply relationships among sectors of the economy. The interactions are essentially transaction flows from a sector *i* to another sector *j* indicating value of commodity transaction from the i^{th} input providing sector to the j^{th} output producing sector. The mathematical representation of the model is conventionally through the use of matrices. The cost structure of a producing sector is presented in a column providing commodity flows of all inputs (material and service) used. The column also includes expenditure on account of the use of factor of production (i.e. value addition as a composite of labor and capital) and net taxes paid by the sector. The output supply of a sector under consideration can be consumed as intermediate input for sectors of the economy, or as a final good. The supply distribution is presented through the flows within a row corresponding to the sector.

Consider the economy with *n* (a positive integer) sectors inclusive of the production and service activities. Thus, in an economy the output of each sector (column vector X) is either consumed as an intermediate input (matrix Z of transaction flows) in the production process of another sector, or is consumed as a final good (column vector Y). Elements of the matrix Z (of size *n*X*n*) are X_{ij} representing the intersectoral intermediate flows from sector *i* to the sector *j* as follows:

$$Z = [X_{ij}] = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{nn} \end{bmatrix}, \text{where } i, j = 1,2, \dots, n \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Eq (1)}$$

$$\text{Similarly, } X = [X_i] = \begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} \text{ and } Y = [Y_i] = \begin{bmatrix} Y_1 \\ \vdots \\ Y_n \end{bmatrix}, \text{where } i = 1,2, \dots, n \dots\dots\dots\dots \text{Eq (2)}$$

The disposition of total output is compactly written in a matrix notation as:

$$\underbrace{Z}_{\text{intermediate consumption}} * \underbrace{i}_{\text{identity column vector}} + \underbrace{Y}_{\text{final use}} = \underbrace{X}_{\text{total output}} \dots\dots\dots\dots \text{Eq (3)}$$

The intersectoral relations in the economy are represented through the technical coefficient matrix, A (*n* X *n*) whose ij^{th} element shows the amount of input from the i^{th} sector required to produce one unit output of the j^{th} sector. The matrix A is also called as the *direct coefficient matrix* or *technology matrix* as it shows the dependence of inter-industry flows on total output of each sector of the economy and is defined as:

$$A = [a_{ij}], \text{where } a_{ij} = \frac{X_{ij}}{X_j}, \text{where } i, j = 1,2, \dots, n \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{Eq (4)}$$

Thus, $A = Z * \widehat{X}^{-1} \Rightarrow Z = A * \widehat{X}$ ……Eq (5)

where $\widehat{X}$ is a diagonal matrix of the sector outputs.[21]

Using Eq (5) in Eq (3), the output is expressed in terms of technology matrix as:

$X = (I - A)^{-1} * Y$ ……Eq (6)

Let, $L = (I - A)^{-1} = [r_{ij}]$, where $i, j = 1,2, \dots, n$ ……Eq (7)

The matrix L is called the Leontief inverse and shows the dependence of gross output (X) on final demand (Y). It is also referred to as the *total requirement matrix* and is inclusive of the indirect effects which occur due to multiple and nested rounds of inter-relationship among sectors.

A1.2 Separating imported and domestically produced intermediate requirements

The separation of imported and the domestically produced intermediate inputs, as needed for implementation of the methodology adopted in the present paper, requires separating the transaction flows (X_{ij}) into two additive components. Individual transactions in the intermediate matrix are expressed as the sum of corresponding domestic and import flows. Thus, we write the following:

$X_{ij} = D_{ij} + M_{ij}$ ……Eq (8)

Accordingly, the corresponding output coefficients of domestic and imports requirements can be written as:

$D = [d_{ij}]$, where $d_{ij} = \frac{D_{ij}}{X_j}$, where $i, j = 1,2, \dots, n$ ……Eq (9)

and $M = [m_{ij}]$, where $m_{ij} = \frac{M_{ij}}{X_j}$, where $i, j = 1,2, \dots, n$ ……Eq (10)

Thus referring to Eq (8), $a_{ij} = d_{ij} + m_{ij}$ ……Eq (11)

Define, the total domestic requirement matrix of inputs as

$S = (I - D)^{-1} = [s_{ij}]$, where $i, j = 1,2, \dots, n$ ……Eq (12)

An element s_{ij} provides the total input requirements of all domestically produced inputs (material and services) from sector *i* for a unit output in the j^{th} sector.

A1.3 Estimating factor proportions

Factor requirements of domestically produced inputs

In an I-O framework, the direct factor coefficients are required to initiate the estimation of total factor use in a given sector. The direct factor coefficients, f_j^k, measure the amount of the k^{th} production factor directly used for a unit output of the j^{th} sector. For instance, a direct

[21] Diagonlaization of vectors is required for conformity in matrix operations.

labor (capital) coefficient of a sector measures the amount of labor (capital) used directly in the sector activity. Since this information is not explicitly available for different factors of production from within the IOTT, the direct coefficient values are sourced from the KLEMS database of the RBI, 2020.[22] These coefficients are then integrated into the I-O model through their interaction with the total requirement matrix, S.[23] Details are discussed as follows.

For a k^{th} factor of production, consider the diagonal matrix of direct coefficients, $\widehat{f^k}$ as shown in Eq (15) where k = employment, labor, capital.[24]

$$\widehat{f^k} = \begin{bmatrix} f_1^k & 0 & \cdots & 0 \\ 0 & f_2^k & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & f_n^k \end{bmatrix} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \text{Eq (13)}$$

Let F_j^k denote the total use of k^{th} factor required for production of one unit output of the j^{th} sector. Following the methodology suggested by Riedel (1975), the value of F_j^k is obtained by interacting (multiplying) $\widehat{f^k}$ with the total domestic requirement matrix S and adding across rows within a column. Thus, for all k and j = 1,2,…,n, we write the following equation:

$$[F_j^k] = [F_1^k \quad F_2^k \quad \dots \quad F_n^k] = \widehat{f^k} * \mathrm{S}$$

$$= \underbrace{\begin{bmatrix} f_1^k & 0 & \cdots & 0 \\ 0 & f_2^k & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & f_n^k \end{bmatrix}}_{direct\ use\ of\ kth\ factor\ per\ unit\ output\ of\ sector\ j}$$

$$* \underbrace{\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{21} \\ \vdots & \vdots & \ddots & \vdots \\ s_{n1} & s_{n2} & \cdots & s_{nn} \end{bmatrix}}_{total\ domestic\ input\ from\ sector\ i\ required\ for\ a\ unit\ output\ of\ sector\ j}$$

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[22] Details of the KLEMS data are discussed in Section 4.

[23] The total requirement matrix, S, differs from the total requirement matrix, L. While the former provides total requirements of domestically produced inputs, the latter provides total inputs requirements inclusive of imported inputs. Therefore, the interaction of factor coefficients with the elements of S provides total domestic factor requirements.

[24] Employment refers to number of person employed, while labor and capital as factors of production are measured through the income shares.

$$= \underbrace{\begin{bmatrix} f_1^k s_{11} f_1^k s_{12} & \cdots & f_1^k s_{1n} \\ f_2^k s_{21} f_2^k s_{22} & \ddots^{\cdots} & f_2^k s_{21} \\ \vdots \quad \vdots & & \vdots \\ f_n^k s_{n1} f_n^k s_{n2} & \cdots & f_n^k s_{nn} \end{bmatrix}}_{use\ of\ kth\ factor\ \ in\ domestic\ production\ of\ input\ i\ used\ in\ one\ unit\ of\ sector\ j} \quad \dots\dots\dots\dots\dots. \text{Eq } (14)$$

$$= \left[\sum_{i=1}^{n} f_i^k s_{i1} \quad \sum_{i=1}^{n} f_i^k s_{i2} \quad \dots \quad \sum_{i=1}^{n} f_i^k s_{in} \right] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. \text{Eq } (15)$$

Summation of the elements within a column of the matrix on RHS of Eq (15) provides F_j^k, as the total (direct and indirect) requirement of the k^{th} factor through its use in production of all inputs used in one unit output of the sector represented in the column *j*. The Eq (15) is further used to estimate total factor requirement to meet the final demand or any sub-component of final demand e.g. exports (E).[25] Factor requirement for of the k^{th} factor to meet the export demand, F_E^k as given as:

$$F_E^k = [F_j^k] * \hat{E} = \left[\sum_{i=1}^{n} f_i^k s_{i1} \quad \sum_{i=1}^{n} f_i^k s_{i2} \quad \dots \quad \sum_{i=1}^{n} f_i^k s_{in} \right] * \begin{bmatrix} E_1 & 0 & \cdots & 0 \\ 0 & E_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & E_n \end{bmatrix}. \text{Eq } (16)$$

Thus, we have,

$$F_E^k = \left[\left(\sum_{i=1}^{n} f_i^k s_{i1} \right) * E_1 \quad \left(\sum_{i=1}^{n} f_i^k s_{i2} \right) * E_2 \quad \dots \quad \left(\sum_{i=1}^{n} f_i^k s_{in} \right) * E_n \right] \dots. \text{Eq } (17)$$

The j^{th} element of the row vector in the RHS of Eq (17) represents the total factor use to meet export demand in the j^{th} sector. Summing over the columns gives requirement of the k^{th} factor to meet the overall exports in the economy, F_E^k as:

$$F_E^k = \sum_{j=1}^{n} \left(\left(\sum_{i=1}^{n} f_i^k s_{i1} \right) * E_j \right) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \text{Eq } (18)$$

Factor requirements of imported inputs

On the other hand, factor use in imports is not explicitly known due to the unavailability of a foreign production technology matrix, separately for each import partner. Thus, we proxy the factor use in imports through measurement of factors in an equivalent export production (used to earn foreign exchange for purchasing imports). Thus, even though the total requirement coefficients used pertain to domestic technology, their use in the production of the export equivalent of imports provides the required estimate of imported

[25]The column vector $E = [E_j]$ represents the export value for sectors where j = 1,2, .., ,n

factor use. The proxy computation requires to express imports as a function of – (i) export, and (ii) the production technology used in process of export production of an amount equivalent to imports.

In order to account for factor use in imported inputs, define $M_i = \sum_{j=1}^{n} m_{ji}$ as the direct requirement of all imported inputs (denoted by subscript *j*) in one unit production of output in the i^{th} sector. Multiplying M_i with s_{ij} provides the (direct and indirect) import requirement in the i^{th} input used in one unit output of the j^{th} sector. Summing over all inputs (index *i*) provides the requirement of all imported inputs for a unit output of j^{th} sector, M_j. This is given by the following expression:

$$M_j = \sum_{i=1}^{n} (M_i s_{ij}) = \sum_{i=1}^{n} \left(\sum_{j=1}^{n} m_{ji}\, s_{ij} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq (19)}$$

Total import requirement for a unit export from the economy is based on the structure of the export basket and is represented by e_j as the export share of j^{th} sector. Accordingly, imports requirement for producing export, e_j, of the j^{th} sector are given by $M_j * e_j$. Further, summation over sector-wise requirements provides total import requirement for the production of exports as shown in the Eq (20).

$$M_E = \sum_{j=1}^{n} (M_j * e_j \;) = \underbrace{\sum_{j=1}^{n} \left(\underbrace{\sum_{i=1}^{n} \left(\underbrace{\sum_{j=1}^{n} \underbrace{m_{ji}}_{A} * s_{ij}}_{B} \right)}_{C} * e_j \right)}_{D} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq (20)}$$

where the expressions have the following representation:

A: direct import use of j^{th} input in a unit output of i^{th} sector

B: direct and indirect import requirement of all inputs per unit output of j^{th} sector

C: import requirement for export of j^{th} sector

D: sum of import requirements for all exports

The Eq (20) provides an export equivalence of imports. It shows the amount of imports purchased with the foreign exchange earned from the exports. In other words, M_E is the amount of exports (exchanged) for imports. It may be clarified here that although value of imports are directly available, their factor use cannot be assessed directly due to difference in production technology in the country of origin. Therefore, an export proxy of the import value is used to estimate the factor equivalence in the domestic production.

Estimating import use in production of exports

The use of factor imports `ed in the production of additional exports to exchange for the imported inputs is given by $F_E^k * M_E$ in the first round of import use. However, the production of exports (to finance the imports) in turn requires the use of imported inputs. This imposes a requirement of $M_E * M_E$ units of import, entailing an export equivalent of $(F_E^k * M_E) * M_E$ to finance the additional imports. This nesting of import use gives rise to a second round of requirements and continues further. Similarly, the effect of following rounds is measured by multiplying successive terms with M_E. Thus, the multiple round effect of import use is:

$$F_E^k + (F_E^k * M_E) + (F_E^k * M_E * M_E) + \cdots .. = \frac{F_E^k}{1 - M_E} \ldots \ldots \ldots \text{Eq (21)}$$

since $0 \leq M_E \leq 1$

It may be noted that the ratio on the RHS of Eq (21) is a constant, independent of any sector. However, the ratio is different for a given factor. The ratio is the value of k^{th} factor required to produce one unit of export in exchange for import. On multiplying the ratio with the import requirement in the j^{th} sector (M_j), we get the factor use equivalent of import.

Factor requirements due to domestic and imported all inputs

The estimate of actual factor use of the k^{th} factor in the j^{th} sector, $\tilde{F}_j^k$, is the sum of – (i) factor use in the production of all domestically produced intermediate inputs (F_j^k) (using Eq (18)), and (ii) factor use in the imports of j^{th} sector (M_j), which is estimated by multiplying M_j with multiple round effects of factor use in production of exports to (earn foreign) exchange to pay for imported inputs (in Eq (21)).

$$\tilde{F}_j^k = F_j^k + M_j \left(\frac{F_E^k}{1 - M_E} \right) \ldots \ldots \ldots \text{Eq (22)}$$

The Eq (22) is used separately for the each of the production factors.

Appendix 2 Description of sectors and broad groups

S.No.	Description
1	Agriculture, hunting, forestry and fishing
2	Mining and quarrying
3	Food products, beverages and tobacco
4	Textiles, textile products, leather and footwear
5	Wood and products of wood
6	Pulp, paper, paper products, printing and publishing
7	Coke, refined petroleum products and nuclear fuel
8	Chemicals and chemical products
9	Rubber and plastic products
10	Other non-metallic mineral products
11	Basic metals and fabricated metal products
12	Machinery, nec.
13	Electrical and optical equipment
14	Transport equipment
15	Manufacturing, nec; recycling
16	Electricity, gas and water supply
17	Construction
18	Trade
19	Hotels and restaurants
20	Transport and storage
21	Post and telecommunication
22	Financial services
23	Business service
24	Public administration and defense; compulsory social security
25	Education
26	Health and social work
27	Other services
	Groups
1-27	All
1	Agriculture
2	Mining
3-15	Manufacturing
16-27	Services

nec: not elsewhere classified
Source: Das et al. 2015.