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NOTES FOR REVIEW GROUPS

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Structure for a technical review report

Main title	*What is the impact of higher rates of innovation (measured by faster TFP growth, product innovation, process innovation, and imports of technology) on employment in LICs? How does this vary by gender?*
Sub title	*Innovation and employment in low-income countries: A systematic review*
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Section	TECHNICAL REPORT
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EPPI-Centre reference number	[To be completed by EPPI-Centre]
Month/year of publication	[To be completed by EPPI-Centre]
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Conflicts of interest (if any)	None.
Acknowledgements	We would like to thank DFID for funding this systematic review and for encouraging systematic reviews of international development issues in general. This review has benefitted from helpful comments by DFID reviewers Nirosha Gaminiratne, Stevan Lee, Tom Wagstaff and Leo Thomas; MAER-Net reviewer Tom Stanley; and EPPI-Centre reviewer Sandy Oliver. We thank all our reviewers for their comments and suggestions.

Contents

Tables and Figures in Main Report

Tables in Appendix

List of abbreviations

CRD	-	Centre for Reviews and Dissemination
DFID	-	Department for International Development
EM	-	Empirical
FE	-	Fixed-Effect
FEEs/ REES	-	Fixed-effect Estimates/ Random-effect Estimates
GMM	-	General Method of Moments
GR	-	Green Revolution
HYVs	-	High-yield seed varieties
ILO	-	International Labour office
LICs	-	low-income countries
LMICs	-	Lower-middle income countries
MAER-Net	-	Meta-Analysis of Economics Research Network
NEPAD	-	New Partnership for Africa's Development
OECD	-	Organisation for Economic Co-operation and Development
OLS	-	Ordinary Least-squares
PCCs	-	Partial Correlation Coefficients
PEESE	-	Precision-effect tests with standard errors
PETs/FATs	-	Precision-effect Tests/Funnel-asymmetry Tests
PIOS	-	Population-Intervention-Outcome-Study design
QA	-	Qualitative/Analytical
R&D	-	Research and Development
RCTs	-	Randomised-control trials
RE	-	Random-Effect
SBTC	-	Skill-biased technological change
SETI	-	Skill-enhancing technology import
TFP	-	Total Factor Productivity
VRA	-	Validity-Reliability-Applicability
WLS	-	Weighted Least-squares

WHAT IS THE IMPACT OF HIGHER RATES OF INNOVATION (MEASURED BY FASTER TFP GROWTH, PRODUCT INNOVATION, PROCESS INNOVATION, AND IMPORTS OF TECHNOLOGY) ON EMPLOYMENT IN LICS? HOW DOES THIS VARY BY GENDER?

ABSTRACT

The aim of this systematic review is to provide a synthesis of the empirical and qualitative evidence on the relationship between types of innovation (process and product innovation) and levels of employment; paying attention to skill levels, the level of aggregation/analysis, and gender. We map a narrative synthesis of the evidence from 53 qualitative studies with meta-analysis of effect-size estimates from nine empirical studies. Fifty-three per cent of the studies investigate the effects of innovation on employment in agriculture, whilst the remaining 47 per cent focus on manufacturing. The evidence base relates to the effects of innovation on employment in the short-to-medium term. The review is based on a peer-reviewed and pre-published protocol that specifies the methods for searching, screening and evaluating the existing literature; and for synthesizing the qualitative and empirical evidence from included studies.

The narrative synthesis indicates that innovation's effect on employment depends on the balance between displacement (labour-saving) and compensation (job-creating) effects. The overall effect is reported to be positive when: (i) the demand for skilled labour is analysed; (ii) there are strong forward and backward linkages between innovative enterprises and their suppliers or customers in upstream or downstream industries; (iii) labour-market and governance institutions are supportive of appropriate technology choice and/or technology adaptation; and (iv) innovative activities consist of product innovation as opposed to process innovation. On the other hand, the effect is reported as negative when income distribution is skewed, international trade is capital-intensive, and skill upgrading capacity is low at the enterprise, sector or country levels.

Meta-analysis findings are based on partial correlation coefficients (PCCs). PCCs allow for comparing and synthesizing effect-size estimates based on different metrics with which innovation and employment are measured. However, they can provide information only about the association between innovation and employment taking into account other economic factors that affect the demand for labour.

Meta-analysis evidence (Table 4.3.3, Panel B) indicates that the average effect of process innovation on skilled-labour employment is positive (0.102). According Cohen (1988) criteria, a partial correlation coefficient of 0.1 is a small effect. In this context, it means that process innovation explains only 1% of the remaining variation in skilled-labour employment after other economic factors are taken into account. In contrast, process innovation does not have a significant effect on total employment (Table 4.3.3, Panel A). Taken together, these findings suggest that process innovation tend to be associated with a small skill bias.

When *both* process and product innovation are taken together (Table 4.3.3., Panel B), innovation has a positive but very small effect (0.026) on total employment - i.e., employment of skilled and unskilled labour taken together.

Furthermore, we perform a meta-regression (Table 4.3.5) to control for the skill level, region, industrial sector and level of analysis, finding that the effect of innovation on employment is highly contingent on these factors. All else being equal, this effect is augmented when the evidence relates to skilled-labour employment as opposed to total employment. These findings are congruent with and lend further support to the skill bias evidence reported above.

Innovation's effect on total employment is also augmented when considering manufacturing employment only, and when considering South Asian studies alone. Conversely, and all else being equal, innovation's effect on total employment is dampened when the evidence is related to sector-level employment as opposed to enterprise-level employment (please refer to Table 4.3.5 for the figures). Although this effect is too small to be practically significant, it suggests that employment creation in innovative enterprises may be at the expense of job losses in their non-innovative counterparts within the same sector or industry.

There is convergence between narrative synthesis and meta-analysis findings with respect to three evidence clusters, which reflect different combinations of innovation types, skill types and levels of analysis. First, qualitative studies tend to indicate a positive relationship between process innovation and the demand for skilled labour. This is in line with the meta-analysis finding, which indicates that the effect of process innovation on skilled labour employment is positive but small. Secondly, qualitative studies tend to report that innovation is likely to be skill-biased even when both process and product innovation are taken together. Meta-analysis provides partial support for such predictions: the effect of both process and product innovation on total employment is augmented by a very small amount (0.07) when the evidence relates to skilled-labour employment only as opposed to total employment. Finally, the narrative synthesis indicates that innovation's effect on sector-level employment can be expected to be smaller than the effect on enterprise-level employment. This is because job creation in innovative enterprises may be obtained at the expense of job losses in their non-innovative counterparts. Meta-analysis evidence is congruent with this qualitative prediction, but it also indicates that the difference may be too small to be practically significant.

There is divergence between narrative synthesis and meta-analysis findings with respect to three evidence clusters. The narrative synthesis suggests negative relationship between process innovation and total employment; and positive relationship between product innovation and total employment. However, meta-analysis findings indicate that these relationships are not statistically significant (Table 4.3.3). Finally, the qualitative study evidence indicates that the effect of both process and

product innovation on total employment is uncertain. However, the meta-analysis evidence indicates a positive effect (0.026), albeit this effect is too small to be practically significant.

The meta-analysis is silent in three evidence clusters (evidence on product innovation and skilled-labour employment; process innovation and industry-level employment; and product innovation and industry-level employment). This is due to absence of sufficient number of estimates reported in empirical studies.

With respect to innovation and female labour, limited evidence from four qualitative studies allows for three tentative conclusions. First, mechanization and other Green Revolution technologies are associated with lower female participation in farm activities, particularly among educated women. Second, strong forward/backward linkages increase female labour employment in innovative firms/industries. Third, innovation in manufacturing increases the employment of particularly younger and better-educated women; but it also leads to gender-based job segmentation.

Overall, the evidence allows for two broad conclusions: (i) process innovation is associated with a positive but small effect on the demand for skilled labour; and (ii) the effect of both process and product innovation on total employment is positive but too small to be practically significant. These conclusions, however, should be considered in conjunction with high level of heterogeneity in the evidence base. The latter is due to the fact that the effect of innovation on employment is conditional on a wide range of moderating factors, including type of innovation (process *versus* product innovation), skill levels (skilled *versus* unskilled labour), level of analysis (enterprise *versus* sector level), strength of forward and backward linkages, institutional quality, and the age and education level of female workers.

The review findings must be interpreted with caution for two reasons. First, the moderating variables that we control for in the meta-analysis account only for 33-34% of the variation in the reported effects of innovation on employment. Explained variation is higher (66%) in the elasticities sub-sample. However, the variation is accounted for by one moderating variable only. Secondly, the number of empirical studies on LICs (9) is rather small despite the fact that we have extended the inclusion period back to the 1970s. These limitations do not invalidate the review findings, but they indicate the need for some caution and care in interpreting the results. They also indicate that the evidence base should be strengthened through investment in compilation of innovation data on LICs and via further research that would utilise the new data as well as new developments in theoretical and empirical modelling.

WHAT IS THE IMPACT OF HIGHER RATES OF INNOVATION (MEASURED BY FASTER TFP GROWTH, PRODUCT INNOVATION, PROCESS INNOVATION, AND IMPORTS OF TECHNOLOGY) ON EMPLOYMENT IN LICS? HOW DOES THIS VARY BY GENDER?

EXECUTIVE SUMMARY

1. Background

Since 2005, national, regional and international organisations have been emphasizing the importance of innovation for growth in low-income countries (LICs). The emphasis was evident in the UN World Summit declaration of 2005; and in statements by the African Union, UK Commission for Africa, and New Partnership for Africa's Development (NEPAD). In 2010, the Department for International Development (DFID) of the UK government began to support research on innovation, technological diffusion and economic growth. The aim is to develop a better understanding of how innovation and technological change affect the level and composition of employment in developing countries, including LICs.

Interest in employment-effects of innovation is informed by theoretical and empirical research in which innovation is a major driver of economic growth in the long run. However, the innovation-employment relationship is affected by the interaction between compensation (job-creating) and displacement (labour-saving) mechanisms that affect the demand for labour differently at the firm, industry and macro levels.

This systematic review aims to synthesize the qualitative and empirical evidence on the effects of innovation on employment in low-income countries (LICs), paying attention to differential effects that may be associated with innovation types (process innovation, product innovation and both process and product innovation); skill types (skilled labour, unskilled labour, and mixed-skills labour); female labour; and the level of aggregation/analysis (employment at the enterprise, industry/sector and macro levels). The time horizon of the primary studies reviewed here is limited to the short or medium term (up to 5 years in general), with the exception of one qualitative study on Green Revolution technologies in agriculture. The review findings are based on mapping the narrative synthesis of the qualitative literature with a meta-analysis of the evidence from empirical studies.

2. Review methodology

The review is guided by a peer-reviewed and pre-published protocol that specifies the methods for searching, screening and evaluating the literature; and for synthesizing the qualitative and empirical evidence. Its findings are based on evidence from 53 qualitative and 9 empirical studies. While 53 per cent of the studies examine the

employment-effects of innovation in agriculture, 47 per cent examine the effects in manufacturing. With respect to innovation type, 85% of the studies investigate the relationship between process innovation and employment and the remaining 15% focus on the relationship between product innovation and employment.

The evidence is synthesized by adopting a mixed-method approach, which allows for mapping the narrative synthesis of the qualitative evidence with meta-analysis of the effect-size estimates reported in empirical studies. The narrative synthesis is based on study clusters, with each cluster analysing a particular type of innovation and employment effect. This is followed by and mapped with meta-analysis of the empirical evidence. The latter is conducted in three stages. In stage 1, we provide a descriptive summary of the evidence base by calculating fixed-effect and random-effect weighted averages of the effect-size estimates. In stage 2, we conduct precision-effect tests and estimations to verify if innovation has a genuine effect on employment after taking account of reporting bias. In stage 3, we conduct multi-variate meta-regression analysis to identify the moderating factors that affect the reported estimates and to verify if the meta-analysis findings with respect to moderating factors are in line with the findings in the narrative synthesis.

3. Findings

The narrative synthesis of the qualitative evidence indicates that innovation's effect on employment in LICs would depend on the balance between job-creating and labour-saving effects. Job-creating effects are more likely to dominate when:

- The evidence is related to skilled-labour employment as opposed to unskilled or all-skills employment
- Forward and backward linkages between innovative enterprises and the rest of the economy are strong
- Labour-market and governance institutions are supportive of appropriate technology choice and/or technology adaptation
- Innovative activities consist of product innovation as opposed to process innovation
- The evidence is related to firm-level employment as opposed to sector or macro levels

On the other hand, the labour-saving effects are likely to dominate when:

- Income distribution is skewed and generates demand for up-market goods produced with capital-intensive technologies
- The skill-bias of innovation is exacerbated by capital-intensive imports and exports
- Skill upgrading capacity at the enterprise/sector or country levels is low

- Innovative activities consist of process innovation as opposed to product innovation
- The evidence is related to sector- or macro-level employment as opposed to firm level

Meta-analysis findings based on partial correlation coefficients (PCCs) indicate that the average effect of process innovation on skilled-labour employment is positive (0.102) (Table 4.3.3, Panel B). In the light of Cohen (1988) criteria, a partial correlation coefficient of 0.1 is a small effect. It indicates that process innovation explains only 1% of the remaining variation in skilled-labour employment after other economic factors are taken into account. This finding can be interpreted as evidence of a small skill bias in the effect of process innovation on employment. This interpretation draws further support from the meta-analysis finding (in Table 4.3.3, Panel A) that the effect of process innovation on total employment (employment of skilled and unskilled labour taken together) is statistically insignificant.

When *both* process and product innovation are taken together (Table 4.3.3., Panel B), innovation has a positive but very small effect (0.026) on total employment. This effect is too small to be practically significant.

Furthermore, we perform a meta-regression (Table 4.3.5) to control for the skill level, region, industrial sector and level of analysis, finding that the effect of innovation on employment is highly contingent on these factors. All else being equal, the effect is augmented by 0.07 when the evidence relates to skilled-labour employment as opposed to total employment. These findings are congruent with and lend further support to the skill bias evidence reported above.

Conversely, innovation's effect on total employment is augmented by 0.133 when considering manufacturing employment only, and by 0.123 when considering South Asian studies alone. Finally, and all else being equal, innovation's effect on total employment is dampened by -0.042 when the evidence is related to sector-level employment as opposed to enterprise-level employment (Table 4.3.5). Although this effect is too small to be practically significant, it suggests that employment creation in innovative enterprises may be at the expense of job losses in their non-innovative counterparts within the same sector or industry.

The table below maps the narrative synthesis and meta-analysis findings with respect to nine evidence clusters, each of which is defined by a type of innovation (process innovation, product innovation, or process & product innovation) and a type of employment (skilled-labour employment at the enterprise and sectors levels, total employment at the enterprise and sector levels, or total employment at the sector level only).

Mapped narrative synthesis and meta-analysis findings: Convergence and divergence

Innovation type ➡ / Effect on ⬇	1. Process innovation	2. Product innovation	3. Process & product innovation
A. Skilled labour employment at enterprise and sector levels ***Narrative synthesis*** ***Meta-analysis***	*A1* *Convergent findings* *Positive effect is predicted* *Positive but small effect found (0.102)(Table 4.3.3, Panel B)*	*A2* *Narrative synthesis evidence only* *Positive effect is predicted* *No control*	*A3* *Convergent findings* *Positive effect is predicted* *Employment effect is augmented by 0.07 when data relates to skilled-labour as opposed to total employment (Table 4.3.5)*
B. Total (skilled and unskilled labour) employment at enterprise and sector levels ***Narrative synthesis*** ***Meta-analysis***	*B1* *Divergent findings* *Negative effect is predicted* *Insignificant effect found (Table 4.3.3, Panel A)*	*B2* *Divergent findings* *Positive effect is predicted* *Insignificant effect found (Table 4.3.3, Panel A)*	*B3* *Divergent findings* *Uncertain effect is predicted* *Positive but very small effect found (+0.026) (Table 4.3.3, Panel B)*
C. Total (skilled and unskilled labour) employment at sector level only ***Narrative synthesis*** ***Meta-analysis***	*C1* *Narrative synthesis evidence only* *Dampened or negative effect is predicted* *No control*	*C2* *Narrative synthesis evidence only* *Dampened or negative effect is predicted* *No control*	*C3* *Convergent findings* *Dampened or negative effect is predicted* *Employment effect is dampened by -0.042 when data relates to sector-level as opposed to enterprise-level employment (Table 4.3.5)*

The mapping exercise indicates convergence between narrative synthesis and meta-analysis findings with respect to three evidence clusters. First, qualitative studies tend to indicate a positive relationship between process innovation and the demand for skilled labour. This is in line with the meta-analysis finding, which indicates that the effect of process innovation on skilled labour employment is positive but small (Cell A1). Secondly, qualitative studies tend to report that innovation is likely to be skill-biased even when both process and product innovation are taken together. Meta-analysis provides partial support for such predictions: all else being equal, the effect of both process and product innovation on total employment is augmented by a very small amount (0.07) when the evidence relates to skilled-labour employment only as opposed to total employment (Cell A3). Finally, the narrative synthesis indicates that innovation's

effect on sector-level employment can be expected to be smaller than the effect on enterprise-level employment. This is because job creation in innovative enterprises may be obtained at the expense of job losses in their non-innovative counterparts. Meta-analysis evidence is congruent with this qualitative prediction, but it also indicates that the difference may be too small to be practically significant (Cell C3).

There is divergence between narrative synthesis and meta-analysis findings with respect to three evidence clusters. The narrative synthesis suggests negative relationship between process innovation and total employment (Cell B1); and positive relationship between product innovation and total employment (Cell B2). However, meta-analysis findings indicate that these relationships are not statistically significant. Finally, the qualitative study evidence indicates that the effect of both process and product innovation on total employment is uncertain (Cell B3). However, the meta-analysis evidence indicates a positive effect (0.026), albeit this effect is too small to be practically significant.

The meta-analysis is silent in three evidence clusters (evidence on product innovation and skilled-labour employment; process innovation and industry-level employment; and product innovation and industry-level employment). This is due to insufficient number of estimates reported in empirical studies or absence such estimates.

The mapped evidence allows for two broad conclusions: (i) process innovation is associated with a positive but small effect on the demand for skilled labour; and (ii) the effect of both process and product innovation on total employment is positive but too small to be practically significant. These conclusions, however, should be considered in conjunction with high level of heterogeneity in the evidence base. The latter is due to the fact that the effect of innovation on employment is conditional on a wide range of moderating factors, including type of innovation (process *versus* product innovation), skill levels (skilled *versus* unskilled labour), level of analysis (enterprise *versus* sector level), strength of forward and backward linkages, institutional quality, and the age and education level of female workers.

These findings are based on partial correlation coefficients (PCCs), calculated from effect-size estimates reported in empirical studies. The economic interpretation of PCCs is less straightforward compared to elasticities, which measure the percentage change in employment in response to 1% increase in innovation. When we use elasticities data only, the effect of process innovation on skilled labour employment and the effect of process and product innovation on total employment are statistically significant and moderate (0.263 and 0.224, respectively). However, only 3 out of 9 empirical studies included in the review report elasticities. Therefore, we do not recommend taking the effect-size estimates obtained from elasticities data as representative measures of employment effect.

In meta-analysis, we were able to control for a range of moderating variables that account for about 33-34% of the heterogeneity in the full sample of empirical studies.

These include process innovation as opposed product innovation, employment at sector/industry level as opposed to employment at enterprise level, employment in manufacturing as opposed employment in agriculture or services, and employment in South Asia as opposed to employment in other world regions with LICs. Moderating variables that we could not control for in meta-analysis include the strength of forward/backward linkages, distribution of income, capital intensity of international trade, institutional quality, and the Green Revolution. The narrative synthesis findings related to these moderating factors can be summarised as follows:

- Qualitative studies investigating the employment effects of Green Revolution technologies tend to report a negative effect when innovation involves mechanisation but a positive effect when it involves high-yield variety seeds or animals (HYVs). A positive overall effect is reported in the long run and in India, mainly due to job creation through forward and backward linkages and higher farmer incomes.

- The narrative synthesis also indicates that openness to trade is likely to exacerbate innovation's negative effect on employment. This is due to skill- and capital-intensity of imported technologies, which induce entrepreneurs to substitute capital for labour and skilled for unskilled labour.

- With respect to quality of institutions, qualitative studies tends to report that weak governance and labour market institutions reduce the scope for appropriate technology choice and induce entrepreneurs to assign larger weights to productivity gains compared to employment gains.

- Strong forward and backward linkages are reported as significant mechanisms that counter the adverse effects of innovation on employment in two ways: (i) by increasing the demand of the downstream firms/industries for the output of the innovative firms/industries; or (ii) by increasing the demand of the innovative firms/industries for inputs from upstream firms/industries.

With respect to innovation and female labour, limited evidence from four qualitative studies enables us to derive three conclusions. First, introduction of mechanization and other Green Revolution technologies is associated with lower female participation in farm activities, particularly among educated women. Second, strong forward/backward linkages increase female labour employment in innovative firms/industries. Third, innovation in manufacturing increases the employment of particularly younger and better-educated women; but the increase in female employment coexists with gender-based job segmentation.

Overall, the existing evidence indicates that innovation's effect on employment in LICs is conditional on the type of innovation, skill types, and the level of analysis/aggregation; and a range of other moderating factors that include international trade, income levels and distribution, and forward and backward linkages between innovators and the rest of

sector/industry, labour-market and governance institutions. Nevertheless, there is sufficient evidence to indicate that process innovation has a positive but small effect on employment of skilled labour. The effect of process and product innovation taken together on total employment (skilled and unskilled labour taken together) is uncertain in qualitative studies. This effect is positive but too small to be practically significant in empirical studies. Hence, it can be concluded that innovation on its own should not be expected to have a substantial effect on overall employment in LICs. For innovation to have a substantial effect, it must be accompanied with: (i) skill upgrading of the labour force; (ii) good quality institutions that encourage appropriate technology choice and adaptation; (iii) strong backward and forward linkages between innovative enterprises and the rest of the economy; and (iv) lower capital-intensity of imported technology.

4. Limitations

This systematic review investigates a complex question and evidence consists of 53 qualitative and just 9 quantitative studies. Therefore conclusions should be considered as a best evaluation and synthesis of available evidence but not a conclusive assessment of all dimensions of the review question. In particular, evidence on macro-level employment impact of innovation, on the relationship between innovation and gender-specific employment, and on the impact of product innovation is particularly limited.

In addition, the effect-size estimates used in the meta-analysis are highly varied. Some of that variation (33-34% in full sample, and 66% in the elasticities sub-sample) could be explained by observed moderating factors, leaving a substantial level of unexplained variation. It must also be indicated that the number of empirical studies (9) is rather small despite the fact that we have extended the inclusion period back to the 1970s. These limitations do not invalidate the review findings, but they indicate that they should be interpreted with some caution and care. They also indicate that the evidence base should be strengthened through investment in compilation of innovation data and via further research that would utilise the new data as well as new developments in theoretical and empirical modeling.

5. Implications

Despite limitations in the evidence base, the review findings do not indicate a negative relationship between innovation and the demand for skilled and unskilled labour taken together. However, the evidence also indicates that the overall effect of innovation on employment is likely to be small and to be conditional on a number of moderating factors. Therefore, it is necessary to combine pro-innovation policies with complementary policies that would strengthen the positive effects whilst minimising the adverse effects.

For example, the evidence indicates that innovation is associated with skill bias and the latter's adverse effects on employment can be exacerbated by international trade and financial integration. Therefore, policies aimed at fostering innovation must be accompanied with: (i) support for education and skill upgrading; and (ii) technology adaptation that takes account of existing skill and factor endowment in LICs. Investment in education and skill upgrading is a prominent policy issue on the agenda of the national governments in LICs and that of international organisations. However, there is little or no attention paid to the issue of adapting technology to skill endowment in LICs.

Studies on the innovation-employment relationship in developed and middle-income countries tend to rely on rich survey data and control for different types of innovation, skill levels and openness to trade. Similar work on LICs is yet to emerge. This type of work is hampered by lack of data and absence of theoretical work that would bridge the gap between technology adaptation perspectives of the 1970s-1980s on developing countries and the skill-biased technical change (SBTC) debate of the 1990s on developed and middle-income countries. Therefore, there is a case for investment in compilation of rich datasets on innovation and economic performance (including employment outcomes) in LICs.

Future research should make better use of existing firm-level survey evidence in *Enterprise Surveys* compiled by the World Bank and the International Finance Corporation (IFC). Evidence in these surveys can be analysed and, if necessary, compared with evidence on middle-income countries to enrich the existing evidence base. Another avenue would be to make use of the emerging African Science Technology and Innovation Indicators (ASTI) from recent R&D and Innovation surveys compiled by the New Partnership for Africa's Development (NEPAD).

1. BACKGROUND FOR THE REVIEW

1.1 The review question and approach

The review question is:

What is the impact of higher rates of innovation (measured by faster TFP growth, product innovation, process innovation, and imports of technology) on employment in LICs? How does this vary by gender?

To address this question, we have conceptualised innovation as the 'intervention' and employment as the 'outcome' variable. The overall effect of innovation on employment depends on the balance between the effects of displacement and compensation mechanisms. Displacement mechanisms lead to lower levels of employment for several reasons. As innovation enhances productivity, firms may shed labour as the same level of output can be produced by lower levels of labour input. In addition, innovation reduces the demand for low-skill labour relative to skilled labour. Similarly, it also causes substitution away from labour towards capital. These displacement effects are expected to be larger when innovation is skill-biased, involves process rather than product innovation, and is evaluated at the sector- or macro-level as opposed to firm level

However, innovation also induces a range of compensation mechanisms that may lead to higher levels of employment. One such mechanism is the structure of the product markets. If innovation takes place in the context of competitive product markets, efficiency gains from innovation leads to lower prices. As lower prices enable innovative firms and industries to increase market share or create new markets, the demand for labour can be expected to increase. However, innovation may not lead to employment gains if product markets are concentrated and firms are able to use innovation as an additional source of market power. The other compensation mechanism is labour market flexibility. In flexible labour markets, innovation shocks are more likely to be absorbed through changes in wages rather than real changes in employment levels. Hence, any adverse effect on employment is likely to be reversed without long-term deviations from the optimal employment path. A third compensation mechanism consists of backward and forward linkages, which generate employment in downstream customers and/or upstream suppliers of the innovative firms and industries.

In this review, we will pay attention to these and other displacement and compensation mechanisms – as indicated in Table 1.2.1 and Figure 1.2.1 below. In addition, we will also account for the effects of other mediating variables that may exacerbate the

displacement or enhance the compensation effects. One set of mediating factors consists of institutions (rules, norms, rules, and values) and their enforcement mechanisms. Another set of mediating variables relates to international trade and its country as well as product composition.

We have discussed this analytical framework with Policy Leads at DFID – both prior to and after the conclusion of the Protocol. The deliberations have led to agreement on combining meta-analysis of the empirical evidence with a narrative synthesis of the qualitative evidence. The mapped evidence will take account of: (i) the type of innovation (product *versus* process innovation); (i) the level of analysis (firm/farm, sector and macro levels); and (iii) the type of employment (skilled, unskilled, total employment). The mapping exercise will enable us to establish the extent of convergence/divergence between quantitative and qualitative findings.

1.2 Aims and rationale

The UN World Summit of 2005 stated that science and technology are vital for achieving the Millennium Development Goals (UN, 2005). In the same year, the UK Commission for Africa highlighted the need to develop effective policies for innovation and exploit the benefits of international trade (Commission for Africa 2005; 137). The African Union Commission and the New Partnership for Africa's Development (NEPAD) expressed similar views: promoting science, technology and an innovation is essential for sustainable development, including employment (NEPAD, 2006).

These statements reflect optimism about the extent to which policy-makers and entrepreneurs in low-income countries (LICs) can emulate the experience of developed countries, in which innovation, growth and employment creation went hand-in-hand for a long time (Harrison et al., 2008). This optimism is based on the assumption that the employment-creating effects of innovation are stronger than its employment-destroying effects.

Yet, the relationship between innovation and employment may be more complex for several reasons. Although it is widely agreed that innovation is necessary for growth and employment in the long run, the adjustment to innovation shocks may be protracted and lead to long spells of frictional unemployment (Aghion and Howitt, 1992; Baumol and Wolff, 1998). Also, as reported by Acemoglu (1998 and 2002), skill-replacing innovation of the late-eighteenth and nineteenth centuries was conducive to job creation whereas skill-biased innovation of the twentieth and early twenty-first centuries is not. Furthermore, Edquist (2001) draws attention to differential effects of product and process innovation: whereas product innovation may be job-creating, process innovation may lead to substitution of capital for labour.

These findings are based on evidence mainly from developed and middle-income countries. Therefore, it is necessary to cast a wider net to uncover studies on innovation and employment in LICs and synthesize their findings in a systematic manner. This systematic review aims to address this need by synthesizing the evidence reported in 62 primary studies published between 1970 and 2011. Included studies focus mainly on LICs as currently defined by the World Bank. However, we have also included studies of the innovation-employment relationship in some lower middle income countries (LMICs) such as India and China, which were considered as LICs until the end of the 1990s.

This systematic review aims to inform evidence-based policy and future research through:

1. A *narrative synthesis* of the qualitative evidence, with a view to derive policy-relevant conclusions by identify the effects of mediating factors such as forward and backward linkages, institutions, skill levels, type of innovation, and international trade;
2. A *meta-analysis* of the empirical evidence with a view to: establish if innovation has a genuine effect on employment after controlling for reporting bias; and quantify the effects of the moderating factors indicated above as well as other factors such as publication type and estimation methods that reflect the characteristics of the research field;
3. Mapping the findings in (1) and (2) to establish the extent of convergence or divergence between qualitative and quantitative evidence;
4. Relating the mapped findings to underlying theoretical perspectives and distilling some policy and future research implications.

1.3 Definitional and conceptual issues

In this section, we provide definitions for the intervention (innovation) and outcome (employment) variables. Adopted definitions are related to criteria set by international organisations – the OECD criteria for innovation and ILO criteria for employment. We also review the theoretical literature on the innovation-employment relationship, paying attention to the displacement and compensation mechanisms at work. Overall, we will demonstrate that the effect of innovation on employment depends on the balance between the opposite effects of *displacement* and *compensation* mechanisms. We will also demonstrate that this balance is likely to differ, depending on the level at which employment is observed (firm/farm *versus* sector or macro levels), the type of innovation introduced (product *versus* process innovation), and the level of skills that the labour force possesses (skilled *versus* unskilled labour).

1.3.1 Innovation and employment: definition and measurement

OECD's *Oslo Manual* (OECD, 2005) provides guidelines about what constitutes innovation and how innovative activity should be measured. We draw on this source to decide whether the type of innovation analysed by a primary study satisfies the intervention (or independent) variable criterion for inclusion. Although some of the studies predate the *Oslo Manual*, the latter provides a wide yet systematic definition of innovation: 'the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.' Furthermore, innovation must be *implemented* rather than referring to potential innovative capacity. Finally, innovation activities can be either 'new to the firm' or 'new to the world or industry'.

The emphasis on implemented innovation is pertinent because measures of innovative capacity (e.g., R&D expenditures or patents data) are either lacking or constitute poor indicators for innovation efforts in LICs. The focus on innovation as activities that are new both to the world and to the firm itself is in line with the Oslo Manual, which requires that innovation surveys should aim to capture not only new patents and know-how, but also purchase of technical information, acquisition of licences; and purchase of capital goods or intermediate inputs that embody innovative inputs from third parties (OECD, 2005: 36).

Studies included in this review measure innovation with different metrics, including mechanization, irrigation, fertiliser use, use of high-yield variety seeds in agriculture; as well as technology adaptation, imported technology and introduction of new products or process in manufacturing. For example, Conte and Vivarelli (2007) and Mitra (2009) use import of capital goods and licensing as measures of innovation. This is in line with the wider literature on developing countries (Piva, 2003; Xu and Wang, 2000; Eaton and Kortum, 2001), which indicate that imported capital goods can be taken as approximate measures of innovation because they contribute to capital upgrading. Furthermore, they constitute a significant source of innovation as developing countries (particularly LICs) tend to rely on external rather than internal sources of innovation such as R&D investment and patenting.

The review question also refers to employment-effects of total factor productivity (TFP) and to innovation's effects on female employment. Both electronic and manual searches yielded only a handful of studies addressing these issues in low-income countries. Dutz et al (2011) examine the relationship between TFP growth and employment, but this study could not be included because its evidence is based on LIC and non-LIC data pooled together. In addition, it does not control for wages or output in its estimations. However, four studies on the effect of innovation on female labour have been included (Ahmed, 1987; Bhala, 1989; Billings and Arjan, 1970; and Tuyen, 1998).

The outcome variable in this review is *employment*, which is defined by ILO (2000) as economically-active persons (usually, aged 15-64) who were in paid or self-employment for a specified period at the time when data is compiled. Primary studies with a focus on sector or macro levels use national employment statistics compiled in accordance with ILO guidelines. However, adherence to these guidelines is known to be uneven – depending on capacity and traditions of the national statistical offices (Inter-Secretariat, 1993). On the other hand, studies that examine the effect of employment at the firm or farm level utilise employment data based on national surveys or field-study evidence.

In this review, we include studies that examine the effect of innovation on total employment as well as employment of skilled and unskilled labour. We have coded the skill types and used resulting variables as moderating factors that mediate the overall effect of innovation on employment. However, we do not include studies that examine the effect of innovation on the composition of the wage bill only. Such studies have been excluded because the composition of wage bill is an indicator of wage-income distribution rather than levels of employment, which is the outcome variable specified in the review question.

1.3.2 Innovation and employment: types, levels and sector coverage

This systematic review distinguishes between two *types* of innovation. *Product innovation* enhances the quality and variety of goods and may open up new markets – leading to higher demand for labour. However, new products can simply replace old ones produced by the innovative firm itself or its competitors, leading to destruction of old jobs. In contrast, process innovation occurs at the intensive product margin and is usually associated with negative employment effects (Edquist et al, 2001). Nevertheless, even process innovation may create jobs if it is introduced in firms or industries with strong forward and backward linkages with other firms or industries. Therefore, the employment-effects of innovation types separately or collectively can be established only empirically (Pianta, 2001).

The distinction between product and process innovation is justified at the analytical level, but may be blurred in practice as firms engage in both types of innovation simultaneously. Primary studies address this issue by focusing on the primary innovation type and treating the other type as necessary adjustment. For example, the introduction of high-yield varieties (HYVs) is treated as product innovation whereas required irrigation and use of fertilisers are considered as complementary process innovation. In contrast, the shift from non-irrigated farming to irrigated farming or from manual to mechanised farming is considered as process innovation and the increased production level or product mix is considered as by-products of process innovation. In

this review, 85% of the included primary studies investigate the employment-effects of process innovation and 15% examine the effects of product innovation. The latter are mainly related to product innovation in agriculture, with the exception of two qualitative studies (Agbesor, 1984 and Aryee, 1984) and one empirical study (Otsuka et al, 1994) on product innovation in manufacturing.

The review synthesizes the evidence at three *levels* of analysis: firm/farm (enterprise), industry/sector and macro levels. From a policy perspective, the effect at the macro level may be of greater interest compared to effects at firm/farm or industry levels. Indeed, such preference has been expressed during our deliberations with DFID policy leads. However, only five studies investigate the employment-effects of innovation at the macro level; and all of these are qualitative studies. Hence, the macro-level effects of innovation are analysed only in the narrative synthesis.

Finally, there is the issue of *sector coverage*. As Piva (2003) has observed, the large majority of existing work tend to examine the impact of innovation on employment in the manufacturing sector. This is due to data availability and the implicit assumption that innovation is more prevalent in manufacturing industries. This 'manufacturing bias' not only limits the evidence base on LICs severely, but also overlooks the fact that agriculture is still a significant source of employment in these countries. To avoid this limitation, we have included studies that examine the impact of innovation on employment in both agriculture and manufacturing sectors. Of the included primary studies, 53% investigate the employment-effects of innovation in agriculture with the remaining 46% focusing on manufacturing and bout 1% on services.

1.3.3 Innovation and employment: displacement and compensation mechanisms

The relationship between innovation and employment has been debated since the Industrial Revolution. Over the last three decades, the debate has gathered momentum due to concerns about skill-biased technological change (SBTC) and whether SBTC may be the cause of slow job creation in developed countries (see, OECD, 2004). The debate has acquired a new dimension in the context of international development – especially with reference to Millennium Development Goals and the role of innovation in achieving the goal of poverty reduction.

In both exogenous and endogenous growth models, innovation is the source of technological change that, in turn, drives total factor productivity growth (Temple, 1999). Growth models do not account for the effects of innovation on employment directly, but they imply that innovative firms and industries would create employment as a result of increased output and enhanced labour productivity. Labour economists, on the other hand, investigates how innovation affects employment and wages, taking into

account the mediating effects of skill levels, macroeconomic factors, wage bargaining modes, and labour market institutions.

In both approaches, however, the underlying assumption is that macro-level or industry/sector-level adjustments to innovation shocks are rapid unless there are persistent wage rigidities. Even though wage rigidities may delay the adjustment process, there are a number of compensation mechanisms that can counterbalance the initial loss of employment caused by innovation. These include falling prices, increased incomes, increased investment, forward and backward linkages, and market expansion or creation due to new products (Vivarelli, 1995; 2007).

However, the effectiveness of these compensation mechanisms and the speed with which they take effect vary between firms, industries and countries. For example, whilst compensation mechanisms through falling prices and increased incomes are found to be effective, other compensation mechanisms such as falling wages or product innovation are found to be ineffective (Vivarelli, 2007). Factors that affect the outcome include labour market and governance institutions as well as absorptive capacities at the micro and macro levels. Hence, *ex ante* expectations of a complete compensation of the initial labour-saving effects of innovation are unrealistic for two reasons.

First, neither growth nor labour market models specify a time-horizon over which equilibrium is restored. Instead, deviations from equilibrium are assumed to be short-lived because persistent deviations are incompatible with optimizing behaviour of the economic actors (for a critique, see Pianta, 2004; Benavente and Rodolfo, 2008). Secondly, a range of theoretical models demonstrate that innovation shocks can cause significant deviations from equilibrium and such deviations may last for decades despite optimizing behaviour of the economic agents. These include Kaldorian approaches by Pasinetti (1981) and Boyer (1988) as well as eclectic work by Acemoglu (1998, 2003), Aghion and Howitt (1992), and Vivarelli (1995). These models raise doubt about the extent to which the compensation mechanisms identified by neoclassical economists (for example, Hicks, 1932; Harrod, 1939; and Myres, 1929) can counterbalance the initial negative effects of innovation on employment.

Given these conflicting perspectives and the theoretical uncertainty they imply, it is necessary to refer to the empirical evidence on the relationship between innovation and employment. However, empirical work can also provide conflicting findings, depending on the estimation method, the level of analysis (enterprise *versus* industry/sector level), the type of innovation (process *versus* product innovation), the level of skills (skilled *versus* unskilled labour), and the strength of forward/backward linkages between and within industries. Therefore, it is necessary to devise a range of thematic and content identifiers that can be used for two purposes: (i) tracking the causal relationship between innovation and employment; and (ii) extracting and organising the relevant evidence from both qualitative and empirical studies.

Table 1.2. 1: Synthesis framework for qualitative studies: Employment effects by aggregation level and innovation type

	Displacement Mechanisms (Labour-saving effects)	Compensation Mechanisms (Job-creating effects)	Overall Effect
Enterprise Level: Process innovation	**Negative** effect through productivity: less labour for a given output. **Mixed** effect through skill-bias: higher demand for labour with matching skills; lower demand otherwise.	**Positive** effect through output growth, competitive product and labour markets; and strong forward/ backward linkages. **Negative** effect otherwise.	**Uncertain** effect – depending on skill bias of innovation, strategic firm behaviour and scope for forward/backward linkages.
Enterprise Level: Product innovation	Effect through product displacement: **Negative** effect if job destruction in old product lines is greater than job creation in new product lines; **positive** effect otherwise.	Effect through product prices and forward/backward linkages: **Positive** effect if product prices fall and linkages are strong; **Negative** effect otherwise.	**Uncertain** effect: Depends on productivity differences, product prices, and forward/backward linkages.
Industry or Sector Level: Process innovation	**Negative** effect through productivity: less labour for a given output. **Substitution** effect through skill-bias.	**Positive** effect through output growth; competitive market structure; and strong forward/ backward linkages. **Negative** effect otherwise.	**Uncertain** effect – depending on skill bias of innovation, strategic firm behaviour and scope for forward/backward linkages.
Industry or Sector Level: Product innovation	Effect through product displacement: **Negative** effect if job destruction in old industries is greater than job creation in innovative industries; **positive** effect otherwise.	Effect through product prices and forward/backward linkages: **Positive** effect if product prices fall and linkages are strong; **Negative** effect otherwise.	**Uncertain** effect: Depends on productivity differences, product prices, and forward/backward linkages.
Macro Level: Process and Product innovation	**Negative** effect if innovative technologies are capital-augmenting: Substitution of capital for labour. **Skill substitution effect:** Higher demand for skilled, lower demand for unskilled labour. **Negative effect is exacerbated** by skewed income distribution and weak institutions.	**Positive** effect due to increased productivity (labour productivity and TFP). **Positive** effect through output, investment and income growth. **Positive effect is enhanced** by less-skewed income distribution and good institutions.	**Uncertain** effect: Depends on skill bias, TFP growth, demand-side and supply-side constraints, income distribution, and overall institutional quality.

In Table 1.2.1 above, the thematic identifiers capture two innovation types: process and product innovation. The content identifiers, on the other hand, capture the level of aggregation/analysis – i.e., whether the evidence is related to employment effects at the enterprise, sector or macro levels. These identifiers imply a maximum of 6 clusters, each of which is defined by a pair of thematic and content identifiers. Within each cluster, the effect of innovation on employment depends on the moderating factors that determine the balance between the effects of displacement and compensation mechanisms.

The choice of thematic and content identifiers is informed by existing reviews of the literature on the innovation-employment relationship in developed and developing countries (Edquist, 2001; Pianta, 2004; Piva, 2003; and Vivarelli, 1995; 2007). These reviews indicate that the effect of innovation on employment depends on the level of aggregation (enterprise, industry/sector and macro levels) and the type of innovation (process and product innovation). In addition, they also point out that the balance between the displacement and compensation mechanisms depend on a range of moderating factors such as skill levels (skilled and unskilled labour), the level of competition in product and labour markets, the extent of forward (upstream) and backward (downstream) linkages in the production process, the quality of institutions, and the extent of existing income inequalities.

The role of skill upgrading and labour market institutions as moderating factors is analysed in Pissarides et al (2004), who demonstrate that the rate of job losses due to innovation would exceed the rate of job creation if existing employees do not internalise technological progress and upgrade their skills, or when labour markets are rigid. Such displacement effects are likely to be exacerbated when labour market and governance institutions encourage adoption of skill- and capital-intensive technologies.

Innovation's employment effect would also depend on the extent of substitution between 'old' and 'new' products. As innovation increases the productivity of innovative firms and industries, costs (and possibly prices) of these firms and industries would fall; leading to increased demand for the goods and services they supply. This increased market opportunities, in turn, would induce firms to increase employment. However, this is only part of the story: the output and employment growth in innovative firms and industries may be at the expense of output and employment losses in non-innovative counterparts. Therefore, the balance between compensation and displacement effects remains to be an empirical issue.

Ambiguity of innovation's effect on employment can also be due to factor and skill substitution. Factor substitution occurs when innovation induces firms to substitute capital for labour. On the other hand; skill substitution refers to substitution of skilled for unskilled labour. The existing literature indicates that the job-destroying effects of innovation would exceed the job-creating effects if innovation consists of introducing

capital-intensive technologies; or when the new technologies and processes favours skilled labour at the expense unskilled labour.

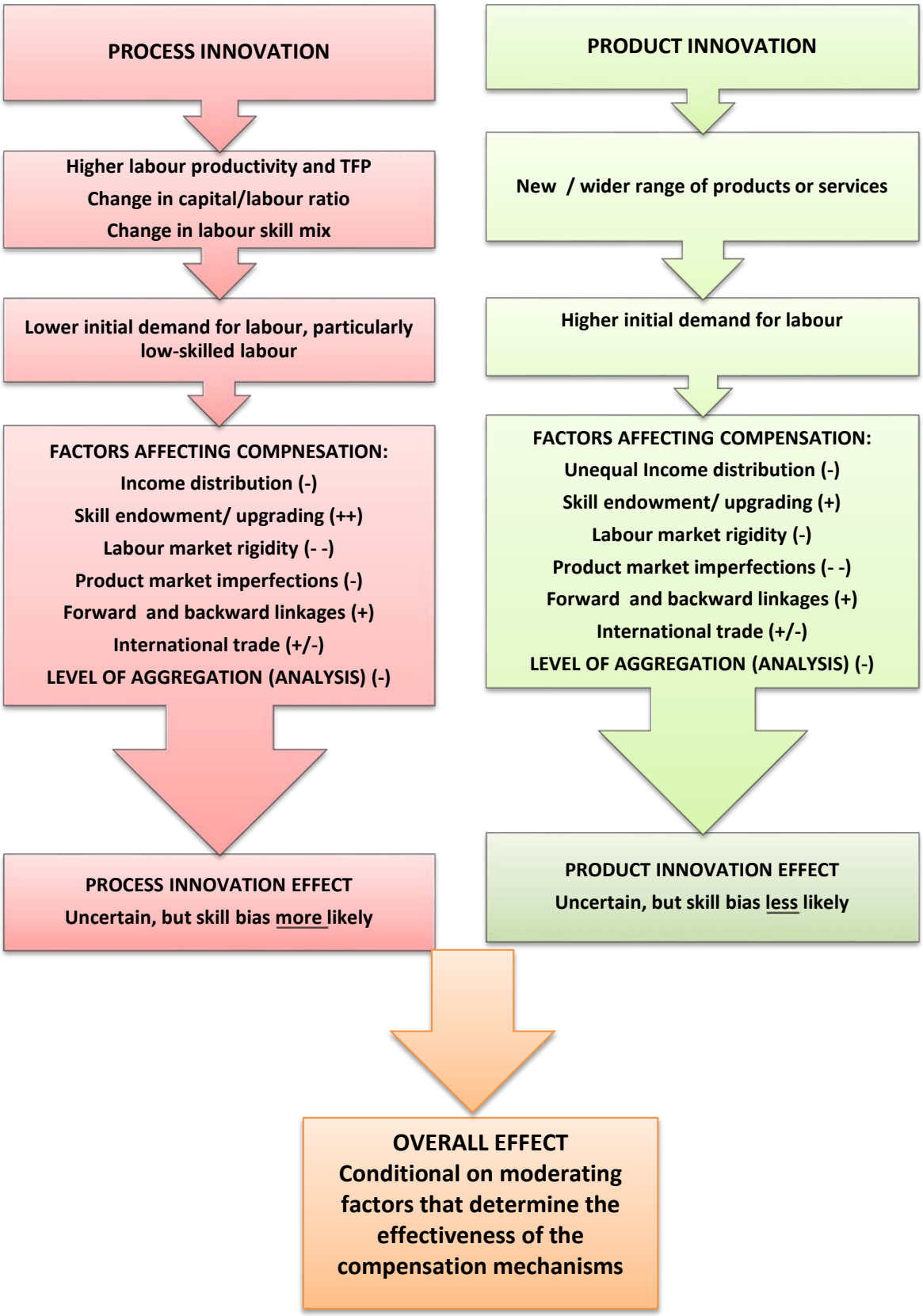
Innovation's employment effects are also mediated through backward and forward linkages (Hirschman, 1969). In the context of this review, backward linkages are strong when innovation generates demand for inputs from upstream firms or industries that supply the innovative firms or industries. On the other hand, forward linkages are strong when goods and services produced by innovative firms or industries are utilised as inputs by downstream firms or industries. Innovation is more likely to have a positive employment effect the higher is number of forward and backward of linkages between innovative firms/industries and the rest of the economy.

International trade is another mediating factor. James (1993) suggests that export can be considered as a kind of forward linkage that enables innovative firms and industries to create employment. However, the majority of the related literature draws attention to negative employment effects via imports channel. This literature demonstrates that innovation is more likely to be associated with job losses when imported technology is capital intensive and/or skill-biased (Jacobson, 1980; Mitra, 2009). However, such adverse effects should be considered in the light of positive effects on skilled labour employment (Conte and Vivarelli, 2007).

Finally, income distribution is also reported as a relevant factor that influences the relationship between innovation and employment. Work in Keynesian tradition (Pasinetti, 1981; Boyer 1988) demonstrates that part of the gains from innovation may be appropriated by labour. As wage increases, aggregate demand increases and this eventually leads to higher output and employment. On the other hand, Aryee (1984) demonstrates that higher levels of income inequality induce firms to adopt skill- and capital-intensive technology that can be deployed in the production of goods for high-income end of the market.

A condensed version of the synthesis framework in table 1.2.1 will be used for extracting and synthesizing evidence from empirical studies. The choice of a condensed version, as depicted in Figure 1.2.1 below, is dictated by the small number of empirical studies on the innovation-employment relationship in LICs. To avoid the problem of having insufficient observations spread across 6 clusters, the evidence from empirical studies will organised within two clusters corresponding to two types of innovation - process and product innovation. Here, the level of aggregation/analysis is included as a moderating factor rather than as a content identifier. The negative sign associated with this moderating factor indicates that the effect of innovation on employment is dampened or becomes negative as the level of aggregation increases from enterprise to industry/sector and macro levels.

Figure 1.2. 1: Synthesis framework for empirical studies: Employment effects by innovation type



The figure indicates that process innovation leads to new production processes and organisational structures; with primary effects on productivity, capital-labour ratio and skill mix. On the other hand, product innovation is conducive to wider range of products and services. Here the effect on employment is conditional on increased demand for the innovator's goods and services as well as the likely fall in the demand for goods and services of non-innovators. Initially, process innovation is labour saving as it increases productivity and enables firms to produce the same level of output by less labour input. Therefore, the initial employment effect of process innovation is more likely to be negative. In contrast, the initial effect of product innovation can be expected to be positive as innovative products enable innovators to increase output. However, these initial effects will then be mediated through the same range of moderating factors that determine the extent of the compensation (job-creating) effects. Therefore, even though product innovation can be associated with an initial positive effect, the final outcome remains uncertain.

1.4 Research background

The debate on the relationship between innovation and economic growth goes back to Schumpeter (1934), who coined the term 'creative destruction' to analyse the relationship between innovation, growth and competition. The work gathered a new momentum with the advent of endogenous growth theory (Romer, 1986) and the incorporation of innovation into growth models (Aghion and Howitt, 1992). Bardhan (1995) provides a comprehensive review of the work until mid-1990s. Another approach is that of labour economists, who explain changes in employment (and other labour market outcomes such as wages) by labour force demography, macroeconomic factors, wage costs, and labour market institutions (Vivarelli, 2007).

Pianta (2004) and Spiezia and Vivarelli (2002) and Vivarelli (1995; 2007) provide good reviews of both types of work on developed and developing countries. Piva (2003), on the other hand, focuses mainly on developing countries. The reviews provide four main conclusions:

- Type of innovation matters. While product innovation is generally found to have a positive effect on employment, process innovation tends to have a negative effect. Studies reporting such effects include Edquist (2001), Benavente et al (2006), and Jaumandreu (2003).

- Innovation-trade interactions matter. International trade may cause innovation to have a negative effect on employment in both developed and developing countries. The adverse effect in developed countries is due to imports of low-technology products from developing countries. The adverse effect in developing

countries is due to capital intensity and skill bias of imported technology. (See, Entorf and Pohlmeier, 1990).

- National innovation systems matter. Countries' technological opportunities and innovating capabilities are embedded in the characteristics of their national innovation systems. Therefore, the strengths, orientation, and priorities of the national innovation systems are likely to affect not only the innovation potential of the countries but also the extent of implementing new ideas, process and practices; with evident effects on employment (Hall et al, 2007).

- Labour market institutions matter. Employment outcomes of innovation and technological change are mediated through national labour market institutions that affect wages, training, and labour market flexibility. (See, Benavente et al, 2006).

These conclusions are based on evidence from developed and developing countries. The evidence base for LICs is small, but encompasses three types of work. First, there is an emerging body of research that uses aggregate measures of innovation such as technology import to estimate the effect on employment in manufacturing (Conte and Vivarelli, 2007; Mitra, 2009). Secondly, there is a long tradition of work on the relationship between technology adoption and employment in labour-intensive sectors such as agriculture or standard-technology sectors such as textiles other consumer goods industries (see, for example, Sing, 1972; von Braun, 1989; and Spielman et al, 2009). Finally, there is a wide range of 'grey literature' consisting of conference proceedings, country reports or policy background papers produced in or for LICs (see, for example, Economic Growth Centre, 1974; Schumacher, 1972; King, 1986).

This review is the first systematic attempt at locating this wide-ranging literature and synthesizing its findings. As such, it will provide an objective and verifiable synthesis of what we know about the innovation-employment relationship in LICs; and derive evidence-based policy and future research implications.

1.5 Authors, funders, and other users of the review

This systematic review is funded by the Department for International Development (DFID). DFID supports systematic reviews with the aim of supporting evidence-based decision-making in the area of international development. DFID considers the production and dissemination of systematic review evidence as a public good; and as a

means of developing a rigorous account of which interventions work and under what conditions.[1]

The review team consists of three researchers with expertise in innovation, employment and systematic reviews. Dr Denise Hawkes has conducted a systematic review on education, skills and growth; and has published work in the area of employment.[2] Professor Arup Mitra has published work in the area of innovation and employment.[3] Dr Ugur is co-convenor of the Cochrane and Campbell Collaboration Economics Methods Group (CCEMG) and has conducted two systematic reviews on international development.[4] The review team has received methodological and technical support from the EPPI Centre of the Institute of Education and from the Meta-Analysis of Economics Research Network (MAER-Net).[5] We have also received support from two information specialists at the University Greenwich Library – Mr Fraser Nicolaides and Mr William Robley; and from Mr Sefa Awaworyi as research assistant.

The advisory board for this review consists of one systematic review specialist one topic specialist. Dr Ian Shemilt is co-convenor of the Cochrane and Campbell Collaboration Economics Methods Group (CCEMG) and has published extensively in the area of systematic reviews and economics evidence synthesis.[6] Professor Mario Pianta is major contributor to the literature on innovation and employment in developed and developing countries.[7]

[1] DFID, Systematic Reviews in International Development : An Initiative to Strengthen Evidence-Informed Policy Making, http://www.dfid.gov.uk/what-we-do/research-and-evidence/case-studies/research-case-studies/2011/systematic-reviews-background/

[2] For information on Dr Hawkes' work, see: http://gala.gre.ac.uk/cgi/search/simple?screen=Public%3A%3AEPrintSearch&_action_search=Search&q_merge=ALL&q=hawkes&order=-date%2Fcreators_name%2Ftitle

[3] For information on Professor Mitra's work, see: http://www.iegindia.org/

[4] For information on Dr Ugur's work, see: http://ideas.repec.org/e/pug9.html. See also, http://gala.gre.ac.uk/cgi/search/simple?screen=Public%3A%3AEPrintSearch&q_merge=ALL&q=ugur&order=-date%2Fcreators_name%2Ftitle&_action_search=Search

[5] See, http://eppi.ioe.ac.uk/cms/ and http://www.hendrix.edu/maer-network/

[6] For Information on Dr Shemlit's work, see: http://www.medschl.cam.ac.uk/gppcru/index.php?option=com_content&id=521%3Ashemilt-ian&Itemid=82&catid=29%3Abehaviour-and-health-research-unit

[7] For information on Professor Pinta's work, see: http://ideas.repec.org/d/feurbit.html

2. SYSTEMATIC REVIEW METHODOLOGY

2.1 Type of review

Using EPPI-Centre's systematic review typology (Gough, 2007), this systematic review can be described as *user-driven*. It aims to provide a synthesis of the empirical and qualitative evidence on the relationship between two types of innovation (process and product innovation) and three types of employment (employment skilled, unskilled and mixed-skill labour). In terms of depth and bread, it is a full systematic review of the literature on the relationship between innovation and employment in LICs. The review includes studies published between 1970 and June 2011.

Study selection is conducted in three stages:

> Stage 1: Identification of relevant studies on the basis of **PIOS** (population-intervention-outcome-study design) criteria, using **title and abstract information** for all search results
>
> Stage 2: Inclusion/exclusion of studies on the basis of **PIOS** criteria and **full-text information**
>
> Stage3: Critical evaluation of included studies using validity-reliability-applicability (**VRA**) criteria.[8]

In terms of method, it is a mixed-method review that maps the narrative synthesis of the qualitative evidence with meta-analysis of the effect-size estimates reported in empirical studies. Combining meta-analysis with narrative synthesis can enhance review quality for two reasons. First, the narrative synthesis allows for contextualising the cause-effect relationship and for revealing the effects of moderating/mediating variables. Secondly, meta-analysis allows for deriving synthesized conclusions from diverse sources and for quantifying not only the overall effect of innovation on employment but also the effects of the moderating/mediating factors.

2.2 User involvement

DFID is a major actor in international development, providing aid, policy advice, and impact assessment. The Department expects systematic reviews to provide transparent and replicable evidence that enhances the policy-makers' capacity to design and implement evidence-based policy interventions. DFID also consider the '... creation and dissemination of systematic reviews as public goods' (http://www.dfid.gov.uk/R4D).

[8] PIOS and VRA criteria are explained in sections 2.3.2 - 2.3.4 below.

We have held one consultation meeting and two conference calls with DFID Policy Leads, MAER-Net representatives and representatives from the EPPI-Centre. In the consultation meeting we have clarified the review question and extended the range of innovation indicators to include TFP growth as a measure of innovation. In the first conference call, we discussed the indirect nature of TFP as an innovation measure and the need for a clear, accessible and informative exposition of how/why and to what extent innovation may affect employment. In the second conference call, we agreed on the feasibility of conducting meta-analysis of two types of estimates reported by included studies: elasticities where reported; and partial correlation coefficients (PCCs) for other estimates.

In the light of these deliberations, we have incorporated TFP as a measure of innovation in our search strategy. However, we could not include any study that examines the relationship between TFP and innovation. A World Bank Working Paper that examines the effect of firm-level TFP growth on employment (Dutz et al, 2011) could not be included in this review because its sample does not differentiate between firms from LICs only and firms from mixed countries. In addition, the study does not control for wage levels in its estimation of TFP's effects on the level of employment.

To analyse innovation's gender effects on employment, we have included 'female employment' and its synonyms in our search terms. However, the search has yielded only four studies that could be included: Ahmed (1987); Bhalla (1989); Billings and Arjan (1970); and Tuyen (1998). As these are qualitative studies, we have synthesized their findings as part of the narrative synthesis.

Our search strategy allows for identifying studies on formal and informal employment; as well as underemployment in LICs. This is because we have selected a wide range of search terms that capture the dimensions of the research in labour economics. As can be seen in ***Table A2.2.1*** in ***Appendix 2.2***, the search terms include not only general terms such as 'employment' and 'unemployment' but more specific terms such as 'labour', 'factor demand', or 'labour mobilisation. Nevertheless, the search yielded only a few studies that address these issues (Annable, 1971; Richards and Ramezani, 1990; and Sharma, 1990). Their findings relate to effects of innovation on rural-urban migration and the resulting labour market segmentation and underemployment in urban areas; and are incorporated in the narrative synthesis.

In this review, we investigate the effects of innovation on three types of labour: skilled, unskilled and total labour. However we do not investigate the effects on wages. This is because our investigations prior to completion of the Protocol have indicated that the literature on LICs tend to focus on the level and composition of employment rather than wages. That is why we have indicated in the Protocol that this systematic review will focus only on the employment effects of innovation (see Protocol, p. 7).

Our search and selection process has confirmed that studies tend to focus mainly on the level of employment. Sporadic references to wage structure and income distribution have been synthesized in the narrative synthesis and indicate the following: (i) innovation tends to increase the wages of skilled labour at the expense of unskilled labour; and (ii) innovation, especially in agriculture, tends to increase the incomes of the poorest but does not reduce the income disparity (see, for example, Ahmed, 1988; Baker and Jewitt (2007); De Klerk (1984); and Jacobsson, 1980).

2.3 Identifying and describing studies

2.3.1 Search strategy

We have followed an inclusive search strategy to capture a wide range of studies. The search in electronic databases yielded 4,055 results, which we have uploaded on to *EPPI-Reviewer*. These results were obtained by using 24 search terms for innovation as the intervention variable, 20 terms for employment as the outcome variable and 20 terms for LICs as population (see ***Appendix 2.2***). The search strategy was informed by two aspects of the evidence base. First, the literature uses different measures and types of innovation and employment; and the descriptor for low-income countries has changed significantly over time. Secondly, we wanted to capture studies that investigate the employment-effects of innovation not only in manufacturing but also in agriculture.

We have searched in 30 databases, the list of which is given in **Table A2.3.1** in ***Appendix 2.3***. The database list is informed by our research experience, recommendations by EPPI-Reviewer staff at the Institute of Education, and Librarians at the University of Greenwich. In three databases that support complex searches (*Business Source Premier*, *EconLit*, and *IBSS)*, we searched in 'Title', 'Abstract', 'Keyword' and 'All' fields as standard. In the case of *JSTOR*, we searched in the 'Abstract' only and in four iterations. This was due to restriction that the search engine imposes on the number of search terms can be used. The Abstract filed was chosen because it yielded the highest number of hits. In *Web of Knowledge,* we restricted the search to title and abstract as the search results yielded a high proportion of duplicates with previous searches.

The remaining databases represent a mixture of databases specialised in working papers (e.g., NBER, SSRN, RePec), two databases for PhD theses, and a number of collections specialised in development studies (e.g., the British Library for Development Studies collection, and the International Development Abstracts). The search engine for these databases allow for simple searches only, which we conducted by using the search terms indicated in ***Table 2.2.1*** of ***Appendix 2.2***. Most of these databases contain a large

volume of the so-called 'grey literature', which consists of working papers, reports, and policy documents. We searched in grey literature databases not only because of the need to minimise the risk of selection bias, but also to cast a wide net and compensate for the small volume of studies on the innovation-employment relationship in LICs. As a result, we were able to locate published and unpublished studies not only on manufacturing but also on technology adoption and the green revolution in agriculture. We have ensured that grey literature studies satisfied the same quality assessment and critical evaluation criteria as published/mainstream studies.

In addition, we hand-searched journals and conference proceedings on innovation and employment. This manual search was conducted by going through the content pages of six journals listed in ***Table A.2.3.2*** in ***Appendix 2.3.*** We have also conducted manual search of the conference site that focus on the relationship between innovation and employment – namely the United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT) conference series (http://www.merit.unu.edu/MEIDE/).

We have also searched in *Google Scholar* and conducted ISI citation search in *Web of Knowledge* to identify relevant studies. For hand search, we have drawn on guidance and recommendations provided by Joanna Briggs Institute (JBI, 2008) and Centre for Reviews and Dissemination (CRD, 2009).

We have encountered two issues during the search process. The first relates to inclusion of country terms aiming to capture the literature on LIC. Country terms were not used in electronic search of some database (e.g., *J-Store* and *Web of Knowledge*). In the case of *J-Store* the search facility of the database required a large number of iterations to include the country names. We have decided to not to follow this route by leaving the country specification open. This has produced a larger volume of search results that include both LICs and non-LICs; and we de-selected the non-LIC studies during the PIOS selection process. In the case of *Web of Knowledge*, the inclusion of country terms led to an unexpectedly low number of hits. Therefore, we have decided to leave the country specification open and de-select the non-LIC studies during PIOS screening.

The second issue relates to high levels of duplicates we obtained when we conducted the search in *Web of Knowledge*. This search was conducted after the search in other databases such as *EBSCO*, *Econ-Lit*, *IBSS*, etc. Given the overlap between the sources covered in these databases and *Web of Knowledge*, we observed a high level of overlap between the hits obtained from previous searches and the *Web of Knowledge* search. Therefore, we restricted our Web of Knowledge search to title only to minimise the overlap problem. This change was effective in reducing the number of duplicates, but the ratio of duplicates to total number of hits remained high at 47% (see ***Table A.2.2.1*** in ***Appendix 2.2***).

2.3.2 Screening studies: applying PIOS criteria with title/abstract information

We screened the electronic search results (4,055 hits in total) on the basis of title and abstract information, using the first-stage PIOS criteria. The PIOS criteria capture study characteristics that relate to **P**opulation, **I**ntervention, **O**utcome, and **S**tudy design.[9] Two reviewers (Dr Hawkes and Dr Ugur) carried out the screening independently. Before independent screening, we conducted a pilot of 10 studies to test whether the selection criteria were being interpreted reliably and consistently; and whether the criteria were effective in identifying the relevant studies. This is in line with CRD (2009: 24) recommendations, which indicate that piloting and independent screening increases the chance of selecting all relevant studies and ensures that the selection procedure can be repeated by third parties, if necessary.

There was 85% congruence between the decisions of the two reviewers. The discrepancy of 15% was due to incomplete information provided in the title and abstract. We agreed that it would be better to err on the inclusion side and decided to include a study for the next stage if the title/abstract information was not sufficient to assess the study with respect to all criteria.

To apply the **PIOS** criteria, we have interrogated the title/abstract information for each study with the following questions. A study has been included for second-stage evaluation if it satisfied all four questions – as specified in the Protocol.

For **population** criterion:

- Is the study relevant for understanding the innovation-employment relationship in low-income countries (or synonyms)?

For **intervention** (innovation) criterion:

- Is innovation (or synonyms) independent rather than outcome variable in the study?

For **outcome** (employment) criterion:

- Is employment (or synonyms) outcome rather than independent variable in the study?

For **study type/design** criterion:

- Is the study original and NOT a review of original studies?

[9] The **PIOS** framework draws on the ***PICOS*** framework recommended by the Centre for Reviews and Dissemination (CRD) of the University of York (CRD, 2009). Although the ***PICOS*** framework has been developed for systematic reviews of randomised-control trials (RCTs) in health care, we have adapted it to systematic reviews of observational or qualitative studies by dropping the 'Comparator' (C) criterion.

The decisions are based on **PIOS** codes created in *EPPI-Reviewer*. The box for a given code is ticked when the study *failed* to satisfy a given criterion implied by the question. The first-stage screening has led to inclusion of 700 studies for full-text evaluation in stage 2. The breakdown of PIOS criteria *not* satisfied by de-selected studies is given in Table 2.1 below.

Table 2. 1 : Stage-1 screening using PIOS criteria on 4,055 search results

Criteria	**Number of studies NOT satisfying the criteria**
Population criterion	1184
Intervention criterion	1883
Outcome criterion	1990
Study design criterion	747
De-selected	***3355***
Selected for stage 2	**700**

2.3.3 Identifying studies: applying PIOS criteria with full-text information

We uploaded the full text of 700 studies into *EPPI-Reviewer* and used stage-two the **PIOS** criteria on full-text information. At this stage, we have also conducted hand search as we gathered more information about major contributors to the literature and the range of journals that tended to publish articles on innovation-employment relationship. We identified 22 studies through hand search and added them to the 700 studies selected in the first stage. The majority of the hand-searched article consisted of working papers (e.g., Berman and Machin, 2000; Berman et al., 2005; Naroula, 2004), some of which were included after the critical evaluation.

We applied stage-two **PIOS** criteria to 722 studies. The full-text information revealed that a large number of studies (343 in total) were duplicates. These duplicates had not been picked up either by *EndNote* or by *EPPI-Reviewer* because of discrepancies in bibliographical information or because a revised version of a working paper was published as a journal article using the same data/evidence. We excluded these duplicates manually, leaving 379 studies for detailed evaluation. The results of stage 2 evaluation are given in Table 2.2 below.

Table 2. 2 : Stage 2 inclusion/exclusion decisions using PIOS criteria on 379 full-text studies

PIOS criterion	Question	Studies NOT satisfying the criterion
Population	Does the study have a theoretical/analytical framework that applies to LICs or low-middle-income countries (LMICs); or does it use data on LICS exclusively or together with LMICs?	165
Independent Variable	Is innovation independent variable and does it conform with the definition in the protocol?	81
Outcome	Does the study report innovation effects on employment, and not on other labour market outcomes such as wages or skills only?	120
Study Design	Does the study have a clearly set out theoretical framework linked to quantitative or qualitative evidence?	
	OR	85
	Does the study have a clearly set out empirical framework tested with quantitative evidence?	
	Total excluded	***299***
	Included for stage 3	**80**

A study was included in the review if it satisfied all stage-two PIOS questions. Included studies were coded as qualitative/analytical (QA) or empirical (EM). We coded a study as QA if it analysed the impact of innovation on employment through mathematical, diagrammatical or verbal models; or if it provided only descriptive statistics that are unsuitable for meta-analysis. We coded a study as EM if it provided empirical evidence that consisted of regression estimation results suitable for meta-analysis.

2.3.4 In-depth review: application of validity-reliability-applicability (VRA) criteria

At this stage, two reviewers evaluated the included studies (80) independently on the basis of **V**alidity, **R**eliability and **A**pplicability (**VRA**) criteria. In this review, *validity* refers to methodological rigour that would minimise the risk of bias; *reliability* refers to the extent to which the findings of the study are re-producible; and *applicability* refers to the extent to which the findings can be generalised/applied to low-income countries.

To pass the **validity** test, a study must have a valid *construct* and a valid *method*. The construct consists of concepts, notions and hypotheses that postulate the relationship between innovation and employment; whereas the method involves the kind of evidence and analysis used to test the hypotheses for the innovation-employment relationship. An empirical and/or qualitative/analytical study was considered to satisfy the *construct validity* requirement if it was based on a coherent set of arguments on why innovation can be expected to affect employment, and if these arguments were clearly related to existing literature. The study was considered to satisfy the *method validity* criterion if its evidence/data was documented and its method of analysis was clearly defined.

For **reliability**, the qualitative or quantitative evidence used in the study must be collected and analysed on the basis of a clear methodology and the results must be replicable. We considered a study to satisfy the reliability criterion if: (i) its evidence base was documented; (ii) the evidence was related to postulated causal mechanisms at work in the innovation-employment relationship; (iii) the analysis controlled for other relevant variables that impact on employment; and (iv) the findings were discussed in the light of existing literature.

To satisfy the **applicability** criterion, the findings of the study must be applicable to low-income countries. We have considered a study to satisfy this criterion if: (i) it was based on evidence from LICs as currently defined by the World Bank; or (ii) the study used pre-1995 evidence on some lower-middle income countries (LMICs) such as India or China that then had similar per-capita income levels to current LICs.

The VRA criteria were applied independently by two reviewers following a pilot of 5 studies. As indicated in Table 2.3 below, the in-depth evaluation of the studies on the basis of VRA criteria led to inclusion of 62 studies for this review.[10]

[10] The draft report was based on 63 studies, including Suryahadi et al. (2001). However, we have decided to exclude this in during the revision of the draft Report upon recommendation from the reviewers. The study is excluded on the grounds that its measure of employment (which is the share of labour in total cost) is not compatible with the definition of employment adopted in this review.

Table 2. 3 : VRA criteria for final inclusion

VRA Criteria	Question	Studies NOT satisfying the criterion
Validity of construct	Is innovation-employment relationship theorised/modelled coherently and in the light of existing literature?	2
Validity of method	Is the method of analysis informed by existing theory/theories?	1
Reliability of data/evidence (1)	Is data/evidence documented and its reliability discussed?	4
Reliability of data/evidence(2)	Is the evidence related to causal mechanisms postulated in the innovation-employment relationship?	1
Reliability of estimation	Are other relevant variables that impact on employment controlled for?	6
Reliability of findings(1)	Are the findings tested for robustness?	
Reliability of findings(2)	Are the findings related to relevant methodological or theoretical/analytical literature?	2
Applicability to LICs	Are the findings applicable to low-income countries on theoretical or empirical grounds?	2
	Total excluded	18
TOTAL INCLUDED IN THE REVIEW	**80 – 18 =62**	
of which:		
Qualitative/Analytical	**53**	
Empirical	**9**	

2. 4 Synthesis of evidence

In this review, we map the empirical and qualitative findings systematically by following the mixed method proposed by Harden and Thomas (2005). Qualitative synthesis compensates for the limited extent to which contextual factors can be incorporated into quantitative meta-analysis. On the other hand, meta-analysis allows for synthesizing the empirical evidence form diverse studies, controlling for the effects of contextual factors that can be measured.

For synthesizing the qualitative evidence, we draw upon the *narrative synthesis* methodology discussed in CRD (2009) and Popay et al (2006). According to the latter, narrative synthesis is a method of summarising and explaining *qualitative evidence* from multiple studies that are dissimilar in terms of conceptual used and/or questions asked. The narrative synthesis enables reviewers to: (i) develop a theoretical account of how the intervention works, why and for whom; (ii) develop a preliminary synthesis of findings in included studies; (iii) explore the effects of the mediating factors on the reported outcome; and (iv) evaluate the robustness of the synthesis derived from meta-analysis (Popay et al, 2006: 10-11).

To extract qualitative evidence for the narrative synthesis, we used thematic (vertical) and content (horizontal) identifiers that would enable us to capture the dimensions of the research field. The thematic identifiers capture two innovation types: process and product innovation. Content identifiers, on the other hand, relate to the level of analysis – i.e., they reflect whether the primary study analyses the innovation-employment relationship at the firm/farm, sector or macro levels. Hence, we evaluated and synthesized the evidence within a maximum of six clusters in the 2x3 matrix of identifiers. Each cluster includes evidence that corresponds to a unique combination of innovation type and level of analysis. We repeated this exercise twice: once for agriculture and once for manufacturing sectors. The synthesis within each cluster pays attention to the role of displacement (job-destruction) and compensation (job-creation) mechanisms as well as the moderating factors that affect the balance between the two (see, *Table 1.2.1* above).

We synthesize the evidence on innovation and female labour as a separate cluster in Section 4.2.10.

In the narrative synthesis, the moderating factors we account for include the different types of labour (skilled, unskilled and all-skill labour, female labour); institutional factors; international trade and finance; income distribution and the role of forward/backward linkages. The narrative synthesis is presented in Section 4.2 below; and structured study abstracts are given in ***Appendix 4.1.***

Meta-analysis, on the other hand, is a statistical method for synthesizing large volume of often divergent and heterogeneous empirical evidence (effect-size estimates) reported in primary studies. It offers a quantitative and transparent alternative to conventional literature reviews; and can be used either to verify a given hypothesis or to derive a synthesized 'effect size'; as well as identifying the sources of heterogeneity in the evidence base. It has significant potential for supporting evidence-based policy and practice. Recently, its relevance has increased as a result of two factors: (i) the exponential growth in the evidence base driven by increased data availability and data processing capacity; and (ii) increased need for evidence-based decision-making by public policy makers as well as business decision makers.

Although meta-analysis has been used widely and for a long time in medicine and public policy, its use in economics and international development is relatively recent. After the pioneering work in environmental economics in the 1980s, meta-analysis is now applied in labour economics, international development, industrial organisation, management and marketing.

Meta-analysis has three distinct advantages. First, it allows for integrating and synthesizing evidence with transparent and verifiable statistical tools. Secondly, it enables researchers to synthesize the effect of policy interventions after controlling for reporting (or publication selection) bias, which may be due to predisposition of authors and journal editors to publish statistically-significant results. Third, it also enables researchers to control for moderating factors that may explain the variation in reported effect-size estimates. The moderating factors could include both study characteristics (e.g., study design, estimation method, sample size, time period, etc.) and other control variables suggested by relevant theories. (For further discussion on meta-analysis in economics and business, see Stanley, 2006; Stanley and Jarrell, 2005; Stanley and Doucouliagos, 2012).

For meta-analysis, we used the data extraction and synthesis framework depicted in *Figure 1.2.1* above. We extracted all effect-size estimates reported by each primary study, provided that the estimates measure the effect of innovation on employment. In other words, we did not extract estimates of the innovation's effect on wages or relative employment - e.g., employment of skilled labour relative to unskilled labour. Then, we coded each estimate to identify the innovation type (process versus product innovation), the skill type (skilled, unskilled and mixed-skills labour), the level of analysis/aggregation (enterprise, sector/industry and macro levels), and other moderating factors that characterise the research field and affect the balance between the effects of displacement and compensation mechanisms.

We opted to include all reported effect-size estimates because the alternative of selecting a 'representative' single estimate or a range of estimates preferred by the

authors is neither objective nor efficient. This is in line with the Protocol, where we had stated that 'selection' is rarely objective and there is no consensus within the literature on the 'best' estimation method on which the preferred estimate should be based. In addition, reliance on a single 'representative' estimate implies inefficient use of all available information. Inclusion of all reported estimates is in line with the best practice in meta-analysis of economics evidence (de Dominicis et al, 2008; Stanley, 2008; and Stanley and Doucouliagos, 2009).

In the meta-analysis section, we first provide fixed-effect (FE) and random-effect (RE) weighted means of the effect-size estimates reported in individual studies. In stage 2, we provide precision-effect and funnel-asymmetry tests (PETS/FATs) that allow for establishing the existence or absence of 'genuine effect' after controlling for reporting (publication selection) bias. Finally, we conduct meta-regression analysis (MRA) to establish if the employment-effect of innovation remains robust to inclusion of moderating variables such as innovation type, employment type, level of analysis, sectors, and publication type; and to quantify the effect of these variables on effect size estimates reported in primary studies. Strengths and shortcomings of each meta-analysis tool are discussed briefly in the meta-analysis section and in more details in ***Appendix 4.2.2***

The meta-analysis results are based on partial correlation coefficients (PCCs) and elasticities. One advantage of PCCs is that they allow for standardising all reported estimates – irrespective of the metrics that primary studies use to measure the innovation and employment variables. PCCs also have the added advantage of providing a measure of association between innovation and employment after controlling for the effects other explanatory variables used in the models of the primary studies. Against these advantages, PCCs have the drawback of having a truncated distribution between -1 and +1. In addition, they do measure the strength of the association between innovation and employment, but they do not measure the *percentage change* in employment that is due to innovation. (Stanley and Doucouliagos, 2012). Elasticities do provide such information, but they are reported only in a small number of studies. Therefore, we calculated PCCs for 147 estimates from a total of 9 empirical studies; and used a subset of 60 elasticities reported in 3 studies. Meta-analysis results are summarised and discussed in Section 4.3 below.

The fixed-effect (FE) and random-effect (RE) weighted means provide summary measures of the effect-size per study. However, these summary measures may be biased for two reasons. The first source of bias is due to within-study dependence. Multiple estimates reported by each study are not necessarily based on random samples. In fact, they are mostly based on the same dataset or sub-set used to obtain alternative estimates and conduct robustness checks. Secondly, the reported effect-size estimates do not tell us anything about those found and not reported. In other words, they may be subject to a selection bias. Therefore, we suggest that FE and RE weighted means should

be considered as descriptive indicators of the research field rather than as robust measures of effect.[11]

Therefore, the FE and RE weighted means are followed with precision-effect and funnel-asymmetry tests (PETs/FATs) to take account of selection (reporting) bias. The PET/FAT procedure allows for establishing if genuine effect exists after controlling for reporting bias, but the test is known to have low power. In other words, the PET/FAT may fail to detect reporting bias when the latter exists. In addition, PETs/FATs assume that reporting is the only source of bias. In other words, they do not model explicitly all sources of heterogeneity within the evidence base. We address this issue in the third stage of the meta-analysis by conducting meta-regression analysis (MRA) that also takes account of within-study dependence. In the MRA, we control for a range of moderating variables, including estimation methods, publication type, types of innovation, type of skills, and level of analysis.

[11] This is especially the case when the reported estimates are not based on observational data rather than randomised control trials (RCT) or quasi-experimental data.

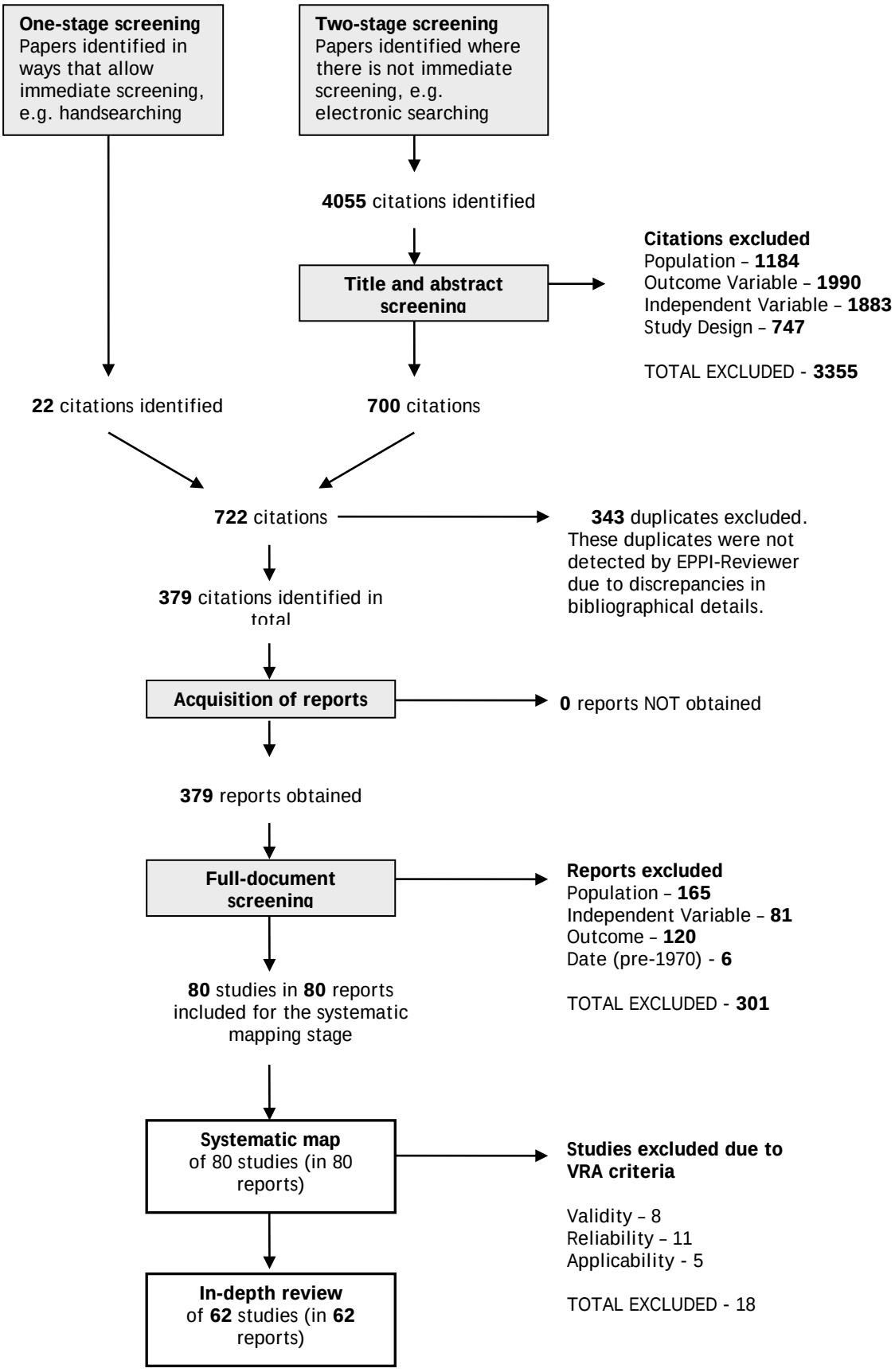
3. IDENTIFYING AND DESCRIBING STUDIES

3.1 Search and screening results

Figure 3.1 below depicts the search and screening process. As indicated above, the search in electronic databases yielded 4,055 records, which we first screened on the basis of title and abstract information. This first-stage screening led to selection of 700 studies for evaluation on the basis of full-text information. The second-stage evaluation included the 700 studies selected in the first stage and 22 studies located through hand search. The evaluation at this stage revealed that a large number of studies (343 in total) were duplicates. We excluded these duplicates manually, leaving 379 studies for detailed evaluation.

Stage-two evaluation led to inclusion of 80 studies for validity-reliability-applicability (VRA) evaluation in stage 3. We coded the included studies as qualitative/analytical (QA) or empirical (EM). We coded a study as QA if it analysed the impact of innovation on employment through mathematical, diagrammatical or verbal models and provided explanations of the causal mechanisms in the innovation-employment relationship. We coded a study as EM if its main contribution was to provide empirical evidence on the effect of innovation on employment. At the end of VRA evaluation, we have included 62 studies for in-depth review.

Figure 3. 1 : Filtering of papers from searching to map to synthesis



3.2 Characteristics of included studies

EPPI-Reviewer allows for coding and reporting a wide range of study characteristics. We have constructed two sets of study characteristics. One set contain *bibliographical characteristics* that consist of study type (qualitative/analytical, empirical), publication year, and publication type (journal article, working paper, book, thesis, etc.). The second set consists of *content characteristics* codes, which relate to: innovation types, levels of innovation analysis; sectors investigated, the world regions in which the sample countries are located; and types of employment analysed. These study characteristics constitute most of the moderating/mediating factors that may influence the reported employment-effects of innovation. Therefore, they are integral parts of this systematic review and shall be referred to in the meta-analysis and narrative synthesis sections below.

Table A.3.1.1 in ***Appendix 3.1*** provides summary statistics on bibliographical characteristics of included studies. It can be seen that 81% of the studies are journal articles. Meta-analysis literature indicates that authors and journal editors may be pre-disposed to publish statistically-significant results. (See, Card and Krueger, 1995; Stanley, 2008). Therefore, in the MRA, we control for 'journal article' as a potential source of bias that may inflate the innovation's effect on employment in a positive or negative way.

Content characteristics of included studies are summarised in ***Table A.3.1.2*** in ***Appendix 3.1.*** Included studies investigate the effect of innovation on employment in agriculture or manufacturing. Therefore, in the narrative synthesis and the MRA, we control for sector type as a potential source of heterogeneity in the evidence base.

The large majority of the included studies (84.8%) examine the effects of process innovation on employment. The preponderance of process innovation is due to shortage of firm-level data on product innovation. In the narrative synthesis and the MRA, we control for process and product innovation in order to quantify the effect of innovation type as a moderating variable.

Finally, included studies investigate the effects of innovation on skilled, unskilled and all-skills labour employment, albeit the majority report findings on the all-skills category. In the narrative synthesis and the MRA we control for skill type as an additional moderating factor.

4. IN-DEPTH REVIEW RESULTS

We organise the narrative synthesis on the basis of two thematic identifiers that capture the innovation types (process and product innovation) and three content identifiers that indicate whether the primary study analyses the innovation-employment relationship at the enterprise, industry/sector or macro levels. Within this framework, we pay attention to compensation and displacement mechanisms and the moderating factors that affect the balance the effects of the two mechanisms. The moderating factors include: skill types (skilled labour, unskilled labour, and mixed-skills labour); institutional factors; market characteristics; role of forward/backward linkages; income distribution, and role of international trade. The narrative synthesis is based on 53 qualitative/analytical studies. The findings are presented separately for agriculture and manufacturing in Section 4.2 below. Structured abstracts of the primary studies that inform the narrative synthesis can be found in ***Appendix 4.1.***

We present the meta-analysis results in Section 4.3. First, we provide fixed-effect (FE) and random-effect (RE) weighted means of the effect-size estimates reported in individual studies. This is followed with precision-effect and funnel-asymmetry tests (PETS/FATs) that allow for establishing the existence or absence of 'genuine effect' after controlling for reporting (selection) bias. Finally, we provide the findings from weighted least-squares (WLS) meta-regression, which enables us to identify the effects of the moderating factors and establish whether the employment-effect of innovation remains robust to inclusion of moderating variables.

In Section 4.4, we map the narrative synthesis with meta-analysis. In this exercise, we will establish the extent of convergence and divergence between qualitative and quantitative evidence; and identify the range of moderating factors that mediate the effect of innovation on employment.

4.2 Narrative synthesis of the qualitative evidence

The narrative synthesis is based on primary studies that use different types of conceptual frameworks, analyse evidence from different countries and time periods, and include both case studies as well as theoretical/analytical studies. Study distribution with respect to evidence type consists of 17 studies using qualitative/verbal evidence, 21 studies using survey and fieldwork evidence, and 13 studies using official statistics. In terms of method, the distribution consists of 11 studies using decomposition method, 23 using descriptive analysis and 17 studies using theoretical/analytical argumentation. Two further studies use official statistics, combined with simulation (Singh and Day, 1975) and labour-intensity ratio estimation (Mitra, 2009) methods. Finally, 85% of the

included studies investigate the effect of process innovation, with only 15% examining the effect of product innovation. In sum, the evidence base is characterised by a high degree of heterogeneity.

Narrative synthesis is considered as appropriate for synthesizing evidence from studies that are heterogeneous in terms of theoretical constructs, methods and data. This is because, instead of providing an overall summary measure for effect, narrative synthesis allows for explaining how the effect is contingent on dissimilar methods used and/or questions asked. Particularly, it is useful for identifying and explaining the causal mechanisms at work (Popay, 2006). In this review, we follow Popay (2006: 10-11) and utilise the narrative synthesis method to: (i) develop a theoretical account of how the intervention works and why; (ii) develop a preliminary synthesis of findings; and (iii) explore the effects of the mediating factors on the reported outcome.

Hence, in what follows, we first present background information on the narrative framework that informs the primary studies. Then we present a summary of the synthesis before discussing the primary study evidence on which the synthesis is based. This procedure is repeated twice: once for the literature on agriculture and once for the work on manufacturing. The qualitative evidence concerning the effects of innovation on female labour employment is synthesized separately.

4.2.1 Innovation and employment in agriculture: the context

Qualitative studies on the innovation-employment relationship in agriculture can be divided into three categories. One category consists of a small number of studies that investigate the effect of product innovation (mainly the introduction of high-yield variety seeds – HYVs) on employment. These studies examine the effect of HYVs on employment at the sector level. The second category includes studies that focus on a mix of process and product innovations (including mechanization, new irrigation methods, new feeds and HYVs) in the context of the Green Revolution (GR). The third category consists of studies that investigate only the effects of mechanization as a particular example of process innovation.

4.2.2 Product innovation and employment in agriculture: farm- and sector-level evidence

Only three studies provide findings on employment-effects of product innovation in agriculture. The evidence in these studies indicates that:

1. Introduction of HYVs tends to have a positive effect on farm and off-farm employment

2. The positive effect is higher if forward/backward linkages are strong
3. The effect is smaller or negative if wages are relatively high.

Barker et al (1972) investigate the introduction of HYVs in the Philippine rice production. The study reports that product diversification has led to slight increase in total labour input, but the effect tended to be smaller and even negative in regions with higher wages. A positive effect is also reported by Chand (1999), who investigates product diversification and its effects on rural and overall employment in Punjab, India. The study concludes that rural employment can increase significantly if production is shifted away from wheat and rice to feed-crop production and dairy farming. Such differentiation is more likely to create employment because of stronger forward and backward linkages in generates with the manufacturing sector in urban areas. However, local employment creation remains limited due to wage increases that follow the increased demand for labour. Innovative farmers tend to draw on labour from outside their region when local labour has strong bargaining power.

Finally, Ahmed (1987) analyses the effects of product innovation (use of HYVs) on male and female labour, taking into account the mediating effects of backward and forward linkages. The author reports that the relative demand for female labour would: (i) increase if the level of mechanisation remains the same; (ii) decrease if product innovation is combined with increased mechanisation.

4.2.3 Process innovation and employment in agriculture: farm-level evidence

The evidence on process innovation and employment at the *farm level* can be synthesized as follows:

1. Mechanization on its own tends to reduce the level of farm employment
2. Adverse effects mechanization are exacerbated as the farm size increases and when mechanization is used for ploughing and harvesting as opposed to sowing
3. Mechanization is associated with more adverse effects on family labour as opposed to hired labour and on young farmers as opposed to older farmers
4. The effect is more likely to be positive when mechanization is accompanied with product differentiation, extension of farm land, and strong forward/backward linkages between agriculture and manufacturing industries
5. Mechanization is associated with positive employment effects when it is combined with new irrigation methods and use of fertilizers
6. The effect is more likely to be positive when the evidence is on India compared to other countries

The studies that support this synthesis examine the relationship between process innovation and employment in India, South Africa and Thailand in the 1970s. Of these, Chopra (1974) is based on survey and interview evidence with 130 farmers in 13 villages of Punjab. Respondents tended to indicate that tractorization has had a negative effect on employment; but this is compensated by positive effects through extension of farmed land and introduction of new product varieties. Family labour input is reported to have increased by about 10 per cent, but the use of hired labour increased by about 40-80 per cent, depending on crop variety and season. The author suggests that strong forward and backward linkages between agriculture and non-farm sectors are likely to increase overall employment in the region.

Bhatia and Gangwar (1981) analyse the effects of new technology and farm planning on labour input in small farms in Karhal district of India. Using survey evidence for 965 small farms and linear programming techniques, the study reports that introduction of new technology only has uncertain effects on employment. However, when new technology is combined with new production plans and capital availability, the demand for labour would increase. This is found to be the case in three categories of small farms, ranging from the very small to medium-size farms.

Agarwall (1981) use data on 240 farms in 1971-72 in India and reports that employment-effects of process innovation depends on farm size and the type of operation (ploughing, sowing, irrigation and harvesting). One overall effect is reduced use of family labour. However, the reduction in family labour is accompanied with increased use of hired labour (casual or permanent). This effect is more pronounced in large farms. Farm size is also reported to have a mediating effect in another study on India. Lalwani (1992) analyses the effect of new feeds on labour use in milk production. Using a Cobb-Douglas production function and controlling for wages and output, the author reports that an increase in concentrated feed (new technology) can be expected to increase employment in large farms only, with negative or no effects in small and medium-size farms.

De Klrek (1984) uses survey evidence on 61 maize farms in South Africa to examine the employment-effects of technology change in maize farming. The study reports that mechanisation of harvesting and delivery, new weeding methods and use of fertilisers led to 20% fall in permanent employment and 50% fall in seasonal employment. The fall in seasonal employment was accounted for mainly by the fall in the number of male employees. Seasonal employment of women remained stable whilst that of children tended to increase.

Finally, Inukai (1970) investigates the effect of mechanisation and new farming techniques on labour input in rice production in Thailand. The author reports that technology change leads to fall in the number of labour-hours required in a given farming unit. This is based on static analysis of the survey data and field interviews.

However a dynamic analysis that takes account of income effects and forward/backward linkages suggests that the effect may be positive.

4.2.4 Process innovation and employment in agriculture: sector-level evidence

In this section, we provide the narrative synthesis based on 12 studies that examine the *sector-level effects* of process innovation on agricultural employment in India (7 studies), Philippines (2), Africa (1), the Middle-East and North Africa (1) and developing countries in general (1). The majority of these studies examine the innovation-employment relationship in the context of the Green Revolution (GR). The findings can be synthesized as follows:

1. The Green Revolution (GR) as a mix of process and product innovation tend to have uncertain employment effects in the short-run
2. In the long run (over 30-40 years), process innovation within GR tends to have positive effects on off-farm employment, but the effect on farm employment remains uncertain
3. Two mediating factors amplify the positive effect of the GR on off-farm employment: increased farmer demand for new products/services as income increases; and increased forward and backward linkages as farm output increases
4. The GR is likely to reduce the seasonality of employment;
5. Increased employment opportunities due to the GR have not been accompanied with improvements in income or wealth distribution.
6. When mechanization is combined with irrigation, the employment effect is positive in the case of gravity innovation but negative in the case of rain-fed cultivation

Ahammed and Herdt (1983 and 1984) analyse the net employment and income effects of mechanization in the Philippine rice production, using national income and input-output data for 1975. Assuming that there is no demand constraint, the innovation's *direct* employment effect is positive if production is switched from the traditional method to mechanised systems with gravity irrigation. The employment-effect is smaller or negative if mechanisation is introduced into rain-fed lowland production. The overall effect depends on the *indirect* effects that arise from production, consumption, and import substitution linkages. In cases studied, the indirect effects tend to offset the employment reduction from machinery adoption and reinforce the employment increase from irrigation intensification.

On Africa, Clayton (1972) reports that tractorization usually has a labour-displacing effect. The adverse effect is mild in Nigeria; but it is strong in Uganda, Tanzania and

Kenya in descending order. The adverse effect and its variation across countries depend on farm size and type of products. Similar findings are reported by Richards and Ramezani (1990), who examine the employment effects of mechanisation in the Middle-East and North Africa. These authors also report that mechanization tend to reduce employment overall and lead to change in the composition of the agricultural labour force. The change is due to migration of younger males into urban areas, with the consequence of more reliance on female labour and male farmers of older age.

Nair (1980) examines the evidence on a large number of developing countries and LICs. The author reports that mechanization can be expected to have a negative effect on employment levels. However, the displacement effect is offset by a compensation effect, whereby mechanization, combined with fertilizer use and irrigation, may increase employment. This positive effect is amplified by product innovation involving the use of HYVs. The author also reports that the negative effect on employment is likely to fall more on seasonal labour compared to permanent labour.

Sharma (1974 and 1990) reports that forward and backward linkages played a significant role in mediating the employment-effects of the GR in Uttar Pradesh. The GR initially increased interregional disparities between eastern and western Uttar Pradesh until mid-1970s. However, in the subsequent decade-and-a-half, the eastern region began to respond to the seed-water-fertilizer technology in the wake of improved infrastructure. Moreover, as rural incomes increased, a dynamic rural but off-farm sector has emerged in response to demand for local goods and services. These off-farm activities were characterized by high labour intensity and were centred in small and medium towns widely dispersed in rural areas. The experience of the four sample-villages indicated that the increasing participation of the landless and near-landless in off-farm activities has led to an improvement in their absolute incomes.

This finding is supported by Cepede (1972 and Ahmed (1988). Cepede (1972) relates the positive outcome to two factors: (i) backward and forward linkages induced by increased productivity and the income-effect this has on rural demand; and (ii) the impact of capital accumulation by innovative farmers. Both effects lead to expansion of off-farm sector from the demand side (farmers' demand for inputs as well as consumption goods) and from the supply side (supply of capital). In this context, skewed distribution of land emerges as a constraint on these compensation mechanisms. Therefore, Cepede (1972) argues that land reform is a necessary ingredient for ensuring that the GR is conducive to higher levels of employment. Singh and Day (1975) also report that the GR has created job opportunities distributed round the year.

Another assessment of the GR over time is provided in Barker and Jewitt (2007), who analyse the experiences of the villages in the Bulandshahr District of western Utra Pradesh over 35 years. Fieldwork in three villages reveals that the GR has been associated with urban development and led to improved employment opportunities.

However, the benefits of the GR technology are not equally spread: the poorest are better off, but the gap between the rich and the poor was greater than ever. These findings are in line with those of Sharma (1970 and 1990) indicated above; and with earlier finding reported by Wills (1972), who identified income and land inequalities as significant constraints on the employment effects of the GR.

Ahmed (1988) takes the debate further by invoking the concept of Biotechnology Revolution. Under the Biotechnology Revolution, plant and seed breeders in developed countries are likely to increase their control, but small farmers in LICs would be able to produce multiple crops over the year. The overall effect of the Biotechnology Revolution would depend on the balance between two conflicting effects: (i) the negative effect of monopolistic control on biotechnology in the North; and (ii) the positive effect of increased entry by small farmers in LICs.

4.2.5 Innovation in manufacturing: the context

A significant number of studies, especially those published in 1970s and first-half of 1980s are informed by the *appropriate technology* perspective. In this perspective, innovation in LICs can create employment only if imported technology is *adapted* to their skill, factor and resource endowments and income distribution. However, the scope for adapting imported technology in LICs is limited for two reasons. First, the local innovation capacity is limited. Secondly, local managers and policy-makers prefer to maximise productivity rather than employment gains.

The findings of the early literature are summarised in Baer (1976): (i) factor-price distortions in LICs encourage the selection of capital-intensive technology; (ii) existing technologies do not match factor supplies in LICs; (iii) technology adaptation in LICs is limited due to low level of research and development by local firms and/or governments; and (iv) skewed income distribution results in a consumer demand profile that favours the establishment of industries with capital-intensive technologies. The overall conclusion is that innovation in LICs is likely to have adverse effects on employment; or the innovation-induced employment is not likely to be large enough to absorb the excess labour supply in LICs.

Technology adaptation is a useful concept that helps understanding the structural and motivational factors that limit the scope for choosing the right technology in LICs. Nevertheless, the usefulness of the concept is limited for two reasons. First, there is no commonly-agreed method that could inform policy-makers to choose the optimal trade-off between productivity and employment gains from innovation. Secondly, over-reliance on technology adaptation discourages appropriate analysis of the complex set

of displacement and compensation mechanisms that determine the employment-effects of adapted technology.

Amartya Sen's seminal contribution in 1974 provides a more nuanced framework aimed at addressing the first shortcoming. Sen proposes that the policy-maker's objective should include a set of employment targets, including: informal sector employment, female employment, family employment, seasonal/casual employment and regular wage employment. He also addresses the second shortcoming by demonstrating that technology, institutions and employment are inter-related. Even if 'appropriate technology' can be identified and even if it is economically efficient, it may not lead to employment creation unless adequate institutions and decision-making criteria exist to facilitate the choice of appropriate factor- and product-mix that generates employment. Therefore, Sen argues, firms in developing countries should make use of available technologies (i.e., they should choose from the 'technology shelf') and concentrate on how these can be adapted to maximize employment.

There is a degree of congruence between these early findings and the findings of the studies reviewed here. However, the narrative synthesis below demonstrates that there are also significant differences. For one, studies reviewed here pay special attention to a range of moderating factors that affect the balance between displacement and compensation effects of innovation, including institutions, forward and backward linkages, and international trade. Secondly, they also differentiate between product and process innovation as well as between effects on different skills.

4.2.6 Product innovation and employment in manufacturing: firm-level evidence

Only two studies analyse the effect of product innovation on employment - Agbesor (1984) on two companies in Nigeria and Aryee (1984) on footwear industry in Ghana. Both studies use firm-level evidence and report that product innovation is associated with employment creation and this positive effect is more likely if:

1. Product innovation creates new markets by catering for local needs;
2. It generates forward linkages through new distribution/dealership networks;
3. It leads to second-round innovation in marketing and product development;
4. Product innovation responds to increased incomes of low-income groups as opposed to high-income groups; and
5. The new technology is skill-matching - i.e., it is standard, semi-automatic and labour-intensive;

Agbesor (1984) is a case study of two manufacturing companies (a bicycle manufacturer and a cooking appliance manufacturer) in Nigeria. These companies had chosen their technology by taking into account the supply of local labour, its skill levels and the availability of local inputs. The companies created forward linkages through a wider product range (e.g. manufacturing of bicycle ambulances for use in rural areas, electric cookers and deep fryers); and a wider network of dealers. Comparison between the two manufacturers reveals that the positive effect on employment is stronger the wider is the range of product innovations.

Aryee (1984) draws on survey evidence to show that existing patterns of demand for footwear is dependent on income distribution. Low-income groups tend to demand low-priced products, but an increase in income levels leads to increased demand for higher-price and fashionable footwear. Hence, new technologies introduced by large-scale firms lead to increased employment only if it is accompanied with increase in income of low-income groups. This is for two reasons. First, the expenditure-budget share allocated to footwear is roughly the same in middle- and high-income groups. Secondly, the expenditure-budget share increases only when one moves from low- to middle-income category.

4.2.7 Process innovation and employment in manufacturing: firm-level evidence

Three studies investigate the effects of *process innovation* on firm-level employment. Ekwere (1983) analyses the scope for job creation in small textiles industries in Nigeria, using field survey evidence. Usha (1985) examines the effects of the Export Trade Control Order of 1973 in India on the innovation-employment relationship in the footwear industry. Braun (2008) analyses the interaction between economic integration, product and process innovation, and relative skill demand in a model of international oligopoly.

The evidence from firm-level studies can be synthesized as follows:

1. Firm-level process innovation in LICs is characterized by skill-bias and capital-intensity;
2. International trade tends to exacerbate the substitution of employment away from unskilled- towards skilled-labour; and
3. Weak institutions inhibit the choice of labour-absorbing technologies and/or exacerbate segmentation in the labour market.

Ekwere (1983) argues that the 'technology shelf' hypothesis of neoclassical economics does not hold for small textiles firms. These firms can choose only between handloom and fly-shuttle loom technologies. The restricted choice is due to high levels of capital

investment required to adopt more advanced technologies. The fly-shuttle technology could increase productivity by five-folds without reducing the demand for labour or requiring change in the required skill set. Hence, expansion of small and labour-intensive firms can create more employment than that of large and capital-intensive firms. However, lack of capital prevents the expansion of small and labour-intensive firms. To address the capital constraint, a 'Small-Scale Industry Development Program' was introduced in the 1970s, but the scheme proved ineffective due to institutional weaknesses.

Usha (1985) examines the patterns of process innovation in Tamil Nadu (India) in the wake of the Export Trade Control Order of 1973, which aimed to encourage the use of new technologies for exporting high value-added products. The author reports that subsequent technological change in the leather industry has led to substitution away from workers with traditional skills. This was compensated by employment of new workers. The larger the tanneries are, the greater is the degree of mechanisation and the larger is the scope for entry of new workers. However, the entry of new workers led to segmentation of the labour force: whilst new workers did the better jobs in the finishing side of the production process, old labour did the less pleasant work in tanneries. The author reports that India's institutional norms have contributed to this segmentation: firm owners/managers had given preferential treatment to new workers on the basis of ethnic and religious affiliations.

Finally, Braun (2008) demonstrates that innovation in developing countries increases the relative demand for skilled workers who are in short supply; but reduces the demand for unskilled or semi-skilled labour that is in excess supply. This asymmetry is exacerbated by the firms' tendency to invest more heavily in process innovation in order to increase productivity and competitiveness. International trade and integration are additional factors that exacerbate the skill-bias of innovations in developing countries. The skill-bias may not lead to fall in employment overall, but would limit the benefits to skilled-labour that is relatively in short supply.

4.2.8 Process innovation and employment in manufacturing: sector-level evidence

We have reviewed 12 studies that examine the effects of process innovation on employment at the industry/sector level. The findings can be synthesized as follows:

1. Choice of appropriate technology matters as technology choice involves a trade-off between productivity and employment
2. The optimal technology choice depends on policy and enterprise objectives; and on the quality of institutions

3. Backward and forward linkages matter, but these are also affected by innovation planning and technology choice
4. Skill-biased technological change has spilled over from developed to developing countries, albeit at lower rates in LICs compared to LMICs
5. International trade reinforces the employment-creating effects of product innovation, but it is more likely to worsen the adverse effects of process innovation on unskilled labour
6. International trade between developing countries is not likely to ameliorate the skill bias because it is *more* capital-intensive than trade between developing and developed countries.

Kelley et al (1972) demonstrate that labour-saving technological change is incompatible with factor endowments in LICs and limits the scope for employment creation. In his study on Kenya, Mureithi (1974) qualifies these pessimistic findings by drawing attention to different stages of the production process, which include: material handling; material processing; packaging; and storage of finished products. Of these stages, only the second need to be capital-intensive. Hence entrepreneurs could minimize the labour-saving effects of innovation by optimizing capital-intensity across different stages of the production process. Differential levels of capital intensity are also emphasized by Stewart (1974) in the context of developing countries in general. Although technology determines factor requirements in the main production processes of the modern plants/sectors, there is significant scope for flexibility in ancillary activities and in the traditional sector in general.

Sigurdson (1990) provides a detailed account of how innovation efforts in China took account of the social and institutional context, including dualism and regional disparity. The Chinese approach is described as deliberate dualism in innovation. Technological innovation and adaptation in large-scale sectors constituted the technology frontier in the country; whereas local and small-scale enterprises specialized in technology adaptation aimed at maximizing labour absorption. Another characteristic of the innovation system in China consists of 'social technology'. This involved institutions and management routines that required compulsory visits by planners and state officials to rural areas to ensure that local needs could be incorporated into technology designs and product development. In this dualist system, labour absorption was much higher than what would have been feasible under a single system that favoured large-scale industrialization and technology adoption only.

Another mediating factor in the innovation-employment relationship is international trade. James (1993) draws attention to the role of exports in promoting innovation and employment. In this study, international specialization is analysed as a framework similar to backward and forward linkages at the national or local levels. The author argues that policy-makers and entrepreneurs can create employment if they choose technologies on the basis of their factor-price ratio and aim to occupy a niche in the

global market. Hence, LICs should choose technologies that would enable them to specialize in the production of labour-intensive goods or components.

However, the positive effects of international specialization are questioned by a number of studies. For example Berman and Machin (2000) and Berman et al (2005) demonstrate that developing countries are not choosing labour-intensive technologies. On the contrary, skill-biased technological change (SBTC) seems to have caught up in these countries. These studies report the following conclusions: (i) in all country groups, increased demand for skills is essentially a within-industry phenomenon and this confirms the existence of SBTC rather than factor-neutral technology shifts; (ii) SBTC-induced demand for skilled labour is increasing in middle-income countries at faster rates compared to high-income countries; and (iii) SBTC-induced demand for skilled labour in LICs is evident but does not increase at fast rates yet.

The two studies by Berman and his co-authors examine only the *relative* demand for skills and as such they do not assess the *overall* effect of technological change on employment. This issue, together with the effects of technological change on growth and welfare, is addressed by Choi et al (2002). This study assumes that technological change does not alter the capital-labour ratio, but rural-urban migration is determined by expected incomes in urban areas – as suggested by Harris and Todaro (1970). The authors demonstrate that the welfare effects of technical progress consist of three components: the primary growth effect, the returns-to-scale effect and the employment effect. Under constant returns to scale, technological change can lead to growth and employment creation at the same time. Under variable returns to scale, however, technological change can cause the sum of the primary growth and employment effects to have any sign. In other words, under variable returns to scale, innovation can lead to growth without employment generation as technical progress reduces labour absorption.

Mitra (2009) investigates the effects of imported technology on labour absorption in the manufacturing sector, after controlling for real wage rate and per-capita GDP in a number of developing and low-income countries. The author reports that the ratio of labour cost to value-added tends to decline as the ratio of manufactured goods import to total merchandise imports increases. It also reports that the technical efficiency index (derived from a stochastic frontier function) tends to be lower the higher is the manufactured goods' share in total merchandise imports. These results suggest that import of technology has an adverse effect on employment as well as technical efficiency. These outcomes may be due to poor skill base and low adaptation capacity in developing countries.

However, manufactured goods import includes not only capital goods and intermediate inputs (relatively good proxies for imported technology), but also finished products that do not embody imported technology. In addition, the ratio of labour cost to value added

may not reflect the level of employment because it depends not only on the latter but also on wage levels. Therefore, the author calls for caution in interpreting the results.

Conte and Vivarelli (2011) utilizes a narrower measure of imported technology – the annual value of the import from high income countries of a detailed list of capital goods which embody a technological component. The authors label this indicator as skill-enhancing technology import (SETI) and report that SETI has a negative effect on the employment of unskilled workers' but positive effect on skilled-labour employment.

Jacobbson (1980) addresses the question as to whether technology embodied in trade between developing countries may have a different effect on employment compared to trade between developed and developing countries. The author reports that the export of investment goods (particularly engineering goods) and manufactures between developing countries had increased significantly from 1973-80. The author considers this as evidence of increasing technology transfers between developing countries. His findings indicates that technology transfers implicit in South-South trade are likely to create *less* jobs than technology transfers implicit in North-South trade. This is because South-South trade is *more* capital intensive than North-South trade.

4.2.9 Innovation and employment in manufacturing: macro-level evidence

We have reviewed 5 studies that examine the innovation-employment relationship at the macro level. These studies do not distinguish between process and product innovation; and their overall conclusions can be summarised as follows:

1. Institutional characteristics of the country and those of the labour markets determine technology choice at the macro level
2. Policy makers and entrepreneurs are constrained in their technology choice
3. Preferred technologies are not likely to generate sufficient employment to absorb the excess supply of labour caused by homogenizing effects of technology and consequent rural-urban migration
4. Financial integration of developing countries may facilitate financing innovation, but increases unemployment risks

Annable (1971) models three constraints that restrict the labour-absorption capacity of innovation in LICs: technical constraints; population growth; and rural-urban migration. Technical constraints induce skill-biased innovation and technology choice for two reasons: (a) the 'technology shelf' may have a very limited set of options on offer; or (b) the set of options may be large, but the technology that minimizes production costs may be unique. The end result is what Annable describes as homogenising of employment

patterns across countries – i.e., skill-biased employment creation. Hence, innovation may not reduce employment overall; but it would fall short of absorbing the surplus labour caused by rapid population growth and rural-urban migration. Fagerberg (2010) is more optimistic about the innovation capacities and growth potentials of developing countries, but the employment-creation effects of innovation would depend on institutional quality that fosters higher levels of interaction between private- and public-sector actors, social capital and financial development.

Garmany (1978) draws on Sen's (1974) analytical framework and the policy debate in Africa. He concludes that developing countries may have to pass through a stage of capital-deepening technology adoption in the main manufacturing industries and rely on forward/backward linkages to generate employment through labour-intensive technologies in secondary sectors such as transport, construction, repair and maintenance where capital-intensive technology may be less necessary. However, the author also indicates that such trade-offs require long-term planning and the latter requires appropriate institutions.

Although the three studies above consider institutional quality in general, they do not analyse the effects of labour-market institutions specifically. Caballero and Hammour (1996) addresses this issue in a formal model and report that incomplete contracting can disrupt innovation as a process of creative destruction. According to the authors, the productive structure of an economy should constantly adapt to innovations in products, techniques, and modes of organization. However, if it is too costly to write and enforce complete long-term contracts between capital and labour, inefficiencies will follow and lead to undervaluation of labour at the margin. This undervaluation involves either slow-paced innovation or innovations that substitute capital for labour. These outcomes tend to obtain whether the bargaining power of the incumbent employees is strong or weak.

Azariadis and Pissarides (2004) take issue with one of the factors that Fagerber (2010) considers as necessary for effective innovation and job creation. Their theoretical model includes one small and one large economy with international capital mobility. The authors demonstrate that the rate of unemployment responds faster and more strongly to TFP shocks as international capital mobility increases. This is because, when capital mobility is high, capital flight reduces the existing capital stock. As the latter ceases to acts as a cushion that moderate the fall in the demand for labour, innovation (as proxied by TFP shocks) would have more amplified effects on job creation or destruction.

4.2.10: Innovation and female labour

We have reviewed four studies on the relationship between innovation and female labour employment. The narrative synthesis can be summarized as follows:

1. Process innovation in agriculture is conducive to lower female participation in farm employment; but higher contribution to housework and child care. (2 studies out of 3).
2. Process or product innovation in agriculture may have positive or negative effect on off-farm employment of women, depending on the nature of forward and backward linkages. (1 study out 3).
3. Process innovation in manufacturing tends to increase employment of relatively better educated and younger women at the expense of less educated and older women. (1 study out of 3).
4. Process innovation is conducive to gender-based job segmentation and this effect is more pronounced in textiles and electronics plants compared to telecommunications. (1 study out of 3).

Of the reviewed studies, Billings and Singh (1981) examine the effects of the GR on female employment and reports the following patterns: (i) In hilly areas, there is limited scope for mechanisation and thus women's participation rate tends to remain stable; (iii) in the Haryana region and Punjab where mechanization is more wide-spread, the GR is likely to reduce female participation. Despite such variations, the GR is expected to reduce the participation of educated women in farm employment. Women who withdraw from farm employment are likely to spend more time doing house work and looking after children's education. This is more likely to be the case among large-farm households.

Bhalla (1989) investigates the effects of the GR on female employment and women's contribution to household earnings, using survey evidence on 153 villages in Haryana district, India. The study reports that the GR has led to expansion in labour demand until mid-1970s, but the demand stabilised and began to fall thereafter. The study concludes that the extension of biochemical-HYV technology tends to reduce the women's share in field-crop labour days. Similar to Billings and Singh (1981), Bhalla (1989) also indicates that the GR is likely to reduce women's relative contribution to household income and increase their contribution to housework.

Ahmed (1987) provides a more nuanced account by taking account of forward/backward linkages between agriculture and related industries. The study reports that mechanization may increase or reduce the demand for female labour, depending on the nature of innovation in upstream or downstream industries linked to agriculture. For example, mechanisation of fishing boats coupled with the use of ice for preservation of fish have led to increased female employment in ice and freezing plants.

A similar result was observed in the case of new technologies for milk preservation. However, female employment can also fall – as it was the case when traditional methods of producing hand-made fishing nets were replaced by factory-made nylon nets.

Tuyen (1999) is the only study that investigates the effects of innovation on female employment in the manufacturing sector. The study is based on field research and interviews conducted between 1994 and 1996 by a Vietnamese research team within the UNU/INTECH Project on New Technology and Women's Employment in Asia. Its findings can be summarised as follows: (i) New technology has brought job opportunities for educated and younger women (less than 40 years old); (ii) job creation for this segment of the female labour force was at the expense of job losses incurred by older and less qualified women; (iii) new technologies have reinforced gender-based job segregation by concentrating women in labour-intensive operations such as weaving and sewing; (iv) concentration of women in such operations has weakened women's control over technology; and (v) women tend to have relatively more managerial roles in telecommunications compared to textiles or electronics manufacturers.

4.2.11: Narrative synthesis: a summary

Conclusions that can be derived the narrative synthesis are summarized below. Each conclusion is followed with the number of studies on which it is based.[12]

A) With respect to **product innovation** in agriculture and manufacturing:

1. Strong forward/backward linkages with upstream/downstream markets or industries tend to reinforce the positive employment-effects of product innovation in LICs (5 studies out 5).
2. Higher wages are likely to reduce or reverse the positive employment-effects of product innovation as labour is substituted by capital (3 studies out 5).
3. The time horizon matters. At sector level, HYVs tended to have positive effects on farm and off-farm employment in the long run. The effect is felt quicker at firm level in the short run (4 studies out 5).
4. Technology choice matters. In both sectors product innovation tend to create employment when it is based on skill-matching and labour-intensive technologies (5 studies out 5).
5. Income levels and distribution matter. Product innovation tended to have more positive employment effects when new products cater for a wide spectrum of low-income consumers. However, skewed income distribution tends to reduce the positive employment effect (2 studies out 5).

[12] This number is relative to total number of studies that investigate the particular type of innovation (process versus product innovation) within agriculture or manufacturing.

B) With respect to **process innovation** in agriculture:

1. Mechanization alone tends to have a negative effect on employment (12 studies out of 19).
2. Adverse effects of mechanization are ameliorated when the latter is combined with irrigation, product differentiation, and extension of farm land (12 studies out of 19).
3. Negative effects of mechanization are moderated by strong forward/backward linkages with upstream/downstream markets or industries (7 studies out of 19).
4. Adverse employment-effects of mechanization are more likely to be felt in large farms, in ploughing and harvesting as opposed to sowing operations, and on family labour as opposed to hired labour (6 studies out of 19).
5. Green Revolution technologies tended to have positive effects on farm and off-farm employment only in the long run (4 studies out of 19).
6. The positive employment effects of Green Revolution technologies are underpinned by effects of increased incomes (2 studies out of 19).

C) With respect to **process** innovation in manufacturing:

1. Process innovation is usually associated with skill bias, with the implication of increased demand from skilled labour but negative effects on unskilled or mixed-skill labour (17 studies out of 20)
2. The negative effects of process innovation is exacerbated by skill- and capital-intensity of imported technologies (17 studies out of 20)
3. Low technology adaptation capacity in LICs exacerbates the adverse effect on employment (17 studies out of 20)
4. Governance and labour market institutions matter as they influence technology choice (13 studies out of 20).
5. Strong forward and backward linkages increase the probability of positive innovation effects on employment at industry level (12 studies out of 20).
6. Capital-intensity of the international trade among LICs and between the latter and developed countries exacerbates the negative effects on employment (6 studies out of 20).
7. Preference formation by LIC policy makers and entrepreneurs is biased in favour of efficiency-enhancing innovation and hence it exacerbates negative effects on innovation (5 studies out of 20)
8. Skewed income distribution in LICs tends to exacerbate the adverse effects on employment (4 studies out of 20)
9. Low skill upgrading among the labour force in LICs has a negative effect on employment (3 studies out of 20).

D) With respect to **process** and **product** innovation at the macro level:

1. Weak economic governance and rigid labour-market institutions induce policy-makers and entrepreneurs to choose skill-biased and capital-intensive technologies. (4 out of 5 studies)
2. Financial integration may facilitate financing innovation, but increases unemployment risks (1 out of 5 studies).

We have reviewed four studies on the relationship between innovation and female labour employment. The following conclusions can be derived:

1. Gender roles: Because women are expected to care for children, the negative effect of innovation on family labour is borne by women. Introduction of mechanization and other Green Revolution technologies is found to be associated with lower female participation in farm activities. This tendency is more pronounced among educated women. (2 studies out of 4).
2. Stronger forward/backward linkages are conducive to a positive innovation effect on women in rural areas. (1 study out 4).

3. Education and age matter: innovation in manufacturing tends to increase employment of relatively better educated and younger women at the expense of their less educated and older peers. (1 study out of 4).

4. Industry type matters: innovation in manufacturing is conducive to gender-based job segmentation and this effect is more pronounced in textiles and electronics plants compared to telecommunications. (1 study out of 4).

An overall summary of the narrative synthesis findings is given in Table 4.1.1. below.

Table 4.2.1: Summary of the narrative synthesis findings

Process innovation and effects on firm/farm and sector level employment	Product innovation and effects on firm/farm and sector level employment
In agriculture (19 studies in total): 1. Mechanization tends to have a negative effect on employment; but the adverse effect is moderated when mechanization is combined with irrigation, product differentiation, and extension of farm land (12 studies). 2. Negative effect is moderated by strong forward backward linkages between enterprises and industries (7 studies). 3. Adverse effect is more likely in large farms, in ploughing and harvesting as opposed to sowing operations, and on family labour as opposed to hired labour (6 studies). 4. Green revolution (GR) technologies have positive effects on farm and off-farm employment in the long run (4 studies). 5. Positive effects of GR technologies are strengthened by increased incomes (2 studies). **In manufacturing** (20 studies in total): 1. Process innovation is skill-biased, with increased demand for skilled and reduced demand for unskilled labour, (17 studies) 2. Low technology adaptation capacity exacerbates the adverse effect on unskilled labour (17 studies) 3. Weak governance and labour market institutions increase the risk of inappropriate technology choice and reduce the scope for employment creation (13 studies). 4. Strong forward/backward linkages ameliorate the negative effect (12 studies). 5. Capital-intensity of international trade exacerbates the negative effect (6 studies). 6. Skewed income distribution exacerbates the adverse effect (4 studies) 7. Low skill upgrading among LIC labour force exacerbate the negative effect (3 studies).	**In agriculture and manufacturing** (5 studies in total) 1. Product innovation is more likely to have a positive effect (2 studies) 2. Strong forward/backward linkages tend to reinforce the positive effect (5 studies). 3. Higher wages are likely to reduce or reverse the positive effect (3 studies). 4. Effect at sector level is uncertain (2 studies) 5. The time horizon matters: positive effect in the short run in manufacturing; in the long run in agriculture. (4 studies). 6. Technology choice matters: innovation tends to create employment when it involves skill-matching and labour-intensive technologies (5 studies). 7. Product innovation tends to have more positive employment effects when new products cater for a wide spectrum of low-income consumers. However, skewed income distribution tends to reduce the positive employment effect (2 studies out 5).
Innovation and employment at the macro level (5 studies): Two conclusions can be derived: (i) weak economic governance and rigid labour-market institutions induce policy-makers and entrepreneurs to opt for skill-biased and capital-intensive technologies. (4 out of 5 studies); (ii) financial liberalisation and integration may facilitate financing innovation, but increases unemployment risks (1 out of 5 studies).	
Innovation and female labour employment (4 studies): Introduction of mechanization and other GR technologies are associated with lower female participation in farm activities, particularly among educated women. (2 studies). Forward/backward linkages increase female labour employment (1 study). Innovation in manufacturing increases employment of younger and better-educated women; but leads to gender-based job segmentation. (1 study).	

4.3 Meta-analysis results

4.3.1 Summary of the findings

In the following sections, we first provide fixed-effect (FE) and random-effect (RE) weighted means of the effect-size estimates reported in individual studies. In stage 2, we provide precision-effect and funnel-asymmetry tests (PETS/FATs) that allow for establishing the existence or absence of 'genuine effect' after controlling for reporting (publication selection) bias. Finally, we estimate a multivariate regression to establish if the employment-effect of innovation remains robust to inclusion of moderating variables such as innovation type, employment type, level of analysis, sectors, and publication type.

Meta-analysis findings can be summarised as follows:

1 At study level, only four studies yield statistically-significant FE and RE weighted means for the partial correlation coefficients (PCCs). Three studies (Almeida, 2010; Conte and Vivarelli, 2011 and Raju (1976) yield positive and significant FE and RE weighted means; one study (Sisson et al, 1985) yields a negative and significant FE and RE weighted mean. One study (Almeida, 2010) yields a negative and significant FE and RE weighted mean when elasticities are used. FE and RE weighted means provide an overview of the evidence base, but cannot be taken as true measures of genuine effect due to risk of bias.

2 The Funnel plots indicate a high level of heterogeneity in the evidence base, with some evidence of positive publication selection (reporting) bias when PCCs are used and negative bias with elasticities. The funnel plots also indicate that the effect-size estimates with the highest level of precision tend to be positive but small. This can be interpreted as indication of positive but weak relationship between innovation and employment.

3 Precision-effect and funnel-asymmetry tests (PETs and FATs) and precision-effect estimation with standard errors (PEESEs) confirm the conclusions derived from visual inspection of the funnel plots. The effect of innovation on employment is positive and significant after controlling for reporting bias. This result is based on the assumption that all moderating variables that may affect the innovation-employment relationship are equal to their sample averages. The effect is stronger when the evidence relate to skilled-labour employment as opposed to employment of all-skill labour. However, whether this finding is robust to inclusion of moderating variables needs to be verified through multivariate meta-regression.

4 Multivariate MRA results indicate that the effect of innovation on employment is conditional on moderating variables such as level of analysis, skilled *versus* unskilled labour, the specific sector analysed and the world region of the samples used in primary studies. These moderating variables are identified following a general-to-specific modelling approach. We report that the marginal effect of innovation, which is conditional on consistently-significant moderating variables, is 0.151 in the full sample of 147 partial correlation coefficients (PCCs). This is a positive but small effect, which is conditional on a range of moderating variables. The effect is stronger when the primary studies report estimates related to: (i) skilled-labour employment as opposed unskilled and mix-skills employment; (ii) employment in manufacturing as opposed to employment in agriculture or services; and (iii) employment in South Asia as opposed to other world regions. The effect is weaker when the primary studies report estimates related to sector-level employment as opposed to enterprise-level employment; The marginal effect is moderate and positive (0.297) in the sub-sample of 60 elasticity estimates, but this effect is conditional only on manufacturing employment as opposed employment in agriculture or services.

5 These results are in line with some of the findings in the narrative synthesis, which suggests that: (a) innovation is more likely to increase the demand for skilled labour; and (b) the employment effect at the sector level may be negative as job creation by innovative enterprises or industries may be at the expense of job losses in their non-innovative counterparts.

The sections below provide further elaboration on these findings and on the meta-analysis methods we have utilised to derive them.

4.3.2 Fixed-effects (FE) and random-effects (RE) weighted means

Tables 4.3.1 and 4.3.2 below present the fixed-effects (FE) and random-effects (RE) weighted means of the effect-size estimates reported by each empirical study. Table 4.3.1 reports the results based on 147 partial correlation coefficients (PCCs) whilst Table 4.3.2 reports the results derived from 60 elasticity estimates. The elasticity estimates from primary studies are multiplied by 100 to ensure comparability between elasticities derived from fully logarithmic and semi-logarithmic models where innovation is measured as a dummy variable. As such, the elasticity estimates in Table 4.3.2 measure the percentage change in employment when innovation increases by 100% or the innovation dummy switches from 0 (no innovation) to 1 (introduction of innovation).

Table 4.3.1 Weighted means per study – using partial correlation coefficients

Panel A: Fixed-Effects (FE) weighted means

Study	Data Period	No. of Estimates	Type of Innovation (Product, process)	Type of Employment (Skilled, Unskilled, All-skills)	Sector (Agriculture, Manufacturing, Services)	Fixed-Effects Weighted Mean	Confidence Interval
Study 1 Almeida (2010)	2003 - 2005	25	Process	Skilled	Manufacturing	0.0947*	(0.0837, 0.1056)
Study 2 Conte & Vivarelli (2007)	1980 - 1991	6	Process	Skilled	Manufacturing	0.0598*	(0.0349, 0.0846)
Study 2 Conte & Vivarelli (2007)	1980 - 1991	6	Process	Unskilled	Manufacturing	-0.01138	(-0.0475, 0.0249)
Study 3 Lundin et al (2007)	1998 - 2004	18	Process	All-skills	Manufacturing	0.0100	(-0.0128, 0.0328)
Study 4 Moore & Craigwell (2007)	1979 - 2001	6	Process	All-skills	Services	0.0186	(-0.0851, 0 .1223)
Study 5 Oberai and Ahmed (1981)	1977	7	Process	All-skills	Agriculture	0.0161	(-0.0658, 0.0980)
Study 5 Oberai and Ahmed (1981)	1977	1	Product	All-skills	Agriculture	0.0740	N.A.+
Study 6 Otsuka et al (1994)	1966 - 1990	17	Process	All-skills	Agriculture	-0.0706	(-0.1813, 0.0402)
Study 6 Otsuka et al (1994)	1966 - 1990	17	Product	All-skills	Agriculture	0.0066	(-0.0360, 0.0492)
Study 7 Pandit & Siddhartan (2008)	1991 - 2001	1	Process	All-skills	Manufacturing	-0.0316	N.A.+
Study 8 Raju (1976)	1968 - 1971	34	Process	All-skills	Agriculture	0.6998*	(0.6246, 0.7749)
Study 8 Raju (1976)	1968 - 1971	4	Product	All-skills	Agriculture	0.1562	(-0.0369, 0.3492)
Study 9 Sison et al (1985)	1979 - 1980	5	Process	All-skills	Agriculture	-0.1529*	(-0.2945, -0.0114)

+ : Not applicable

FE weighted means take account of within-study variation and assign lower weights to less precise estimates. Hence, they are more reliable than simple means; but they may be biased if the underlying effect-size estimates suffer from reporting (publication selection) bias and/or within-study dependence. Given this shortcoming, we also provide random-effects (RE) weighted means. The RE weighted means are similar to FE weighted means in terms of sign, magnitude and statistical significance.

Panel B: Random-Effect weighted means

Study	Data Period	No. of Estimates	Type of Innovation (Product, process)	Type of Employment (Skilled, Unskilled, All-skills)	Sector (Agriculture, Manufacturing, Services)	Random-Effects Weighted Mean	Confidence Interval
Study 1 Almeida (2010)	2003 - 2005	25	Process	Skilled	Manufacturing	0.0919*	(0.0796 , 0.1041)
Study 2 Conte & Vivarelli (2007)	1980 - 1991	6	Process	Skilled	Manufacturing	0.0578*	(0.0329, 0.0828)
Study 2 Conte & Vivarelli (2007)	1980 - 1991	6	Process	Unskilled	Manufacturing	-0.0114	(-0.0475, 0.0249)
Study 3 Lundin et al (2007)	1998 - 2004	18	Process	All-skills	Manufacturing	0.0048	(-0.0145, 0.0240)
Study 4 Moore & Craigwell (2007)	1979 - 2001	6	Process	All-skills	Services	0.0189	(-0.0840, 0 .1219)
Study 5 Oberai and Ahmed (1981)	1977	7	Process	All-skills	Agriculture	0.0155	(-0.0660, 0.0970)
Study 5 Oberai and Ahmed (1981)	1977	1	Product	All-skills	Agriculture	0.0740	N.A.+
Study 6 Otsuka et al (1994)	1966 - 1990	17	Process	All-skills	Agriculture	-0.0593	(-0.1560, 0.0374)
Study 6 Otsuka et al (1994)	1966 - 1990	17	Product	All-skills	Agriculture	0.0061	(-0.0478, 0.0601)
Study 7 Pandit & Siddhartan (2008)	1991 - 2001	1	Process	All-skills	Manufacturing	-0.0316	N.A.+
Study 8 Raju (1976)	1968 - 1971	34	Process	All-skills	Agriculture	0.6074*	(0.5318, 0.6829)
Study 8 Raju (1976)	1968 - 1971	4	Product	All-skills	Agriculture	0.1557	(-0.0374, 0.3489)
Study 9 Sison et al (1985)	1979 - 1980	5	Process	All-skills	Agriculture	-0.1499*	(-0.2912, -0.0087)

+ : Not applicable

Weighted means in Table 4.3.1 are based on PCCs and indicate a high degree of heterogeneity in the estimates reported by primary studies. FE and RE weighted means range from -0.15 to +0.70 and from -0.15to +0.61, respectively; and indicate a high level of heterogeneity in the underlying effect-size estimates. Three out of nine studies report effect-size estimates that yield positive and statistically-significant FE and RE weighted means: Almeida (2010) and Conte and Vivarelli (2011) on skilled labour in manufacturing; and Raju (1976) on all-skills labour in agriculture. Only one study, Sison et al (1985), yields a medium and negative effect on all-skills labour in agriculture.

Table 4.3.2 Weighted means per study – using elasticities++

Panel A: Fixed-Effects (FE) weighted means

Study	Data Period	No. of Estimates	Type of Innovation (Product, process)	Type of Employment (Skilled, Unskilled, All-skills)	Sector (Agriculture, Manufacturing)	Fixed-Effect Weighted Mean	Confidence Interval
Study 1 Almeida (2010)	2003 - 2005	25	Process	Skilled	Manufacturing	25.5640*	(23.7918, 28.4626)
Study 2 Otsuka et al (1994)	1966 - 1990	17	Process	All-skills	Agriculture	-14.0588	(-26.2787, 10.8680)
Study 2 Otsuka et al (1994)	1966 - 1990	17	Product	All-skills	Agriculture	4.7059	(-11.0879, 11.4668)
Study 3 Pandit & Siddhartan (2008)	1991 - 2001	1	Process	All-skills	Manufacturing	-31.7800	N.A.

Panel B: Random-Effects (RE) weighted means

Study	Data Period	No. of Estimates	Type of Innovation (Product, process)	Type of Employment (Skilled, Unskilled, All-skills)	Sector (Agriculture, Manufacturing)	Random-Effect Weighted Mean	Confidence Interval
Study 1 Almeida (2010)	2003 - 2005	25	Process	Skilled	Manufacturing	26.1269*	(23.7913, 28.4626)
Study 2 Otsuka et al (1994)	1966 - 1990	17	Process	All-skills	Agriculture	-7.7089	(-26.2867, 10.8687)
Study 2 Otsuka et al (1994)	1966 - 1990	17	Product	All-skills	Agriculture	0.1894	(-11.0881, 11.4670)
Study 3 Pandit & Siddhartan (2008)	1991 - 2001	1	Process	All-skills	Manufacturing	-31.7800	N.A.

++ : Elasticities from primary studies are multiplied by 100. They measure the percentage change in employment when innovation increases by 100% or the innovation dummy switches from 0 (no innovation) to 1 (introduction of innovation). N.A.: Not applicable.

Results based on elasticities (Table 4.3.2) are also heterogeneous, with one study (Almeida, 2010) yielding a positive and statistically significant weighted mean.

According to Cohen (1988), the weighted mean of the effect size should be regarded as small if its absolute value is 0.10, medium if it is 0.25, and large if it is 0.4 and greater. Using these criteria, we can conclude that the study-based weighted-means of the effect size tend to be small - with the exception of Raju (1976) and Sison et al. (1985) in the PCC sample and Almeida (1976) and Pandit and Siddhartan (2008) in the elasticities sample.

The large weighted-mean effect obtained from Raju (1976) may be due to two factors. First, Raju (1976) measures employment as the number of man-days worked on the farm rather than as the number of farm employees. From the narrative synthesis, we know that introduction of new farming methods reduces the seasonality of employment. Because the effect-size estimates reported by Raju (1976) do not account for reduced seasonality, they may reflect an upward bias when used as a measure of employed labour. Secondly, the narrative synthesis also indicates that some measures of process innovation in agriculture – for example use of fertilizers, pesticides and irrigation - are usually conducive to employment creation; whereas mechanisation is usually associated with a negative effect. Raju (1976) controls for the former, but does not control for use of mechanisation. Therefore, the weighted-mean effects based on this study are likely to be biased upward.

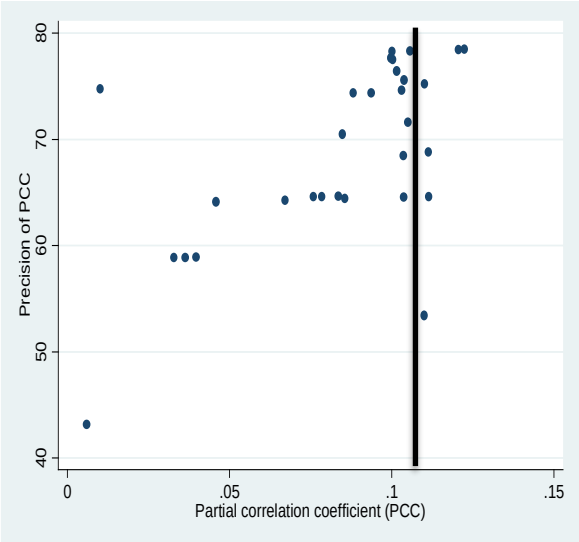
As indicated above, weighted means of the effect size may be subject to reporting (selection) bias and within-study dependence. Secondly, FE and RE weighted means take account of within- and between-study variations respectively, but they do not reveal any information about the sources of such variations. Therefore, neither FE nor RE weighted means can be taken as reliable summary measures of genuine effect. They are reported here merely to provide an overview of the evidence base. To establish whether a genuine effect exists and quantify its magnitude, we use PET-FAT-PEESE methods. These methods are reported to be unbiased and consistent in accounting for reporting bias and sources of heterogeneity; and in estimating the effect size (Stanley and Doucouliagos, 2012).

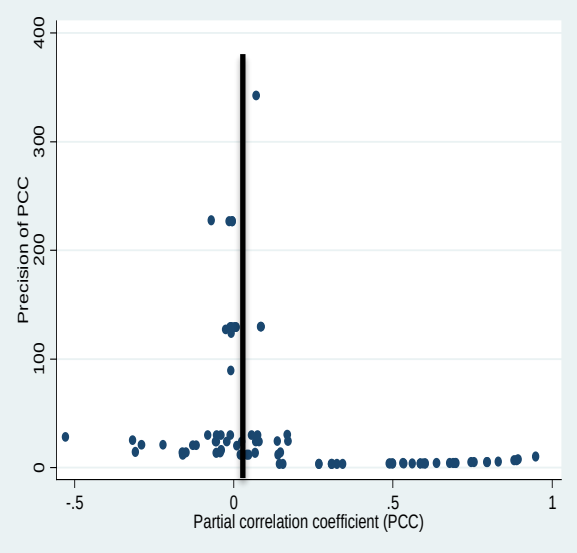
4.3.2 Precision-effect and funnel-asymmetry tests (PETs/FATs)

First, we provide funnel graphs for the evidence base. Funnel graphs plot precision (i.e., the inverse of the standard error) against the partial correlation coefficients (PCCs) or elasticities. In the absence of reporting (publication selection) bias, the effect-size estimates will vary randomly around the 'true' effect. Hence, funnel-graph asymmetry is a key indicator of reporting (publication selection) bias (Stanley, 2008).

Figure 4.3.1: Funnel graphs

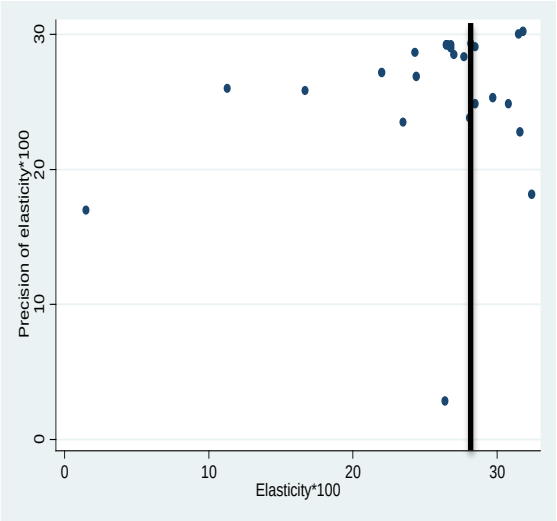
Panel A: With partial correlation coefficients (PCCs) for process innovation and two skill types

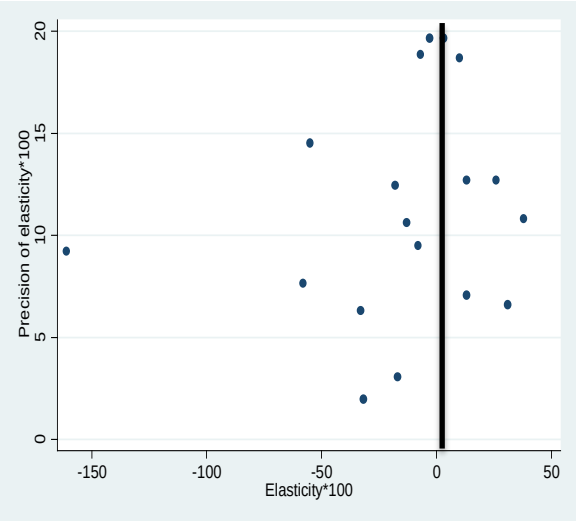




1: Process innovation and skilled-labour employment 2: Process innovation and all-skill employment

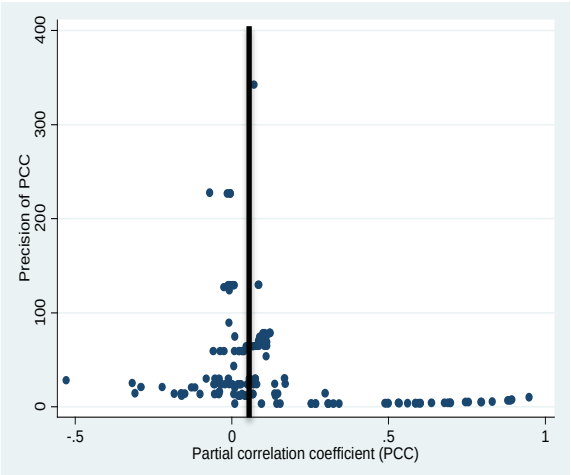
Panel B: With elasticities for process innovation and two skill types

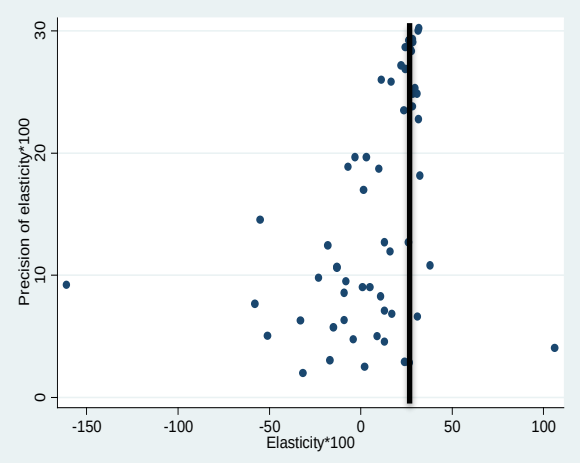




1: Process innovation and skilled-labour employment 2: Process innovation and all-skill employment

Panel C: Full sample – product and process innovation and all skill types





1: With partial correlation coefficients (PCCs) 2: With elasticities

All funnel graphs indicate a positive but small effect, combined with evident asymmetry as an indication of bias. The bias is negative in Panel A(1), B(1) and C(2); but positive in Panel A(2) and C(1). The effect in each evidence cluster can be approximated by the vertical line that fits the estimates with the highest level of precision. This effect is usually less than 0.3; but there is evidence indicating that the effect of process innovation on skilled labour is stronger than the effect on all-skills. If confirmed by the PET/FAT and MRA results, this visual evidence indicates that process innovation tends to be skill-biased as opposed to skill-neutral.

Table 4.3.3: PET/FAT results[+]
Panel A: Weighted least-square (WLS) results
Dependent variable: t-statistics

	Results based on partial correlation coefficients				Results based on elasticities			
	Process and skilled	**Process and all-skills**	**Product and all-skills**	**Full sample**	**Process and skilled**	**Process and all skills**	**Product and all skills**	**Full sample**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Precision	0.214***	0.004	0.009	0.015**	0.311***	0.069	-0.096	0.350***
	(0.036)	(0.008)	(0.041)	(0.007)	(0.052)	(0.201)	(0.146)	(0.043)
Bias	-8.751***	0.728	0.135	1.177**	-1.338	-2.018	0.764	-3.152***
	(2.524)	(0.598)	(0.735)	(0.472)	(1.352)	(2.492)	(1.061)	(0.792)
R^2	0.546	0.004	0.003	0.032	0.612	0.007	0.028	0.538
Prob > F	0.000	0.571	0.827	0.031	0.000	0.734	0.522	0.000
N	31[+]	88[+]	22[+]	147	25	18	17	60

[+] PET/FAT estimations for the full sample based on PCCs are reported for three combinations of innovation and skill types. Estimation for the fourth combination (process innovation and unskilled labour) is not reported here as the number of observations is too small (6 only).

Panel B: PEESE results
Dependent variable: t-statistics

	Results based on partial correlation coefficients (PCCs)		Results based on elasticities	
	Process and skilled	**Full sample**	**Process and skilled**	**Full sample**
	(1')	**(4')**	**(5')**	**(8')**
Precision	0.102***	0.026***	0.263***	0.224***
	(0.006)	(0.005)	(0.013)	((0.026)
Standard error	-19.118***	-0.077*	-1.147	-6.652**
	(5.425)	(0.044)	(4.316)	(3.195)
R^2	0.936	0.156	0.957	0.571
Prob > F	0.000	0.000	0.000	0.000
N	31	147	25	60

PET-FAT results (Table 4.3.3, Panel A) indicate that innovation has a genuine effect on employment in columns (1) and (4) with full-sample data based on PCCs; and in columns (5) and (8) when elasticities data is used. The PET/FAT results enable us conclude that a positive effect exists when effect-size estimates in the primary studies relate to: (a) the effect of process innovation on skilled-labour employment (columns 1

and 5); and (b) the effect of process and product innovation combined on total employment (i.e., employment of skilled and unskilled labour all-skill labour) in columns 4 and 8. The effect of process innovation on skilled labour employment (columns 1 and 5) is stronger than the effect of both types of innovation on total employment (columns 4 and 8). These effects hold after controlling for reporting (selection) bias, which is negative and severe (-8.751 and – 3.152) in columns (1) and (8); but positive and moderate in column (4). There is no significant selection bias in column (5).

The existence of bias in does not invalidate the existence of genuine effect. Therefore, we estimate the magnitude of the true effect identified in columns (1), (4), (5) and (8) by carrying out precision-effect estimation with standard errors (PEESE). PEESE results in *Panel B* of Table 4.3.3 are corrected for the non-linear relationship between effect-size estimates and their standard errors (Stanley and Doucouliagos, 2012).

PEESE result for the full sample of PCCs in column (1') indicates that the effect of process innovation on skilled-labour employment is positive but small (0.102). In the light of Cohen (1988) criteria, a partial correlation coefficient of 0.1 is a small effect. It indicates that process innovation explains only 1% of the remaining variation in skilled-labour employment after other economic factors are taken into account. This finding can be interpreted as evidence of a small skill bias in the effect of process innovation on employment. This interpretation draws further support from the finding in column (2), which indicates that the effect of process innovation on total employment (employment of skilled and unskilled labour taken together) is statistically insignificant.

PEESE result in column (4') indicates that the effect *both* process and product innovation taken together on total employment (i.e., employment of skilled and unskilled labour taken together) is positive but very small (0.026). According to Cohen (1988) criteria, this effect is too small to be practically significant.

We observe similar findings when the sub-sample of 60 elasticities is used. Here, the effect of process innovation on skilled-labour employment is moderate and positive (0.263) in column (5'); and this is slightly larger than the effect of both types of innovation on total employment (0.224) in column (8').

PEESE results from elasticities data are based on evidence from 3 out of 9 empirical studies. Given the small number of studies they are based on, we do not recommend the elasticities results as the measure of true effect. Instead, we rely on the PEESE findings based on the full sample of PCCs.

4.3.3 Meta-regression results

It must be recalled that PET/FAT and PEESE estimations takes account of reporting (selection) bias only. As such, they do not account for effects of other factors that may influence the variation in effect sizes reported in primary studies. To account for such factors, we carry out multivariate meta-regression analysis (MRA) in accordance with model (9) in ***Appendix 4.2.2.***

We estimate model (9) with four different methods to control for Heteroskedasticity, dependence, and study-specific effects (see ***Appendix 4.2.2***). Initially, we specify a general version of model (9), with eight moderating variables that consist of: general method of moments (GMM) estimation as opposed to other methods; enterprise-level evidence as opposed to sector- and macro-level evidence; sector-level evidence as opposed to enterprise- and macro-level evidence; process innovation as opposed to product innovation; skilled-labour employment as opposed to unskilled and skilled labour taken together; manufacturing sector as opposed agriculture and services; South Asia data as opposed to data from other regions including East Asia and Africa; journal article as opposed to book chapters or working papers.

Then we follow a general-to-specific modelling approach to minimise the risk of multicollinearity and over specification. The method involves excluding the most insignificant variables (i.e., variables with the largest p-values) one at a time until all remaining variables are significant. As a result, the number of moderating variables is reduced to four in the full sample of PCCs (147) and to one in the sub-sample of elasticities (60). Summary statistics for the moderating variables included in the specific model are presented in Table 4.3.4 below.

The dependent variable (*t-value*) is the t-Statistic associated with each effect-size estimates (PCC or elasticity). Of the explanatory variables, *Precision* is the inverse of the standard error of the partial correlation coefficients. It is calculated in accordance with equation (2) in ***Appendix 4.2.2***. In the elasticities sub-sample, *Precision* is the inverse of the elasticity estimate reported in primary studies.

Sector-level analysis is a dummy variable that takes the value of 1 if the original estimate measures the effect of innovation on employment at the sector or industry level as opposed to enterprise or macro levels. Otherwise, it is equal to zero. This variable enables us to determine whether job creation within innovative enterprises occurs at the expense job losses within their non-innovative counterparts. The sector-level dummy has a sample average of 0.088, indicating that estimates that measure sector-level effects constitute 8.8 per cent of the evidence base.

Table 4.3.4: Summary statistics for meta-regression analysis

	Obs.	Mean	Std. Dev.	Minimum	Maximum
Full sample with PCCS:					
Unweighted moderating vars.					
Partial corr. coefficient (PCC)	147	0.146	0.278	-0.529	0.948
Standard error of PCC	147	0.089	0.101	0.003	0.316
Sector-level analysis	147	0.088	0.285	0.000	1.000
Skilled-labour employment	147	0.211	0.409	0.000	1.000
Manufacturing employment	147	0.381	0.487	0.000	1.000
South Asian countries	147	0.320	0.468	0.000	1.000
Full sample with PCCs:					
Vars. weighted with precision					
t-Statistic	147	1.834	4.440	-16.000	24.000
Precision	147	45.084	54.084	3.162	342.450
Sector-level analysis	147	5.035	16.616	0.000	64.639
Skilled-labour employment	147	14.559	28.527	0.000	78.475
Manufacturing employment	147	36.696	58.724	0.000	342.450
South Asian countries	147	2.847	6.891	0.000	30.077
Elasticities sample[+]:					
Unweighted moderating var.					
Elasticity*100	60	7.472	34.301	-161	106
Standard error of elasticity*100	60	11.069	10.185	3.31	50.444
Manufacturing employment	60	0.433	0.500	0.000	1.000
Elasticities sample[+]:					
Vars. weighted with precision					
t-Statistic	60	2.418	4.642	-14.830	9.607
Precision	60	15.934	9.745	1.982	30.211
Manufacturing employment	60	10.684	13.222	0.000	30.211

[+] : Only a few moderating variables are controlled for due to multicollinearity in the smaller set with elasticities.

Skilled-labour employment is equal to 1 if the primary-study estimates measure the effect of innovation on skilled-labour employment; and it is zero if the effect is on unskilled or mixed-skill labour employment. Controlling for skilled-labour employment enables us to test if innovation is associated with skill bias in LICs. The skilled-labour dummy has a sample average of 0.211, indicating that the estimates reporting effects on skilled-labour employment constitute 21.1 per cent of the evidence base

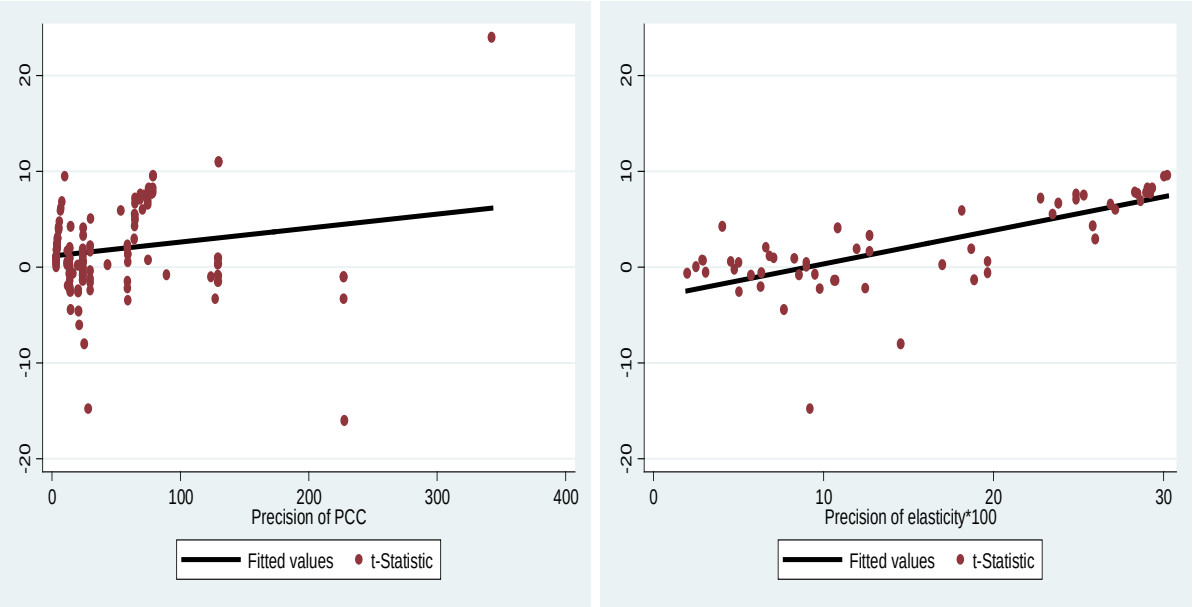
Manufacturing is equal to 1 if the original estimates measure the effect of innovation in the manufacturing sector as opposed to services or agriculture. It enables us to verify if innovation is conducive to more or less job creation in manufacturing as opposed to agriculture or services. The manufacturing dummy has a sample average of 0.381,

indicating that the estimates reporting effects on manufacturing employment constitute 38.1 per cent of the evidence base.

Finally, *South Asia* takes the value of 1 if reported estimates are based on data for South Asian countries; and it is 0 if they are based on data for other regions, which include East Asia, South-East Asia and Middle East and North Africa. We control for South Asia because the evidence from that region tends to be related to agriculture and Green revolution technologies. The South Asia dummy has a sample average of 0.32, indicating that the estimates reporting employment effects in South Asian countries constitute 32 per cent of the evidence base

Figure 4.3.2 below presents the scattered plots, both of which indicate a positive relationship between the effect size (PCC or elasticity) and its precision. This is a visual confirmation of the positive effect established in Table 4.3.3 above. Meta-regression analysis (MRA) will enable us to verify if the positive effect is robust to inclusion of moderating variables.

Figure 4.3.2: Linear-fit scatter plots



Full dataset with PCCs

Dataset with elasticities

MRA results are presented in Table 4.3.5 below. Column (1) presents the estimation results that take account of heteroskedastic standard errors. Results that take account of dependence between estimates from a given primary study are presented in column (2). Column (3) presents the results that take account of two-way dependence between multiple estimates reported in each study. The two-way dependence consists of within-study dependence between the estimates and dependence between estimates derived

from the same method of estimation. Finally, column (4) presents the random-effect estimation results that take account of study-specific effects on the original estimates. The random-effect estimation yields largely similar results to those in columns 1 - 3, with the exception of the coefficient for sector-level employment – which has the same sign (negative) but is statistically insignificant. The random-effect estimation results confirm the stability of the estimates in columns 1 – 3, which we take as our preferred estimates of the effect size measured as PCC.

Table 4.3.5: Meta-regression results based on full dataset of PCCs
Dependent variable: t-values

	Het. robust (1)	Cluster-robust (2)	Two-way cluster-robust (3)	Random Effects (4)
Precision	-0.133**	-0.133**	-0.133**	-0.096*
	(0.053)	(0.046)	(0.048)	(0.058)
Sector-level employment	-0.042***	-0.042***	-0.042***	-0.037
	(0.010)	(0.006)	(0.007)	(0.025)
Skilled labour employment	0.070***	0.070***	0.070***	0.075***
	(0.013)	(0.006)	(0.008)	(0.016)
Manufacturing employment	0.133***	0.133**	0.133**	0.105*
	(0.043)	(0.041)	(0.043)	(0.055)
South Asia data	0.123***	0.123**	0.123***	0.125**
	(0.042)	(0.044)	(0.022)	(0.062)
Constant	1.787**	1.787*	1.787*	0.810
	(0.765)	(0.832)	(0.886)	(0.906)
Observations	147	147	147	147
Model degrees of freedom	5	5	5	5
R-squared	0.339	0.339	0.339	
Overall 'R-squared'	---	---	---	0.330
P>F	0.000	0.000	0.000	---
P>Chi^2	---	---	---	0.000

Standard errors are in brackets. *, ** and *** denotes significance at 10%, 5% and 1%.

Results in Table 4.3.5 enable us to quantify the *marginal* effects of the moderating variables on the relationship between *both types* of innovation (product and process innovation) and total employment (employment of skilled and unskilled labour taken together). *All else remaining the same*, we can derive the following conclusions: (a) when the evidence relates to employment at the industry/sector level as opposed to enterprise level, innovation's effect on employment is dampened by -0.042; (b) when

the evidence is related to skilled labour employment as opposed to mixed-skills employment, the effect is augmented by 0.07; (c) when the evidence is related to manufacturing employment as opposed to employment in agriculture or services, the effect is augmented by 0.133; and (d) when the evidence is related to employment in South Asia as opposed employment in East Asia, the Middle East or Africa, the effect is augmented by 0.123.

The finding in (a) lends support to the narrative synthesis finding that the employment effect of innovation is likely to be negative or dampened when the level of analysis is at the industry/sector level as opposed to enterprise level. This is because employment gains by innovative firms may be obtained at the expense of employment losses by non-innovative firms. The inter-firm displacement effect leads to dampened or negative employment effects at the industry/sector level, depending on the relative magnitude of the employment gains in innovative enterprises and job losses in their non-innovative counterparts.

The finding in (b) lends support to both narrative synthesis findings and the finding from PEESE above. The finding indicates that the effect of *both* process and product innovation on total employment is augmented when the evidence is related to skilled-labour employment as opposed to total (skilled- and unskilled-labour) employment. Taken together with the PEESE result of positive effect from process innovation on to skilled-labour employment, it indicates that innovation in LICs is associated with a skill bias - even though the skill bias is small.

The findings in (c) and (d) are also in line with the findings from narrative synthesis, which indicate that forward and backward linkages tend to be stronger in manufacturing and that the employment effects of Green Revolution technologies tend to be positive and larger in South Asia (mainly India) compared to other regions.

Unlike the PET/FAT/PEESE results, the findings in Table 4.3.5 do not allow for conclusions about an unconditional average effect. They merely allow for deriving expected effects (i.e., expected values of the partial correlation coefficient - PCC) that are conditional on the values of the moderating variables. Given that the moderating variables are binary with values of 0 and 1 only, the expected value of the effect-size estimate (PCC) *conditional* on the moderating variables will be equal to:

$$\beta_0 + \beta_1 + \beta_2 + \cdots + \beta_k \quad if \quad Z_1, Z_2, \ldots Z_k = 1; \qquad \text{and}$$

$$\beta_0 \qquad\qquad\qquad if \quad Z_1, Z_2, \ldots Z_k = 0$$

Hence, if we assume that all moderating variables are equal to 1, the *conditional* effect is 0.151 (= -0.133 – 0.042 + 0.070 + 0.133 + 0.123). This value refers to the effect of both process and product innovation on employment when the underlying evidence relates to: (i) skilled-labour employment as opposed total employment (i.e., skilled- and unskilled-labour employment); (ii) employment in the manufacturing sector as opposed to employment in agriculture and services; (iii) employment in South Asian countries as

opposed to other world regions; and (iv) sector-level employment as opposed to enterprise-level employment.

If we assume that the moderating variables are all equal to zero, the conditional effect is equal to the precision's coefficient (β_0) – which is -0.133. Under this scenario, innovation has a negative effect on employment and the negative effect is conditional on evidence related to: (i) employment of unskilled or mixed-skill labour as opposed to skilled labour; (ii) employment in agriculture or services as opposed to manufacturing; (iii) enterprise or macro-level data as opposed to sector level data; and (iv) data for other world regions as opposed to South-Asian data.

Another scenario could be to assume that the moderating variables are equal to their sample means in the summary statistics table (Table 4.3.4). These sample means are 0.088 for sector-level estimates, 0.211 for skilled-labour estimates, 0.381 for estimates related to manufacturing-sector employment, and 0.32 for estimates based on South-Asian data. Multiplying these values with the coefficients in the MRA yields a negative conditional effect of -0.032 – which is too small to be practically meaningful.

A third scenario could be to assume that the moderating variables and the reference variables against which they are defined have equal probability of being observed. In this scenario, all moderating variables have the same value of 0.5 – and the conditional effect is positive but practically zero (0.009).

Thus, we can reiterate that the effect of innovation on employment is very much conditional on the moderating variables that characterise the research field. The moderating variables we could include explain about 34% of the variation in the evidence base and enable us to conclude that innovation's employment effect is augmented when the evidence relates to employment of skilled labour, employment in manufacturing, and employment in South Asian countries. The effect is dampened slightly when the evidence relates to sector-level employment as opposed to firm/farm or macro levels.

Combining PET/FAT/PEESE and MRA findings, we can derive the following conclusions. First, there is evidence to suggest that *process innovation* is associated with a small but positive effect (0.102) on *skilled-labour employment*. Even though this effect is small, it is larger than the effect of process innovation on total (skilled- and unskilled-labour) employment (0.004), which is statistically insignificant. Secondly, the MRA results indicate that the effect of *both* process and product innovation on total employment is augmented by 0.07 when the evidence is related to skilled-labour employment as opposed to total employment. Taken together, these results indicate that innovation in LICs is associated with a small skill bias. The third conclusion is that the effect of *both* process and product innovation on total employment is augmented when the evidence is related to: (i) manufacturing employment as opposed to employment in agriculture or services (0.133); and (ii) employment in South Asia as opposed to other world regions. Finally, the MRA evidence also indicates that the effect of *both* process and product

innovation on total employment is dampened by -0.042 when the evidence is related to employment at the sector/industry level as opposed to enterprise level.

These conclusions are robust to within-study dependence and two-way dependence within studies and between estimation methods. However, the small number of studies (9) and methods (3) we can use for cluster-robust estimations must be noted. The econometrics literature cautions that cluster-robust estimation may not be well-specified for taking account of within-cluster dependence when the number of clusters is small. Therefore, we complemented the one-way cluster-robust estimation method with two-way cluster-robust estimation as a sensitivity check. Gow et al. (2010) provide simulation results that show that the two-way cluster-robust method allows for better inference than one-way cluster-robust methods even when the number of clusters is around 10. Furthermore, Cameron et al. (2006) demonstrate that having few clusters does not warrant reliance on approaches that control only for one-way dependence.

Table 4.3.6: Meta-regression results based on elasticities
Dependent variable: t-values

	Robust Std. Errors	Cluster-robust Std. Errors	Two-way cluster-robust Std. Errors	Random Effects
Precision	-0.018	-0.018	-0.018	-0.012
	(0.091)	(0.025)	(0.025)	(0.091)
Manufacturing employment	0.297***	0.297***	0.297***	0.276***
	(0.067)	(0.014)	(0.014)	(0.067)
Constant	-0.459	-0.459	-0.459	-0.459
	(0.921)	(0.293)	(0.293)	(0.921)
Observations	60	60	60	60
Model degree of freedom	2	1	1	1
R-Squared	0.656	0.658	0.656	
Overall 'R-squared'	---	---	---	0.656
P>F	0.000	N/A	N/A	---
P>Chi^2	---	---	---	0.000
Wald test: precision = manufacturing employment = 0	0.000	0.000	0.000	0.000

Standard errors are in brackets. *, ** and *** denotes significance at 10%, 5% and 1%.

We repeat the estimation procedure with data based on elasticities reported by 3 studies (Table 4.3.6). Because of the smaller sample size and the resulting high levels of multicollinearity, the general-to-specific modelling procedure has led to a highly-reduced meta-regression model – with manufacturing employment dummy remaining

as the only significant variable. The manufacturing employment dummy represents 43.3% of the evidence base in the elasticities dataset. Hence, it is important to establish how the employment-effect of innovation changes when the evidence is related to manufacturing employment only.

Results from the elasticities data confirm the findings from the full sample where the effect-size is measured with PCCs: innovation is associated with a positive effect on employment in manufacturing. Although the effect in the elasticities data is moderate (+0.293), it must be indicated that the F-Test of joint significance was not reported when we conducted the cluster-robust estimations. This is because of the extremely small number of papers (3) and estimation methods (3) that we can use as clusters. Therefore, we have run a Wald Test for joint significance. Although this confirms that the coefficient on the manufacturing employment is statistically significant, we do not recommend this as a representative effect.

4.4 Mapping key findings

In Table 4.3.7 below, we provide a summary of the mapped narrative synthesis and meta-analysis findings. One conclusion in the narrative synthesis is that the overall effect of innovation on total employment is uncertain. However, the qualitative literature also tends to report that innovation's effect on employment is skill-biased rather than skill-neutral; and that the skill-bias is likely to be exacerbated by import of capital-intensive technology. Meta-analysis findings lend support to the qualitative literature claims concerning skill bias. PET-FAT-PEESE results confirm that the effect of process innovation on skilled-labour employment is larger than the effect on all-skill labour; and the MRA results indicate that the effect of both process and product innovation on total employment is augmented by 0.07 when the evidence is related to skilled-labour employment as opposed to total (skilled- and unskilled-labour) employment. Both qualitative and empirical studies relate the skill bias to skill-intensity of imported technology, which is usually not adapted to local skill endowment

Another conclusion supported by narrative synthesis and meta-analysis relates to the effects of innovation on employment at the sector level as opposed to enterprise (firm or farm) level. Meta-analysis results from the full sample of 147 PCCs indicate that sector-level is a moderating factor that dampens the overall effect. This is in line with qualitative evidence indicating that innovation's employment effect at the sector level can be smaller or even negative compared to the enterprise level as job-creation in innovative enterprises or industries may be obtained at the expense of job losses in non-innovative counterparts.

Table 4.3.7: Mapping the narrative synthesis and meta-analysis findings

Process innovation and employment		Product innovation and employment	
Narrative synthesis	**Meta-analysis**	**Narrative synthesis**	**Meta-analysis**
In agriculture (19 studies in total): 1. Mechanization tends to have a negative effect on employment; but the adverse effect is moderated when mechanization is combined with irrigation, product differentiation, and extension of farm land (12 studies). 2. Negative effect is moderated by strong forward backward linkages between enterprises and industries (7 studies). 3. Adverse effect is more likely in large farms, in ploughing and harvesting as opposed to sowing operations, and on family labour as opposed to hired labour (6 studies). 4. Green revolution (GR) technologies have positive effects on farm and off-farm employment in the long run (4 studies). 5. Positive effects of GR technologies are strengthened by increased incomes (2 studies). **In manufacturing** (20 studies in total): 1. Process innovation is skill-biased, with increased demand for skilled and reduced demand for unskilled labour, (17 studies) 2. Low technology adaptation capacity exacerbates the adverse effect on unskilled labour (17 studies) 3. Weak governance and labour market institutions increase the risk of inappropriate technology choice and reduce the scope for employment creation (13 studies). 4. Strong forward/backward linkages ameliorate the negative effect (12 studies). 5. Capital-intensity of international trade exacerbates the negative effect (6 studies). 6. Skewed income distribution exacerbates the adverse effect (4 studies) 7. Low skill upgrading among LIC labour force exacerbate the negative effect (3 studies).	1. Indirect support: effect in manufacturing as opposed to agriculture is positive 2. No control, but indirect support from manufacturing. 3. No control 4. Indirect support: effect in South Asia with GR evidence is positive 5. No control 1. Direct support: effect is positive on skilled labour employment 2. No control 3. No control 4. Indirect support – positive effect in manufacturing where linkages are strong 5, 6. No control 7. Direct support: innovation has a positive effect on skilled-labour employment.	**In agriculture and man.** (5 studies in total) 1. Product innovation is more likely to have a positive effect (2 studies) 2. Strong forward/backward linkages tend to reinforce the positive effect (5 studies). 3. Higher wages are likely to reduce or reverse the positive effect (3 studies). 4. Effect at sector level is uncertain, but likely to be dampened or negative (2 studies) 5. The time horizon matters: positive effect in the short run in manufacturing; in the long run in agriculture. (4 studies). 6. Technology choice matters: innovation tends to create employment when it involves skill-matching and labour-intensive technologies (5 studies). 7. Product innovation tends to have more positive employment effects when new products cater for a wide spectrum of low-income consumers. However, skewed income distribution tends to reduce the positive employment effect (2 studies out 5).	1. Meta-analysis result is insignificant 2. Indirect support: positive effect in manufacturing where linkages are strong 3. No control 4. Effect at sector level is negative but small 5. No control 6. Indirect support: effect on skilled labour employment is positive 7. No control
Empirical studies do not provide either macro-level evidence on overall employment or disaggregated evidence on female labour employment. Therefore, the narrative synthesis findings related to these categories are not reproduced here for mapping purposes.			

We detect a difference between the narrative synthesis and meta-analysis findings with respect to the role of product innovation. The narrative synthesis indicates that product innovation is more likely to be associated with a positive employment-effect compared to process innovation. This is reported to be the case both in agriculture and manufacturing. This conclusion is not supported by meta-analysis. The PET-FAT-PEESE results indicate the employment effect of product innovation is insignificant. This is confirmed in the process of general-to-specific modeling, during which the product innovation dummy had to be dropped as it was insignificant.

The narrative synthesis enables us to derive a number of additional conclusions. It was not possible to verify the extent to which all of these conclusions are also supported by meta-analysis due to lack of relevant data. Nevertheless, it is important to highlight these conclusions as they provide further insights about the roles that mediating factors play in the innovation-employment relationship.

One additional conclusion relates to the role of forward and backward linkages. Qualitative studies report that strong forward and backward linkages constitute a significant compensation mechanism. They can counter the adverse employment-effects of innovation in two ways: (i) by increasing the demand of the downstream firms/industries for the output of the innovative firms/industries; or (ii) by increasing the demand of the innovative firms/industries for inputs from upstream firms/industries. Although qualitative studies emphasize the role of forward and backward linkages, the empirical studies do not investigate how these linkages interact with innovation and with what consequences for employment.

Other additional conclusions relate to the roles of Green Revolution (GR) technologies, international trade and institutions. With respect to GR technology, qualitative studies tend to report a positive effect and the positive effect is more pronounced in the long run and in South Asia, particularly in India. In the meta-analysis, we could not control for GR technology as such. However, when we controlled for South Asia, we found that studies using data on South Asian countries tend to report positive and larger effects on employment. This lends partial support to the narrative synthesis concerning GR technologies.

With respect to international trade, qualitative studies report that openness to trade is likely to dampen the positive or exacerbate the negative effects of innovation on employment. This is due to skill- and capital-intensity of the imported technologies, which induce entrepreneurs in LICs to substitute capital for labour and skilled labour for unskilled labour. Similar conclusions are reported with respect to institutions: weak institutions reduce the scope for appropriate technology choice and induce entrepreneurs to assign larger weights to productivity gains rather than employment gains. Although these factors feature prominently in the narrative synthesis, they are not controlled for in the meta-analysis as the empirical studies are yet to incorporate them into their analysis.

5. IMPLICATIONS

5.1 Strengths and limitations

In this review, we have conceptualised innovation as the 'intervention' and employment as the 'outcome' variables. The existing literature suggests that innovation can either destroy jobs as a result of skill substitution and substitution of capital for labour; or it can create employment through compensation mechanisms such as new entry into the market, emergence of new markets or products or strong forward and backward linkages.

The existing literature identifies a range of moderating factors that influence the balance between the displacement and compensation effects. To capture these factors, we have adopted an inclusive search strategy and coded the extracted evidence with respect to type of innovation (process *versus* product innovation), skill types (skilled, unskilled and all-skill labour), levels of analysis (firm/farm, sector and macro levels), world region, publication type, estimation methods, etc. To ensure inclusiveness, we used a wide range of search terms (64 terms excluding individual names of low-income countries), searched in 31 electronic databases, and conducted hand search using citation information as well as drawing on our knowledge of the research field.

We have also drawn on best practice in the use of mixed methods for mapping meta-analysis and narrative synthesis findings. The narrative synthesis is documented diligently and organised along identifiers used to code the empirical evidence for meta-analysis. Furthermore, we have followed best practice in meta-analysis, including PET-FAT-PEESE methods, general-to-specific modeling, and different estimation methods for taking account of within-study dependence and study-specific random effects. In our mapping of meta-analysis and narrative synthesis findings, we have indicated clearly the areas of convergence and divergence between the two sets of evidence.

Nevertheless, it must be emphasized that this systematic review investigates a complex question, with evidence from 53 qualitative and just 9 quantitative studies. Therefore conclusions should be considered as best evaluations and synthesis of available evidence but not a conclusive assessment of all dimensions of the review question. In particular, evidence on macro-level employment impact of innovation, on the relationship between innovation and gender-specific employment, and on the impact of product innovation is particularly limited.

In addition, the effect-size estimates used in the meta-analysis are highly varied. In the full sample, some (34%) of the variation could be explained by observed moderating factors, leaving a high level of unexplained variation. In the elasticities sample, a higher proportion (66%) of the variation could be explained, but this was accounted for by one moderating variable only. It must also be indicated that the number of empirical studies (9) is rather small despite the fact that we have extended the inclusion period back to the 1970s. These limitations do not invalidate the review findings, but they indicate the need for some caution and care in interpreting the results. They also indicate that the

evidence base should be strengthened through investment in compilation of innovation data and via further research that would utilise the new data as well as new developments in theoretical and empirical modelling.

With these caveats in mind, this systematic review demonstrates that process innovation has a positive but small effect (+0.102) on skilled-labour employment. The effect of both process and product innovation on total (skilled- and unskilled-labour) employment is positive (+0.026) but too small to be statistically significant. When we control for sources of heterogeneity, we observe that the effect of innovation on employment is conditional on a range of moderating factors. When the statistically-significant moderating factors are taken into account, the effect is equal to 0.151 in the full sample of 147 PCCs. This effect is conditional on evidence related to: (i) employment of skilled labour as opposed to unskilled and mixed-skills labour; (ii) employment in manufacturing sector as opposed to agriculture or services; (iii) employment at the sector level as opposed to enterprise level; and (iv) employment effects in South Asian countries as opposed to other world regions.

When the observed moderating variables are assumed equal to zero, the effect of innovation on employment is negative (-0.133). This is the case when the evidence is related to: (i) employment of unskilled or mixed-skill labour as opposed to skilled labour; (ii) employment in agriculture or services as opposed to manufacturing; (iii) enterprise or macro-level data as opposed to sector level data; and (iv) data for other world regions as opposed to South-Asian data.

5.2 Policy and research implications

Review findings supported *both* by narrative synthesis and meta-analysis can be summarized as follows:

1. The effect of innovation on employment is mediated by a range of moderating factors such as type of innovation (product versus process innovation), skill types (skilled, unskilled and all-skill labour employment), level of analysis (effects at firm/farm, sector and macro levels), forward/backward linkages, income levels and distribution, international trade, and institutional quality.
2. Innovation's effect on employment is more likely to be positive when the evidence is related to skilled-labour employment, employment in the manufacturing sector, and employment in South Asian countries.
3. Innovation's effect on employment is more likely to be negative when the effect is measured at sector rather than enterprise (firm or farm) level, and the skill category is unskilled labour.

Further findings supported by the narrative synthesis *only* can be summarized as follows:

1. The employment-effects of innovation are more likely to be positive when there are strong forward/backward linkages between innovative firms/farms/industries and upstream or downstream firms/industries; and when governance institutions encourage and facilitate technology adaptation.
2. International trade between LICs or between the latter and developed countries is capital- and/or skill-intensive and hence it is more likely to increase the skill-bias of innovation.
3. There is qualitative evidence indicating that technology adaptation is more likely to create employment compared to off-the-shelf technology imported from developed countries. However, there is no consensus on how to strike an optimal balance between efficiency and employment gains when technology choices are made.
4. With respect to female employment, there is limited evidence indicating that innovation is likely to increase the employment of younger and more educated women in manufacturing. However, it is also likely to increase gender-based segmentation in the labour market. Innovation in agriculture is reported to increase the time that rural women are likely spend on housework and child care; and this tendency is more prevalent as the level of literacy increases.

These findings have policy and practice relevance for international development agencies and policy makers. Also, they point out some implications for future research.

One policy implication concerns the positive relationship that policy statements tend to establish between innovation and desirable objectives such as growth, employment and achievement of the Millennium Development Goals. This systematic review indicates that policy statements about the relationship between innovation and employment in LICs must be qualified. Although process innovation is associated with a positive effect on skilled-labour employment, the effect of both process and product innovation on total (mixed-skills) employment is too small to be practically significant. Stated differently, innovation tends to be associated with a small skill bias in LICs, which is in line with findings of skill-biased technological change in developed countries. Furthermore, the effect of innovation employment in LICs is mediated through a range of moderating factors.

The review findings do not imply that innovation is detrimental to job creation in LICs, but they indicate that pro-innovation policies should be accompanied with complementary policies that would increase the effectiveness of the compensation mechanisms. Skill-biased innovation is likely to exacerbate income and wage disparity in LICs; and this effect is likely to be exacerbated by international trade. Therefore, policies aimed at fostering innovation must be accompanied with: (i) support for education and skill upgrading; and (ii) support for technology adaptation that takes account of existing skill and factor endowment in LICs. Investment in education and skill upgrading is a prominent policy issue on the agendas of national and international organisations. However, there is little or no attention paid to the issue of adapting technology to skill endowment in LICs.

The existing research does not provide clear guidelines on how technology can be adapted to reconcile efficiency and employment objectives of the enterprises and/or

policy makers. Nevertheless, it does provide case-study evidence that indicates that innovation is usually conducive to job creation when capital-intensive technology is introduced for core production processes and complemented with labour-intensive technology for secondary processes; and when national and regional institutions exist to encourage the combination of off-the-shelf technology with local knowledge and skill/factor endowment. Hence, this review indicates that the national and international policy emphasis on innovation as a driver for growth should be accompanied with similar emphasis on the role of national/regional institutions that would facilitate technology adaptation with a view to maximize the employment-creating (or minimise the employment-destroying) effects of innovation.

Although these policy recommendations are supported by the evidence synthesized in this review, we should also indicate two potential sources of weakness in the evidence base. First, the empirical evidence is limited and the qualitative studies tend to be dated back to the 1970s and 1980s. Secondly, and with the exception of few studies (e.g., Berman and Machine, 2000; Berman et al, 2005; and Conte and Viavrelli, 2011), there is little or no cross-fertilisation between recent studies on LICs and the large volume of work on innovation-employment relationship in developed and middle-income countries, which is usually based on comprehensive survey data.

As indicated above, the small empirical evidence base has limited the extent to which we can control for the effects of moderating factors on the overall effect of innovation in LICs. In addition, studies on developed and middle-income countries tend to rely on rich survey data and control for different types of innovation, skill levels and openness to trade. Similar work on LICs is yet to emerge. The delay so far has been due to lack of data and absence of theoretical work that would bridge the gap between technology adaptation perspectives of the 1970s-1980s on developing countries and the recent debate on skill-biased technical change (SBTC) in developed and middle-income countries. These constraints do not invalidate the proposed policy implications, but they indicate an evident need for further research on the innovation-employment relationship in LICs.

One avenue for future research is to make better use of existing firm-level survey evidence in *Enterprise Surveys* compiled by the World Bank and the International Finance Corporation (IFC).[13] These surveys provide evidence on a wide range of firm-specific indicators including innovation and employment, export orientation, and financial and governance factors in a number of LICs. This evidence can be analysed and, if necessary, compared with evidence on middle-income countries to enrich the existing evidence base. Another avenue would be to make use of the emerging African Science Technology and Innovation Indicators (ASTI) from recent R&D and Innovation surveys compiled by the New Partnership for Africa's Development (NEPAD).[14]

[13] The range of innovation-related questions in these surveys has increased recently, as a result of DFID and World Bank collaboration. See, http://www.enterprisesurveys.org/

[14] See, http://www.nepad.org/system/files/June2011_NEPAD_AIO_2010_English.pdf

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APPENDICES

Appendix 1.1: Authorship of this report

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Acknowledgements

We would like to thank DFID for funding this systematic review and for encouraging systematic reviews of economics literature in general. We would also like to thank the EPPI-Centre and MAER-Net for their technical and methodological support.

Appendix 2.1: Inclusion and exclusion criteria

At the title/abstract screening stage, study relevance was ascertained by interrogating each study with 4 questions derived from the PIOS framework. The questions and their relationship with the PIOS framework are as follows:

a. With respect to **Population:**

   - Is the study relevant for understanding the innovation-employment relationship in **low-income countries** (or synonyms)?

b. With respect to **Independent variable:**

   - Is innovation (or synonyms) **independent** rather than outcome variable in the study?

c. With respect to **Outcome variable:**

   - Is employment (or synonyms) **outcome** rather than independent variable in the study?

d. With respect to **Study design**

   - Is the study **original** and NOT a review of original studies?

The PIOS criteria tested with these questions were coded in EPPI Reviewer – our main data storage and management platform. The selection/de-selection decisions were taken in accordance with the following rule:

- Studies **satisfying the 4 PIOS criteria** were **selected** for the next stage
- Studies **failing to satisfy any of the PIOS criteria** were coded accordingly and **de-selected** from the review.

At the full-text stage, we assessed the ***eligibility of the studies for inclusion in the systematic review.*** Full-text of selected studies were read in order to assess the extent to which the study satisfies the PIOS criteria. Three reviewers (Denise Hawkes, Arup Mitra and Mehmet Ugur) applied the PIOS criteria to full-text studies independently. However, before independent screening, we conducted a pilot of 10 studies listed in search results. The aim here was to test whether the proposed inclusion criteria could be interpreted reliably and consistently; and whether they are effective in identifying studies for inclusion/exclusion. Any discrepancies between reviewer decisions were discussed, and both the discussion and the basis of *ex-post* agreement are documented. The PIOS criteria for inclusion/exclusion at the full-text stage are specified as follows:

Table A2.1. 1 PIOS criteria for inclusion/exclusion with full-text information

PIOS Heading	Inclusion/Exclusion Criteria	Question	Decision
Population	1**. Data/evidence including low-income countries and/or LMIC**	1. **Does the study use data including 'low-income countries' or LMIC its synonyms?**	Yes -Include No -Exclude
Independent Variable	2.Documented/recognised innovation data/evidence source	2. Does the study use a documented/recognised data/evidence source for innovation?	Yes -Include No –Exclude
Outcome	3. Employment is a main outcome variable, measured with recognised/documented data/evidence	3. Does the study report innovation effects on employment rather than other labour market outcomes such as wages only?	Yes -Include No –Exclude
Study Design	4. Valid study design	4. Does the study have a clearly set out theoretical framework linked to quantitative or qualitative evidence? OR Does the study have a clearly set out empirical framework tested with quantitative evidence?	Yes–Include and code as Qualitative/analytical (QA) No –Exclude Yes–Include and code as empirical (EM) No –Exclude

Decision rule: a study was included for critical evaluation if it satisfied 4 criteria/questions

To establish validity, reliability and applicability (VRA), we interrogated each study with the set of questions listed in the table below.

Table A2.1. 2 : Validity-Reliability-Applicability (VRA) criteria for final inclusion

	VRA Criteria	Question	Decision
1.	**Validity of construct**	Is innovation-employment relationship theorised/modelled coherently and in the light of existing literature?	Yes -Include No -Exclude
2.	**Validity of method**	Is the method of analysis informed by existing theory/theories?	Yes -Include No –Exclude
3.	**Reliability of data/evidence (1)**	Is data/evidence documented and its reliability discussed?	Yes -Include No –Exclude
4.	**Reliability of data/evidence (2)**	Is the evidence related to causal mechanisms postulated in the innovation-employment relationship?	Yes–Include No –Exclude
5.	**Reliability of estimation**	Are other relevant variables that impact on employment controlled for?	Yes–Include No –Exclude
6.	**Reliability of findings (1)**	Are the findings tested for robustness?	Yes–Include No –Exclude
7.	**Reliability of findings (2)**	Are the findings related to relevant methodological or theoretical/analytical literature?	Yes–Include No –Exclude
8.	**Applicability to LICs**	Are the findings applicable to low-income countries on theoretical or empirical grounds?	Yes -Include No -Exclude

A study was included for meta-analysis and/or narrative synthesis if it satisfied 6 out of 8 VRA criteria – provided that it satisfied at least one of the two 'data/evidence reliability' and 'findings reliability' criteria. In other words, a study was included if it satisfied criteria 1, 2, 3, and 6; and one of 4 or 5 and one of 7 or 8. We provided a breakdown of included and excluded studies, and the latter was also broken down with respect to the number of criteria they failed to satisfy.

Appendix 2.2: Search strategy for electronic databases

Table A2.2 1 : Search strategy with number of results returned

Database/Platform	Date	String	Overall Hits
Business Source Premier ***Search conducted by using 'Title', 'Abstract', 'Keyword' and 'All' fields.***	1 June, 2011	**Search 1 – Innovation and Synonyms in Title, Abstract and Keywords (1118952hits)** TI (Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) or AB (Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) or SU (Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) **Search 2 – Employment and Synonyms in Title, Abstract and Keywords (941041hits)** TI (Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") or AB (Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") or SU (Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") **Search 3 – LICs and Synonyms in All fields + Text (334510hits)** "Low income country" OR "Low income countries" OR "Low-income country" OR "Low-	1050 (559 After Managing Duplicates)

		income countries" OR LIC OR LICs OR "Developing country" OR "Developing countries" OR "Less developed country" OR "Less developed countries" OR "Underdeveloped country" OR "Underdeveloped countries" OR Africa OR Asia OR "Latin America" OR "third world" **Search 4 – Combine Search 1, 2 & 3 with the Boolean operator "AND" (1050 hits)** ("Low income country" or "Low income countries" or "Low-income country" or "Low-income countries" or LIC or LICs or "Developing country" or "Developing countries" or "Less developed country" or "Less developed countries" or "Underdeveloped country" or "Underdeveloped countries" or Africa or Asia or "Latin America" or "third world") AND (TI(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR AB(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR SU(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization")) AND (TI(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR AB(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR SU(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or	

		Mechanisation or "Knowledge transfer" or Diffusion))	
IBSS ***Search conducted by using 'Title', 'Abstract', 'Keyword' and 'All' fields.***	8 June, 2011	**Search 1 – Innovation and Synonyms in Title, Abstract and Keywords (111016hits)** ti(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR ab(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR tag(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) **Search 2 – Employment and Synonyms in Title, Abstract and Keywords (88144hits)** ti(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR ab(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR tag(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") **Search 3 – LICs and Synonyms in All fields + Text (248619hits)** "Low income country" or "Low income countries" or "Low-income country" or "Low-income countries" or LIC or LICs or "Developing country" or "Developing countries" or "Less developed country" or "Less developed	1529 (1072 after managing duplicates)

		countries" or "Underdeveloped country" or "Underdeveloped countries" or Africa or Asia or "Latin America" or "third world" **Search 4 – Combine Search 1, 2 & 3 with the Boolean operator "AND" (1529 hits)** ("Low income country" or "Low income countries" or "Low-income country" or "Low-income countries" or LIC or LICs or "Developing country" or "Developing countries" or "Less developed country" or "Less developed countries" or "Underdeveloped country" or "Underdeveloped countries" or Africa or Asia or "Latin America" or "third world") AND (ti(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR ab(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR tag(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization")) AND (ti(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR ab(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR tag(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion))	
	19 June,	**Combination 1**	1171 (838

JSTOR **Search conducted in 'Abstract' field only as this field yielded the highest number of hits. In this database, the number of search terms that can be used is restricted. Therefore, the search was conducted in four iterations.**	2011	(ab:(Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services") AND ab:(Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution)) (392hits) **Combination 2** (ab:(Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services") AND ab:("Labo*r mobilization" OR manpower OR "work force" OR Workforce OR "labo*r pool" OR "labo*r market")) (64hits) **Combination 3** (ab:("Techn* progress" OR "Techn* chang*" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion OR mobilisation OR mobilization OR "modern method" AND ab:(Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution)) (54hits) **Combination 4** (ab:("Techn* progress" OR "Techn* chang*" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion OR mobilisation OR mobilization OR "modern method" AND ab:("Labo*r mobilization" OR manpower OR "work force" OR Workforce OR "labo*r pool" OR "labo*r market")) (23hits) **Combination 5** (ab:("modern methods" OR "new process" OR "novel technology" OR "novel processes" OR Techn* OR "know-how" OR knowhow OR "knowledge utilisation" OR "knowledge utilization" OR "knowledge capital" OR TFP AND ab:(Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand"	after managing duplicates)

		OR Substitution)) (541 hits) **Combination 6** (ab:("modern methods" OR "new process" OR "novel technology" OR "novel processes" OR Techn* OR "know-how" OR knowhow OR "knowledge utilisation" OR "knowledge utilization" OR "knowledge capital" OR TFP AND ab:("Labo*r mobilization" OR manpower OR "work force" OR Workforce OR "labo*r pool" OR "labo*r market")) (97 hits)	
EconLit ***Search conducted by using 'Title', 'Abstract', 'Keyword' and 'All' fields.***	14 August, 2011	**Search 1 – Innovation and Synonyms in Title, Abstract and Keywords (861023hits)** TI (Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) or AB (Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) or SU (Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) **Search 2 – Employment and Synonyms in Title, Abstract and Keywords (571931hits)** TI (Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") or AB (Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") or SU (Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r	(710 after managing duplicates)

		Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") **Search 3 – LICs and Synonyms in All fields + Text (205823hits)** "Low income country" OR "Low income countries" OR "Low-income country" OR "Low-income countries" OR LIC OR LICs OR "Developing country" OR "Developing countries" OR "Less developed country" OR "Less developed countries" OR "Underdeveloped country" OR "Underdeveloped countries" OR Africa OR Asia OR "Latin America" OR "third world" **Search 4 – Combine Search 1, 2 & 3 with the Boolean operator "AND" (1123hits)** ("Low income country" or "Low income countries" or "Low-income country" or "Low-income countries" or LIC or LICs or "Developing country" or "Developing countries" or "Less developed country" or "Less developed countries" or "Underdeveloped country" or "Underdeveloped countries" or Africa or Asia or "Latin America" or "third world") AND (TI(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR AB(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization") OR SU(Employment or Unemployment or Jobs or Job or Worker or workers or Employee or employees or "Labo*r composition" or "Labo*r Force" or Labo*r demand or "Factor demand" or Substitution or "Labo*r mobilization")) AND (TI(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR AB(Innovation or Techniques or "Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion) OR SU(Innovation or Techniques or	

		"Capital utilization" or Technolog* or "Factor intensity" or "Total factor productivity" or "New products" or "New processes" or "New methods" or "New services" or "Technical progress" or "Technical change" or "Modern method" or "Green revolution" or Mechanisation or "Knowledge transfer" or Diffusion))	
Web of Knowledge **Search conducted in 'Title' field only due to high level of duplicates. The rate of duplicates remained high even when the search was conducted in the 'Title' filed only.**	21 July, 2011	Title=(Innovation OR Techniques OR "Capital utilization" OR Technolog* OR "Factor intensity" OR "Total factor productivity" OR "New products" OR "New processes" OR "New methods" OR "New services" OR "Technical progress" OR "Technical change" OR "Modern method" OR "Green revolution" OR Mechanisation OR "Knowledge transfer" OR Diffusion) AND Title=(Employment OR Unemployment OR Jobs OR Job OR Worker OR workers OR Employee OR employees OR "Labo*r composition" OR "Labo*r Force" OR Labo*r demand OR "Factor demand" OR Substitution OR "Labo*r mobilization") Refined by: Subject Areas=(BUSINESS ECONOMICS)	818 (435 after managing duplicates)
Other Databases **Databases listed in column 3 do not allow for complex search.** **We conducted simple search in these databases, using the following strings:** **Innovation, Employment and Low-income countries** **Innovation, Employment and developing countries** **Innovation, Labour and Low-income countries** **Innovation, Labour and developing countries**	25-28 August, 2011	**List of Databases** Africabib.org Africa Development Bank Asian Development Bank British Library for Development Studies CAB Abstracts Centre for International Development Directory of Open Access Journals Electronic Thesis Online Service Economics Search Engine FAOBIB Google Scholar Index of Conference Proceedings Index to Theses Ingenta Connect International Development Abstracts Information Portal Rural Innovation Systems ILO Library NBER Working Papers Research Papers in Economics SSRN World Bank e-Library ZETOC	Total number of studies identified: 441

Technology, Employment and Low-income countries **Technology, Employment and developing countries** **Technology, Labour and Low-income countries** **Technology, Labour and developing countries**			
		Total number of study records uploaded to EPPI-Reviewer	**4,055**

Appendix 2.3: List of databases and hand searched articles

Table 2.3.1 List of databases searched

Database	Description and Access
1. **Africabib.org**	http://www.africabib.org/africa.html
2. **Africa Development Bank**	http://www.afdb.org/en/documents/
3. **Asian Development Bank**	http://ss.adb.org/?type=advanced
4. **BLDS (British Library for Development Studies)**	The British Library for Development Studies (BLDS) contains the largest collection of economic and social development materials in Europe, with over half originating from developing countries. http://blds.ids.ac.uk
5. **Business Source Premier** 6. **(EBSCO - Business and Economics Databases)**	Very wide-ranging within the Business discipline, including marketing, management, accounting, finance, economics, *etc*. Largely full-text journal articles, plus market research reports, industry reports, country reports, company profiles and SWOT analyses. (University of Greenwich portal)
7. **CAB Abstracts**	A bibliographic database compiled by the Commonwealth Agricultural Bureau International (CABI). It covers the significant research and development literature in the fields of agriculture, forestry, human health and nutrition, animal health, and the management and conservation of natural resources, with particular attention to the needs of developing countries.
8. **Centre for International Development**	CENTRE FOR INTERNATIONAL DEVELOPMENT OF HARVARD UNIVERSITY http://www.hks.harvard.edu/centers/cid/publications
9. **DOAJ (Directory of Open Access Journals)**	A multi-disciplinary database of freely available, peer-reviewed full-text journals. (These may not be contained in any of the aggregate databases such as ABI/Inform or Business Source Premier.)
10. **EconLit**	Provides bibliographic citations, with selected abstracts, to the international literature on economics from 1969, plus full text for more than 400 journals. It provides indexing and full text for articles in all fields of economics, including [...] country studies, and labour economics". (University of Greenwich portal)
11. **EThOS (Electronic Thesis Online Service)**	The British Library's repository of post-doctoral theses from participating UK universities (see: http://ethos.bl.uk/HEIList.do).
12. **ESE (Economics Search Engine)**	Contains "over 23,000 economics websites and utilizes yolink to mine results and retrieve actionable, keyword-rich content. Results can be saved to Google Docs, bookmarked or shared via major social networks. Each site is certified by RFE". Available at:

Database	Description and Access
	http://ese.rfe.org/
13. FAOBIB (UN Food & Agricultural Organization)	On-line catalogue of documents and publications produced by FAO since 1945, books added to the library collections since 1976, and serials. http://www4.fao.org/faobib/index.html
14. Google	http://www.google.com
15. Google Scholar	Searches across many disciplines and sources: articles, theses, books, abstracts and court opinions, from academic publishers, professional societies, online repositories, universities and other web sites. http://scholar.google.co.uk/schhp?hl=en&tab=ws
16. IBSS (International Bibliography of the Social Sciences)	Contains references to journal articles and some books. Broad ranging coverage of the social sciences, including economics, demography, political science and sociology. International coverage. (University of Greenwich portal)
17. Index of Conference **18. Proceedings**	Lists conference proceedings newly acquired by the British Library and available for loan or document supply. The BL acquires the proceedings of all significant conferences held worldwide regardless of subject or language and currently holds the proceedings of over 450k conferences.
19. Index to Theses	References to higher degree theses accepted by universities in Great Britain and Ireland. (University of Greenwich portal)
20. IngentaConnect	Multidisciplinary collection of full-text articles and bibliographic citations. (University of Greenwich portal)
21. International Development Abstracts (Elsevier)	*International Development Abstracts* was founded in response to the need for a reference journal covering the growing literature on topics and issues relating to developing countries and remains the leading bibliographical reference source in the field. Papers are divided into 40 main headings including sections on agriculture and rural development; environment and development; industrial policy; social policies such as health, housing, and education; health, demography; gender and culture; aid, international relations and politics. (University of Greenwich portal)
22. JSTOR	References to journal articles. Full text available for the Business Collections (1 & 2). (University of Greenwich portal)
23. KIT Information Portal Rural Innovation Systems	This information portal provides access to free, full-text electronic documents on Rural Innovation Systems (RIS), both as an analytical concept and a development tool. It is also a unique entry point for all other Internet sources on RIS, including newsletters, discussion groups, websites, bibliographic databases, and directories of organizations and projects. http://portals.kit.nl/-/7587/KIT-Portals/Portal-Rural-Innovation-Systems
24. Labordoc (ILO Library)	Contains references to print and electronic publications, including journal articles, from countries around the world, on all aspects of work and sustainable livelihoods, and the work-related aspects of economic and social development and human rights. Available at:

Database	Description and Access
	http://labordoc.ilo.org
25. NBER (National (U.S.) Bureau of Economic Research) Working Papers	Full-text access to working papers, plus references to selected books/book chapters. (University of Greenwich portal)
26. OECD iLibrary	References to journal articles, book chapters and datasets. (Greenwich has limited access to some full-text resources.). (University of Greenwich portal)
27. RePEc (Research Papers in Economics)	Collaborative international project for the dissemination of economics literature. Contains full text and references to book chapters, journal articles and working papers. (Note that the working papers are also offered through EconLit.) Can be searched via the IDEAS interface at: http://ideas.repec.org/search.html
28. SSRN	The SSRN eLibrary consists of two parts: an Abstract Database containing abstracts on over 336,600 scholarly working papers and forthcoming papers and an Electronic Paper Collection currently containing over 272,800 downloadable full text documents in Adobe Acrobat pdf format. The eLibrary also includes the research papers of a number of Fee Based Partner Publications. http://papers.ssrn.com/sol3/DisplayAbstractSearch.cfm
29. Web of Knowledge	Includes the *Social Sciences Citation Index*, and *Conference Proceedings Indices* for *Science* and *Social Sciences and Humanities*
30. World Bank e-Library	Contains books, journal articles, working papers and other research publications. Full text is available only to subscribers. However, it is fully searchable at: http://elibrary.worldbank.org/search/advancedsearch
31. ZETOC	The British Library's multi-disciplinary Electronic Table of Contents service. Contains references to journal articles and conference papers. (British Library)

Table 2.3.2: List of hand-searched journals

In addition to database searches, we have also conducted manual searches in journals and in conference websites with specialism in innovation and/or employment. Hand-searched journal websites included:

Labour - Review of Labour Economics and Industrial Relations;

http://eu.wiley.com/WileyCDA/WileyTitle/productCd-LABR.html

International Labour Review;

http://www.ilo.org/public/english/revue/index.htm

Indian Journal of Industrial Relations;

http://www.srcirhr.com/ijir.php

Science and Public Policy;

http://spp.oxfordjournals.org/

Journal of Development Economics;

http://www.journals.elsevier.com/journal-of-development-economics/

Journal of Development Studies and *World Development*

http://www.journals.elsevier.com/world-development/

Appendix 2.4: EPPI-Centre Keyword sheet including review-specific keywords

Review-specific keywords

Searches in databases were mainly conducted as 'Title', 'Abstract', 'Keyword', and 'Text' searches. The search procedures were based on recommendations provided in the **EPPI Workshop** held at the Institute of Education and the text mining method suggested in CRD (2009); and were driven by the following specifications:

Keyword - Innovation

Synonyms: Innovation OR "New Technique*" OR "New Technolog*" OR "Factor Intensity" OR "Total Factor Productivity" OR "New Product*" OR "New Process*" OR "New Method*" OR "New Service*" OR "Techn* Progress" OR "Techn* Change" OR "Modern Method" OR "Green Revolution" OR Mechanisation OR "Knowledge Transfer" OR "Technolog* Diffusion" OR "Technolog* Choice" OR "Technolog* Adoption" OR "Technolog* Import" OR "Import of Technolog*" OR TFP OR "Purchase of Technology" OR "Technolog* Transfer" OR "Capital Goods Import"

Keyword - Employment

Synonyms: Employment OR Unemployment OR "Labo*r composition" OR Labo*r Demand OR "Factor Demand" OR "Substitution Effect*" OR "Substitution Mechanism*" OR "Labo*r mobilization" OR "Job Creation" OR "Job Destruction" OR "Demand for Labo*r" OR "Labo*r Demand" OR "Demand for Skill" OR "Skill demand" OR "Skill-bias*" OR "Skill Bias" OR "Compensation Effect*" OR "Compensation Mechanism*" OR "Female Labo*r" OR " Women Employment"

Added: Informal employment (upon DFID recommendation)

Keyword - Low-income countries

Synonyms: "Low* income countr*" OR "Low-income countr*" OR LIC OR LICs OR LMIC* OR "Low* Middle Income Countr*" OR "Developing countr*" OR "Less developed country" OR "Less* developed countries" OR "Low* income econom*" OR "Low* Middle Income econom*" OR "Underdeveloped country" OR "Underdeveloped countries" OR Africa OR Asia OR "Latin America" OR "third world" OR "low and middle income" OR "lower middle income"; names of LICs or LMICs in World Bank list (Appendix, Table A2).

Time period: January 1970 – May 2011.

Language: Open

Appendix 3.1: Details of studies included in the systematic map

80 Studies were included in the Systematic Map. At the VRA criteria level, 8 studies were excluded based on validity, 11 excluded based on reliability and 5 based on applicability making a total of 17 excluded. The total number of studies included finally for the review is 63. The bibliographical and content characteristics of these studies are provided in **table A3.1.1 and A3.1.2** below.

Table A3.1 1 Bibliographical characteristics of include studies

BIBLIOGRAHICAL CHARACTERISTICS		Count	Percent
Publication Type			
Journal Articles		51	81.0
Book Chapter		3	4.8
Dissertation		3	4.8
Whole Book		4	6.3
Research Project (WP)		2	3.2
	Total	63	100
Publication Year			
1970 – 1975		14	22.2
1976 – 1980		5	7.9
1981 – 1985		11	17.5
1986 – 1990		7	11.1
1991 – 1995		4	6.3
1996 – 2000		6	9.5
2001 – 2005		5	7.9
2006 – 2010		10	15.9
2011		1	1.6
	Total	63	100
Study Type			
Qualitative/Analytical		53	84.5
Empirical		9	14.5
	Total	62	100

Table A3.1 2 Content characteristics of 62 included studies

CONTENT CHARACTERISTICS	% of studies
Sector analysed	
Agriculture	52.7
Manufacturing	45.9
Services	1.4
Innovation Type	
Process	84.8
Product	15.2
Employment type	
Skilled labour	21.6
Unskilled labour	24.6
Mixed skill	54.8
Level of analysis	
Firm	11.3
Farm	20.9
Sector/Industry	54.2
Macro	8.1
Female labour	6.5
REGION	
Africa	24.4
East Asia	29.9
South-East Asia	36.2
Latin America	17.3

Appendix 4.1: Structured abstracts of studies included in the review

Table A4.1.1: Structured abstracts and details of studies

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Agarwal, B.. (1981)	India: 1982-83	Farm	Intervention: mechanisation and HYV seeds Type: Process + product innovation	Survey evidence: Decomposition	Fall in family labour input, increase in hired and causal labour input.
Study summary/findings: This provides a disaggregated account of how mechanisation and introduction of high-yield varieties affect labour use in agriculture. It is based on evidence from 240 farms in 1971-72. The study reports that the employment effects of mechanisation and new seed varieties depends on farm size and the type of operation (ploughing, sowing, irrigation and harvesting). One overall effect is reduced use of family labour. However, the reduction in family labour is accompanied with increased use of hired labour (casual or permanent). This effect is more pronounced in large farms.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Agbesor, K. N. (1984)	Nigeria: 1982-83	Firm	Intervention: Technology adoption Type: Process + product innovation	Interviews, company records: descriptive analysis	Process innovation requires choice of appropriate technology. Product innovation that follows creates employment.

Study summary/findings:

This study (PhD Thesis) reports findings based on interviews with company managers and company records for two manufacturing companies: a bicycle manufacturer and a household cooking appliances manufacturer. It draws on the literature examining appropriate technology adoption and adaptation in the context of developing countries. In that literature, technological innovation is likely to have a positive effect on employment if: (i) the technology is skill-complementary (i.e., it is standard, semi-automatic and labour-intensive); (ii) it creates forward linkages through new distribution/dealership networks and backward linkages through suppliers; (iii) it leads to second-round innovation in marketing and in product development. The author reports that the two companies considered technology choice carefully in the light of labour and skill supply and local inputs. They have also created forward linkages through new dealers and wider product ranges (e.g. manufacturing of bicycle ambulances for use in rural areas, electric cookers and deep fryers). Quantifying job creation through forward linkages is more feasible compared to job creation through backward linkages – and the level of job creation is a positive function of product development. The bicycle manufacturer had created more new jobs through forward linkages than the cooking appliance manufacturer did as the former had developed 12 product- innovations and the latter only 4.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Ahammed and Herdt (1983)	Philippines, 1975.	Sector	Intervention: New irrigation techniques and mechanisation Type: Process innovation	Official statistics: Decompisition.	Technology change is conducive to increased employment in rice production. Overall effect depends on balance between production, consumption and import substitution linkages.
Narrative synthesis: This study uses a social accounting matrix approach to estimate the net employment and income effects of mechanization in the Philippine rice production. It draws on national income and input-output data in 1975. It calculates the direct and indirect employment increase from a 1% change in consumer spending for rice. The increase is the largest if production is switched from carabao to power tiller system with gravity irrigation. The calculated employment increase is greater if the increase is met from production in gravity irrigated rather than rain-fed lowland production. The change in employment that occurs depends on the indirect effects arising from production, consumption, and import substitution linkages. Indirect effects may either offset or reinforce the direct effects. In the cases studied here, the indirect effects tend to offset the employment reduction from machinery adoption and reinforce the employment increase from irrigation intensification.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Ahammed and Herdt (1984)	Philippines, 1975.	Sector	Intervention: New irrigation techniques and mechanisation Type: Process innovation	Official statistics: Decompisition.	Mechanisation and irrigation combined lead to increased employment in rice production. The effect depends on consumption linkages and the combination of irrigation and mechanisation techniques.

Narrative synthesis:

This study also uses a social accounting matrix approach to estimate the net employment of mechanization in the Philippine rice production. It draws on national income and input-output data in 1976. Mechanisation (use of power tillers and tractors instead of traditional carabao) leads to increase in employment if it is combined with irrigation. It leads to fall in employment if it is introduced in rain-fed farms. Mechanical threshers lead to fall in employment irrespective of irrigation technique. Similar to Ahammed and Herdt (1983), the study demonstrates that the indirect effects of technology change are due to consumption linkages. These effects outweigh the labour-reducing direct effects of mechanisation in most scenarios, with the exception of large tractors combined with large threshers.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Ahmed (1987)	South Asia	Female labour	Intervention: Green revolution, mechanisation Type: Process innovation	Qualitative: Theoretical/analytical Study	Use of tractors leads to fall in male and female employment.

Study summary/findings:

This study analyses the direct employment implications of technological change at different stages of the sex-sequential labour and production process, taking into account the effects of backward and forward production linkages. Green revolution (i.e., introduction of high-yield varieties – HYVs) leads to two opposing effect on the demand for female labour: (i) increased demand if the level of mechanisation remains the same; (ii) reduced demand if the Green Revolution is combined with increased mechanisation. Mechanisation (with or without Green revolution) leads to lower *direct* demand for female labour. The *indirect* effect depends on forward and backward production linkages. Forward linkages can have a negative effect on the demand for female labour when new/mechanised technology replaces old/traditional technology. Examples of negative effects have been observed in rice and oil mills, where larger and mechanised mills were labour-saving. Labour savings affect male and female labour, but demand for female labour falls more than the demand for male labour. Backward linkages can also have a negative effect on female employment. This is the case when traditional methods of producing inputs (for example hand-made fishing nets) are replaced by factory-made nylon nets. However, backward and forward linkages can also lead to increased demand for female labour - even if innovation affects the downstream and upstream production processes. For example, mechanisation of fishing boats coupled with the use of ice for preservation of fish have led to increased female employment in ice and freezing plants. A similar result was observed in the case of new technologies for milk preservation. The new technologies have led to establishment of large milk-processing plants and increased demand for female labour in neighbouring villages.
The study concludes that the total (direct and indirect) effects of innovation on female employment in agriculture and the fishery sector depend on technology choice. However, it does not analyse the factors that determine technology choice.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Ahmed (1988)	Third World	Sector	Intervention: Bio-technology/Bio-revolution Type: Process and product innovation	Qualitative: Theoretical/analytical study	Bio-technology in the North has led to employment fall in the Third World. Bio-revolution can lead to poverty alleviation in the Third World.

Study summary/findings:

The study makes a comprehensive assessment of the impact of biotechnology on agriculture, and poor in particular. Biotechnology revolution (BR) is likely to enhance the production of the crops that the small farmers are likely to grow and thus beneficial effects are ensured. In BR technology generation, the role of plant breeders remains very important and the BR by no means will displace the green revolution (GR). GR will continue to have positive effect on agricultural growth in favourable areas but BR will be beneficial in the neglected areas and for small farmers particularly. The existing patterns of trade and agricultural production are affected by biotechnological developments in plantation crops. Enzyme technology and the development of tissue culture in the North are taking jobs away from the palm-oil and thaumatin plantations in the Third World, for example. Hence, there is a need to look into the adverse consequences of technological growth.

The study argues that BR will contribute to poverty reduction in the Third World by rendering support to the small farmers.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Almeida (2010)	Eight East Asian countries / 2002-2005	Firm	Intervention: Technological innovation	Quantitative: Survey data; OLS estimation	International trade and technology adoption are both conducive to increased demand for skilled labour in East Asia. The effect is weaker in low-income countries such as China, Vietnam and Cambodia.
Study summary/findings: This paper investigates the effects of openness and technological innovation on the demand for skilled labour among East Asian Firms. It utilizes World Bank's Enterprise Survey data from the years 2002, 2003 and 2005. Using a demand function for skilled labour and ordinary least squares estimation method, the study reports that technological innovation and international openness have increased the demand for skills. The effect is stronger in middle income countries compared to China and low-income countries. The study argues that the skill bias of technological innovation and the intensification of international trade requires policy interventions aimed at skill enhancement.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Annable, J. E. Jnr . (1971)	LICs: 1970 and before	Macro	Intervention: Technology transfer Type: Process + product innovation	Qualitative: Theoretical/analytical study.	Transfer of western technology to LICs has a homogenising effect on labour and reduces the scope for labour absorption in the modern urban sector.

Narrative synthesis:

This study (PhD Thesis) investigates the question as to why the modern sector does not generate sufficient labour demand to absorb the labour supply in urban areas. It utilises a mathematical model that highlights various complementary pressures that restrict the labour-absorption capacity of the modern sector. These include technical constraints, population growth and rural-urban migration. The modern urban sector draws heavily on technology transfers from developed countries; and these technology transfers have a homogenising effect on LIC labour markets. In other words, they induce producers in LICs to generate employment patterns that are similar to those observed in developed countries. The causes of the homogenising effect are traced and identified as follows: (i) business decisions based on fixed production coefficients that imply a single feasible production technique irrespective of the latter's labour intensity; and (ii) decisions based on assessment of variable production coefficients, which generally tend to yield efficiency-based project ordering in LICs that are similar to developed countries. Hence, labour-surplus in LICs tend to adopt labour-saving technologies on the basis of arguments/deliberations that include feasibility, efficiency, prestige, technical/engineering familiarity, training costs, and market imperfections in LICs. The study, in contrast to the standard Marxist and non-Marxist displacement mechanism, indicates that technology transfers from developed countries may not necessarily reduce employment; but they may attract high levels of rural-urban migration that exacerbates the unemployment problem in urban areas.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Aryee (1984)	Ghana	Firm	Intervention: Mechanisation Type: Process innovation	Survey evidence: descriptive analysis.	Innovation's effect on employment is mediated through income distribution.

Narrative synthesis:

This study analyses the effect of innovation on employment in footwear industry by incorporating income distribution as a moderating variable. It draws on survey evidence to show that existing patterns of demand for footwear is dependent on income distribution. Low-income groups tend to demand low-priced products, but an increase in income levels leads to increased demand for higher-price and fashionable footwear. Hence, new technologies introduced by large-scale firms lead to increased employment only if it is accompanied with increased in income in low-income groups. This is for two reasons. First, the expenditure-budget share allocated to footwear is roughly the same in middle- and high-income groups. Secondly, the expenditure-budget share increases only when one moves from low- to middle-income category.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Azariadis, Costas and Pissarides, Christopher A. (2004)	Small economy and large economy with international capital mobility; Capital mobility in OECD countries and unemployment implications in many small OECD countries.	Macro	Intervention: Capital flows Type: process innovation	Qualitative: Theoretical/analytical study	Increases unemployment and increases the risk involved in labour income.
Study summary/findings: Capital markets of industrial countries have become integrated. The study examines the following question: does international capital mobility really make a difference to the job creation and job destruction flows, and through them to the equilibrium unemployment rate of a country? The model does not imply that the mean value of unemployment should increase with international capital mobility but that the variance of cyclical unemployment should increase. Small economies trading in a world with large international capital flows need to devise ways of 'insuring' the income of workers whose wealth is poorly-diversified across countries. This is because international capital flows tend to shift income risk from capital to labour.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Baer, W. (1976)	Developing countries, LICs	Firm	Intervention: Technology adoption Type: Process + product innovation	Pre-1970 reported evidence: analytical	Effect of process and product innovation on employment is mediated by income distribution, factor-price distortions, and technology adaptation.

Narrative synthesis:

This study reviews the existing literature of the 1960s and early 1970s and summarises the main arguments as follows: (i) factor-price distortions encourage the selection of capital-intensive technology; (ii) existing technology is inadequate because it does not correspond to factor supplies in LICs; (iii) technology adaptation in LICs is limited due to low level of research and development by local firms and/or governments; and (iv) skewed income distribution results in a demand profile which favours the establishment of industries with capital-intensive technologies.

On the one extreme, there are those who conclude that technology choice is not a deterministic process. These contributors are optimistic about the scope for government actions that would influence the degree of labour absorption. For instance, governments can take action directly in public sector industries by making project appraisals on the basis of social cost-benefit analysis, explicitly introducing employment into the objective function. Also, private firms can be encouraged to employ more labour-intensive methods in several ways, including measures to make the use of equipment less attractive compared to that of labour. On the other hand, there are those who argue that creating obstacles to the use of capital-intensive methods is a misguided policy that can retard technological development and condemn developing countries to stagnation. Furthermore, a technology adapted to existing factor supplies in LICs (i.e., unskilled labour) can lead to marginalization of these countries in the scientific and technological progress and can cause perpetual technological dependence.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Barker et al (1972)	Philippines (1970)	Farm	Intervention: Mechanisation and HYVs Type: Process and product innovation	Periodical farm surveys: descriptive analysis	Mechanisation and HYVs combined led to about 6.5% increase in labour input, which is combined with 40% in output.
Narrative synthesis: This study examines the patterns of mechanisation and introduction of HYV seeds in the Philippine rice production. It reports that these innovation processes led to slight increase in total labour input, but a significant increase in output. The increase in labour input was small and even negative in regions with higher wages. With respect to specific innovation types, the study's findings can be summarised as follows: introduction of tractors into wet season farming reduced the demand for labour; introduction of mechanical weeders did not lead to fall in employment because HYVs and fertilisers combined made weeding more necessary and more profitable; increase use of threshers led to fall in labour input and real wages.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Barker and Jewitt (2007)	India.	Farm	Intervention: Mechanisation and HYVs Type: Process and product innovation	Field study survey evidence: descriptive analysis	The Green Revolution has been a significant factor in explaining the economic and social transformation of 3 villages surveyed in 1972 and 2001/2003.
Narrative synthesis: This paper analyses the experiences of over 35 years of Green Revolution (GR) technology in villages of the Bulandshahr District, western UP. Fieldwork in three villages reveals that perceptions of GR were extremely positive because higher yields brought food security for all in the area, and financial security for many. Indirect benefits, such as urban development, have improved employment opportunities – which have benefited even the poorest – and rural electrification has transformed rural livelihoods, especially for women. Predictably, the benefits of GR technology are not equally spread: the poorest are better off, but the gap between rich and poor is now greater than ever.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Berman and Machin (2000)	Multi-country sample, including LICs, LMICs and HICs.	Industry	Intervention: Technological change Type: Process innovation	Industry-level evidence from UNIDO Database: Decomposition	Skill-biased technological change is a major determinant of increased demand for skilled labour. Capital-skill complementarity plays little or no role in explaining increased demand for skilled labour
Narrative synthesis: This study decomposes the changes in wage bill shares into between- and within-industry components. Within-industry shifts in wage bill in favour of skilled labour can be due to skill-biased technical change (SBTC) or capital-skill complementarity. Further decomposition to separate the two effects reveals that increased wage bill of the skilled labour are due to SBTC rather than capital-skill complementarity. These findings are based on the assumption that the elasticity of substitution between skilled and unskilled labour is unity. If this assumption is relaxed, the findings are confirmed only for some middle-income countries. The study derives the following conclusions: (i) in all income groups, increased demand for skills is essentially a within-industry phenomenon and this confirms the existence of SBTC rather than trade, taste or factor-neutral technology shifts; (ii) SBTC-induced demand for skilled labour is increasing in middle-income countries at faster rates compared to high-income countries; (iii) SBTC-induced demand for skilled labour in LICs does not reflect the same trend yet; and (iv) the extent of capital deepening does not explain the demand-shift towards skilled labour.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Berman et al (2005)	India.	Industry	Intervention: Technological change Type: Process innovation	Industry-level data from Annual Survey of Industry: Decomposition	Skill-biased technological change appears to have arrived in India in the 1990s; but it is not the only factor. Increased capital-skill complementarity and increased output are also significant.
Narrative synthesis: This study decomposes the changes in wage bill shares into between- and within-industry components. Within-industry shifts in wage bill in favour of skilled labour can be due to skill-biased technical change (SBTC) or capital-skill complementarity. Further decomposition to separate the two effects reveals that SBTC is one of the determinants of wage bill and employment increases for skilled labour in India. SBTC is confirmed by increased demand for skilled labour within rather than between industries. This finding is based on the assumption that the elasticity of substitution between skilled and unskilled labour is unity. In addition, the study reports that capital-skill complementarity has also affected the demand for skilled labour. Hence, the study concludes that the reforms introduced in the 1990s have instigated a period of SBTC in India, but the pattern is not strongly correlated with what has happened in the United States in the 1990s yet.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Bhalla (1989)	India, 1972-73.	Female labour	Intervention: Mechanisation and HYVs Type: Process and product innovation	Survey evidence: Descriptive analysis	Green Revolution technology has led to fall in female employment and decreased the contribution of women to household earnings.
Narrative synthesis: This study is based on survey evidence on 153 villages in Haryana district, India. It investigates the effects of Green revolution technology on female employment and women's contribution to household earnings. It reports that Green Revolution has led to expansion in labour demand until mid-1970s, but the demand stabilised and began to fall thereafter. The study reports evidence on employment patterns of women form landless households. The findings include the following. Until mid-1970s, the impact of irrigation-based new technology was to increase male employment. The new technology seems to have made little difference to the absorption of female labour. The exception is when the shift to new irrigation technology was from exclusively dry-land farming. The study concludes that the extension of biochemical-HYV technology tends to reduce the female share in field crop labour days. Moreover, even on farms which hire in little labour after its advent, it is the male labour intensity which rises most when an assured water supply becomes available, thus reducing women's relative contribution to household income.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Bhatia and Gangwar (1981)	India, 1970s	Farm	Intervention: New technology; new farm plans Type: Process innovation	Field survey of small farms: Descriptive analysis	Effect of new technology on labour input in small farms depends of farm plans and availability of capital.
Narrative synthesis: This study analyses the effects of new technology and farm planning on labour input in small farms in Karhal district of India. It is based on survey evidence for 965 small farms and derives its conclusion by using linear programming techniques. The study reports that new introduction of technology only has uncertain effects on employment. However, when new technology is combined with production plans and availability of capital, the demand for labour would increase. This is found to be the case in three categories of small farms, ranging from the very small to the medium-size farms.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Billings and Singh (1981)	India (Punjab), 1970s	Female labour	Intervention: New technology Type: Process innovation	Government statistics on female employment and agriculture: Descriptive analysis	The effect of new technology on female employment in Punjab depends on literacy rates and productivity.
Narrative synthesis: This study reports that the application of the new technology in agriculture will change the employment patterns of female labour. The impact of new technologies on female employment in agriculture depends on literacy rates, productivity and overall proportion of the labour force employed in agriculture. The effect of the Green Revolution on total female employment cannot be estimated, but there are evident patters, These are: (i) In the hilly areas, there is limited scope for mechanisation and thus women's participation rate is expected to be stable; (ii) this rate can be expected to decrease if educational/literacy levels increase; (iii) in the Haryana region and Punjab, the Green revolution is likely to reduce female participation. In these areas, women are more likely to spend more time doing house work and looking after children's education.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Braun (2008)	Country in general (findings correspond with US labour market)	Firm	Intervention: R&D Type: Product and process innovation	Official statistics: Theoretical/analytical study	Demand for skilled labour increases relative to unskilled labour.
Study summary/findings: This study analyses the interaction between economic integration, product and process innovation, and relative skill demand in a model of international oligopoly. The paper argues that lower trading barriers increase the degree of foreign competition. Two main objectives in the paper are to analyse the effects of lower trading barriers on the incentives of firms to undertake R&D investment and secondly, to explore the subsequent effect on firms' demand for skilled relative to unskilled workers. The paper notes that increased competition following economic integration induces firms to bring down production costs by investing more aggressively in process R&D. At the same time, competitors expand their investments in product innovation in order to reduce the substitutability of their products. The paper further illustrates that economic integration may increase the relative demand for skilled workers; assuming R&D is intensive in skilled labour (relative to production).					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Caballero and Hammour (1996)	General	Macro	Intervention: Technological change Type: Process and product innovation	Qualitative: Theoretical/analytical study	Innovation as creative destruction leads to lower wages and marginalisation of labour

Study summary/findings:

The study analyses the characteristics of an efficiently functioning creative destruction process, the way the malfunctioning of markers can disrupt this process and appropriate policy responses to such disruptions. The disruptive effects on creative destruction of incomplete contracting in the labour market are analysed. The outcome is seen to be technological sclerosis irrespective of whether insiders' bargaining position is strong or weak. The inefficiencies lead to a misuse and undervaluation of labour at the margin. If insiders are weak, labour costs in old techniques are too low and thus firms may retain them for too long. On the other hand if insiders are strong they discourage job creation.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Cepede (1972)	Less developed countries	Sector	Intervention: Green revolution Type: Process innovation	Qualitative: Theoretical/analytical study	Green Revolution leads to higher employment through increased production and backward/forward linkages.

Study summary/findings:

Green revolution can help farms of the less developed countries to overcome hunger and offer work opportunities in areas where they are badly required. In addition, the work opportunities will be better distributed round the year rather than being seasonal. The non-farm sector will also expand to provide an impetus to intensive cultivation. Besides, increased production can lead to industrialization, which in turn leads to more employment generation. However, for green revolution to be successful certain pre-requisites have to be carried, of which land reform is one.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Chand (1999)	India, 1990s.	Sector	Intervention: product diversification Type: Product innovation	Mix of survey evidence and national statistics: Descriptive analysis	Product diversification towards feed crops and dairy farming can have a positive effect on rural employment, but the effect on overall employment is uncertain.

Narrative synthesis:

This study examines the effect of product diversification on rural and overall employment in Punjab, India. After establishing the scope for diversification, the author demonstrates that rural employment can increase significantly if production is shifted away from wheat and rice to feed-crop production and dairy farming. However, the employment-effect of product diversification will not be large enough to reduce overall unemployment in the region. New technologies in the manufacturing sector may increase the demand for labour in urban areas, but the extra demand is likely to be met by labour from outside the region. The reason for this type of displacement is the relatively higher wages demanded by local labour and the lower bargaining power that workers from outside the province would have.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Choi et al (2002)	General	Sector	Intervention: Technological change Type: process innovation	Qualitative: Theoretical/analytical study	Effect of innovation on employment depends on returns to scale: employment creation if constant returns to scale (CRS); negative effect if non-CRS.

Study summary/findings:

This paper analyses the implications of Hicks-neutral technical progress for a small Harris-Todaro economy with variable returns to scale. The analysis demonstrates that under non-CRS, the welfare effects of technical progress consists of three component effects, i.e., the primary growth effect, the returns-to-scale effect and the employment effect. Under constant returns to scale the possibility of non-immiserizing growth exists. However, with the introduction of non-CRS, technical progress can lead to the returns-to-scale effect, which can be of any sign, and causes the sum of the primary growth effect and the employment effect to have any sign unlike the CRS case, and, hence, creates the possibility of immiserizing growth.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Chopra (1974)	India, Punjab, 1970-71	Farm	Measure: New Technology Type: Process and product innovation	Farm survey/interview evidence: Descriptive analysis	Mechanisation and product diversification leads to increase in the demand for hired labour. The effect on family labour is also positive, but smaller.

Narrative synthesis:

This study is based on survey and interview evidence with 130 farmers in 13 villages of Punjab. Tractorisation of the village has led to increased demand for capital and induced risk-taking attitudes. It has also led to a perceptible increase in farmers' levels of education/literacy. Respondents tend to indicate that its effect on employment is negative; but this is compensated by positive effects through extension of farmed land and introduction of new product varieties. Family labour input is reported to have increased by about 10 per cent, but the use of hired labour increased by about 40-80 per cent, depending on crop variety and season. The author suggests that strong forward and backward linkages between agriculture and non-farm sectors are likely to increase overall employment in the region.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Clayton (1972)	Nigeria, Uganda, Kenya, Tanzania, late-1960s early 1970s	Sector	Measure: Mechanisation Type: Process innovation	National statistics and review evidence: Descriptive analysis	Impact of tractor use on productivity depends on farm size and product type; employment effect is generally negative.
Narrative synthesis: This study investigates the effects of tractorisation on productivity and employment in a number of African countries. Its findings indicate that tractorisation usually has a labour-displacing effect. The adverse effect is mild in Nigeria; but it is strong in Uganda, Tanzania and Kenya in descending order. The adverse effect and its variation across countries depend on farm size and type of products.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Conte and Vivarelli (2007)	Low and middle income countries; 1980-1991	Sector	Process innovation; Skill-enhancing technology import	Official statistics compiled by the UN and Statistics Canada; GMM.	Skill-enhancing technology imports (SETI) leads to an increase in the demand for skilled labour.
Narrative synthesis: This paper investigates the relationship between the imports of embodied technology and the demand for skilled (white-collar) and unskilled (blue-collar) labour in Low and Middle Income Countries. The data period is from 1980-1991. The data sources consist of: (i) UN General Industrial Statistics Vol. 1 (GIS); and (ii) Statistics Canada´s World Trade Analyser. The estimation method is general method of moments (GMM). The paper reports evidence of skill bias associated with the imports of embodied technology, a measure of Skill-Enhancing Technology Import (SETI). Compared to capital intensity of imports, SETI is found to be the main determinant of increased demand for skilled labour. SETI's effect on the demand for unskilled labour is either insignificant or negative but small.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
De Klerk (1984)	South Africa, 1970s	Farm	Measure: Technology Type: Process innovation	Farm survey data: Descriptive analysis	Technological change has led to fall in seasonal labour employment overall. However, the fall affected men, women and children differently.
Narrative synthesis: This study uses survey evidence on 61 maize farms in South Africa. It examines the causes of technology change (mechanisation, chemical use, fertiliser use, etc.) in maize farming and its effects on employment. It reports that mechanisation of harvesting and delivery, new weeding methods and use of fertilisers led to 20% fall in permanent employment and 50% fall in seasonal employment. The fall in seasonal employment was accounted for mainly by the fall in the number of male employees. Seasonal employment of women remained stable whilst that of children tended to increase.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Edquist et al (2001)	Not country-specific. Theoretical/analytical study.	Firm / Industry	Intervention: Various Type: Process + product innovation	Qualitative: analytical study.	Innovation has direct and indirect effects on employment. Direct effect of product innovation is generally positive; indirect effects and effects of process innovation are usually uncertain.

Narrative synthesis:

This study analyses the relationship between innovation and employment at different levels of analysis and with different types of innovation. Innovation's effect on employment can be direct, but it is mainly indirect. The overall effect is mediated by a number of offsetting factors and compensation mechanisms; which include effects on other sectors/industries, real income (purchasing power) effect), and labour market adjustment. It favours a Systems of Innovation (SI) approach, which views innovation as a collective learning process affected significantly by the institutional context. It emphasizes the differences between systems of innovation rather than their optimality as the latter is very much context-specific. The authors distinguish between product and process innovation. They elaborate on the types of product innovation and process innovation as well as direct and indirect effects on employment. Product innovation may involve new tangible products as well as new intangible services – and it is usually associated with a positive effect on employment. The process innovation entails technological innovation as well as organisational innovation and its effect on employment is uncertain.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Ekwere (1983)	Nigeria	Firm	Intervention: Technology adoption Type: Process innovation	Field survey of small textiles firms: Descriptive analysis	Small firms in the intermediate sector create more employment per unit of investment compared to capital-intensive large firms.

Narrative synthesis:

This study analyses the scope for job creation in small textiles industries in Nigeria, using field survey evidence. It argues that the 'technology shelf' hypothesis of neoclassical economics does not hold for small textiles firms using handloom technology. The only option for these firms is to change from handloom to fly-shuttle loom, which could increase productivity by five-folds without reducing the demand for labour or requiring change in the required skill set. The 'technology shelf' may be available for large, capital-intensive firms. However, the latter tend to choose technologies that substitutes capital for labour in order to minimise production costs. Hence, the expansion of small and labour-intensive firms can create more employment than that of large and capital-intensive firms. The study tries to explain why the number of small and labour-intensive firms does not increase at faster rates in Nigeria by invoking lack of capital. However, it does not explain convincingly why the uptake of credits under the 'Small-Scale Industry Development Program' remained limited – referring only to institutional constraints that are not analysed in detail.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Esfahani (1987)	Egypt	Sector	Intervention: Mechanization Type: Process innovation	Government statistics on agriculture: Descriptive analysis	New irrigation and drainage systems, mechanization and fertiliser use have reduced the demand for labour.
Narrative synthesis: This study investigates the causes of slow growth in Egyptian agriculture in the Nile delta. Its analysis on the effects of mechanization, fertiliser use and new irrigation and drainage system indicates that these innovations have led to increased output and productivity, but reduced demand for labour. However, the displacement effect is very small.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Fagerberg (2010)	LMICs	Macro	Intervention: Multiple measures Type: Process and product innovation	Innovation surveys: Descriptive analysis	Employment effect is NOT measured, but rich information on moderating/mediating factors
Narrative synthesis: This study defines innovation as the attempt to try out new or improved products, processes or ways to do things. It considers innovation as relevant in developing and developed countries. The evidence considered in the paper shows that innovation is quite widespread among developing country firms, is associated with higher productivity and, is dependent on interactions with other private and public actors. In qualitative terms, innovation is found to be a powerful force of growth and employment. However, developing countries often lack data on most indicators of innovation. The study also discusses different factors that shape technological and social capabilities. These include conventional factors such as scientific output, research and development expenditures, patents etc., but also other factors such as governance quality, social values, openness, and financial development.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Garmany (1978)	Developing countries , Africa	Macro	Intervention: Technology adoption Type: Process innovation	Qualitative: Theoretical/analytical study	Positive effect on demand for skilled labour; LICs employment increases only if skill upgrading catches up with innovation.

Study summary/findings:

The paper defines appropriate technology, which takes into account the country's particular stage of economic growth and social development, its development goals and resource factor endowments. Labour intensive techniques can also minimize energy use and imported raw material use. In many developing countries, unfortunately the employment growth in the manufacturing sector has been sluggish not only in the advanced industries but also in traditional industries. At times developing countries do not have requisite skills and hence they prefer capital-intensive technology. Therefore, skill improvement can lead to better labour absorption.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Inukai (197)	Thailand, 1960s	Farm	Measure: New technology, mechanisation Type: Process innovation	Survey data, field interviews: Descriptive analysis	Mechanization and new farming techniques lead to fall in employment in static analysis. However dynamic effect may be positive
Narrative synthesis: This study investigates the effect of mechanisation and new farming techniques of labour input in rice production. It reports that technology change leads to fall in the number of labour-hours required in a given farming unit. This is based on static analysis of the survey data and filed interviews. However a dynamic analysis that takes account of income effects and forward/backward linkages suggests that the effect may be positive.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Jacobsson (1980)	LMICs, LICs	Industry	Measure: Technology implicit in manufacturing trade Type: Process and product innovation	Industry trade data: Descriptive analysis	South-south technology transfer implicit in trade is more capital-intensive than North-South trade. Hence, its job creation effects are smaller.
Narrative synthesis: This study focuses on technology transfers through international trade. It reports that export of investment goods (particularly engineering goods) between developing countries had increased seven-fold from 1973-80. In addition, manufactured goods export is the most dynamic in the South-South trade. The author considers this as evidence of increasing technology transfers between developing countries. Then, it tries to answer the question: do technology transfers implicit in South-South trade lead to more or less employment creation compared to technology transfers implicit in North-South trade? After examining the existing evidence, the author concludes that technology transfers implicit in South-South trade are likely to create less jobs than technology transfers implicit in North-South trade. This is because South-South trade is more capital intensive than North-South trade.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
James (1993)	Developing Countries	Industry	Intervention: Technology adoption Type: Process innovation	Qualitative: Theoretical/analytical study	Uncertain because without technology up-gradation exports may decline and employment may fall. Also with capital-intensive technology employment may fall. Which one causes more employment loss is uncertain.
Study summary/findings: Various aspects of technology diffusion need to be considered. If new technology is not adopted, it may affect the quality of products and thus exports may suffer, resulting in employment loss. On the other hand, adoption of new technology that is not capital intensive in nature can cause employment to fall. Hence, the specific situation where employment loss is greater needs to be considered. Speed of production, product flexibility and locational factors need to be considered in assessing the total effect of technology on employment. If certain products are manufactured in the low-cost countries, labour intensive technology can still be pursued. Hence, the factor price ratio is an important determinant of technology choice and locational decision regarding production, which eventually affects employment.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Kelley et al (1972)	Developing Economies (Asian)	Sector	Intervention: Technological change Intervention: process innovation	Qualitative: Theoretical/analytical study	Effect on labour absorption in industry is negative.
Study summary/findings: Labour-saving technical change is a definite disadvantage to developing economies. The presence of biased technical change also has important implications for rates of industrialization and capital accumulation in the dual economy. The study finds that increases in the bias may tend to inhibit the rate of industrialization and reduce the rate of capital accumulation without appreciable changes in per capita GNP growth. Related to these results is the extent to which labour absorption in the industrial sector is affected: it observes an important retarding influence that accumulates over time. It questions the wisdom of introducing labour saving technology in the industrial sector in order to enhance per capita growth. The authors rather note that per capita income is mostly insensitive to the technological bias introduced in the industrial sector of the developing countries.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Lalwani (1992)	India	Farm	Measure: New feeding techniques Type: Process innovation	Field survey of farms: Descriptive analysis	Introduction of new feeds leads to increased labour use in milk production.
Narrative synthesis: This study analyses the effect of introducing new feeds on labour use in milk production. It utilizes a Cobb-Douglas production function and estimates the effect new feeds on employment, controlling for wages and output. It reports that an increase in green or dry fodder leads to increased employment in the sample of farms. This result holds for all types of milch bovines, including buffalos, crossbred cattle and indigenous cows. However, the effect differs between farm sizes. In small and medium-size farms, green fodder has a higher impact on employment, whereas in large farms the effect of concentrated feed is the largest. Given the larger share of small and medium-sized farms in the total farms, the study concludes that increase in dry and green fodder use can lead to higher levels of employment in the province.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Lundin et al (2007)	China, 1998-2004.	Firm	Process innovation (science and technology activities)	National Bureau of Statistics of China, survey data; Heckman selection and panel data estimation.	Innovation activities increase the probability of firm survival; but have no or small negative effect on employment creation.
Narrative synthesis: This paper investigates the relationship between science and technology (S&T) and job creation in the Chinese industrial sector. S&T can be expected to have both positive and negative effects on employment. On the one hand, new technology might increase competitiveness and enable Chinese firms to expand their labour force. On the other hand, new technology might be labour-saving, enabling Chinese firms to produce more output with fewer employees. Based on a large sample of manufacturing firms in China between 1998 and 2004, the study reports S&T activities have no effect on job creation in the Chinese manufacturing firms. Descriptive evidence indicates that the number of large and medium sized firms has increased by about 24 percent while employment has only increased by about 4 percent. Moreover, most of the expansion has taken place in firms without any S&T. Taking account of survival bias, the study reports that S&T activities have a positive effect on the probability of form survival, but no or even small negative effect on employment creation.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Mehta (1993)	Multi-country	Industry	Measure: Technology Type: Process innovation	UNIDO data: Decomposition	Technological change is associated with increased output but lower demand for labour in 7 LICs and LMICs.

Narrative synthesis:

This study uses a translog production function to estimate the derived demand for labour. The model estimates the demand for labour as a function of technology, production, wages and input substitution. It reports that technological change has been associated with lower demand for labour in 7 out of 8 countries in the sample. The results are based on industry-level manufacturing data for 28 industries over 12 years. Technological change has also led to increased output; however, the positive effect of increased output on employment is more than offset by the negative effect of technological change on employment. The study also reports that the demand for labour is elastic with respect to wages, with the implication that fall in wages may compensate for the adverse effect of technological change on employment. However wages tend to be rigid downward.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Mitra (2009)	Multi-country	Industry	Measure: Imported technology Type: Process innovation	UNIDO data: estimation of labour-to-value added ratio	Technology import, proxied by ratio of manufactures imports to total imports, leads to lower labour utilisation per unit of valued added.
Narrative synthesis: This study utilizes UNIDO industrial statistics and ILO's *Key Indicators of Labour Market* to investigate the effects of imported technology on labour absorption in the industrial sector, after controlling for real wage rate and GDP per capita. It reports a negative relationship between the two: as the ratio of manufactures to total merchandise imports increases, the ratio of labour to value-added tends to decline. It also reports that the technical efficiency index derived from a stochastic frontier function is negatively related to import of technology. In other words, the higher is the import of technology, the greater is the distance between the actual production and the maximum attainable level of output. These results suggest that import of technology has an adverse effect on employment as well as technical efficiency. These outcomes may be due to poor skill base. However, manufactures imports include finished products other than capital and intermediary inputs, and, therefore, the results need to be interpreted carefully.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Moore and Craigwell (2007)	Barbados, 1979-2001	Firm (Banks)	Process innovation, measured by introduction of ATMs	Bank accounting data; instrumental variable estimation.	Introduction of automatic teller machines (ATM) has a small positive, but generally insignificant effect on employment in the banking sector.
Narrative synthesis: This study utilizes bank accounting data to estimate the employment effects of introducing ATMs in Barbados commercial banks from 1979-2001. It utilizes instrumental variable estimation method. It estimates the ATMs' effect on employment after controlling for the effects of output, capital and wages. The study does not find a negative ATM effects on employment, but the positive effects are small usually insignificant.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Mureithi (1974)	Kenya	Industry	Intervention: Technological change Type: Process innovation	Qualitative: Analytical study	Positive effects on employment

Study summary/findings:

Since the capital-labour ratio is rising, it means that it is becoming increasingly more capital-expensive to create one job. Of course, it must not be supposed that rising capital intensity is bad per se. It is likely that a large part of the capital formation in Kenya in the recent past has been devoted to the building of infrastructure like roads, public works, communications, etc. In addition, one should note that production actually takes place in stages: l) material handling, 2) material processing, 3) material handling among processes, 4) packaging, 5) storage of the finished products. of the five stages, only the second, i.e., the central processing, need be capital intensive; this is especially true where fine precision of temperature, pressure, ingredients combination, etc., is important. However, there are many other stages where factor substitutability is technically possible and thus the entrepreneur has a choice to select the technology. The desirability of a technology has to be judged not merely by its scientific or technical sophistication, but rather by its appropriateness in the context of the society in which it will be used. It requires innovative ideas to reduce the labour-saving elements of a technology while maintaining or improving quality and efficiency. In other words, labour-intensive technological progress, which can improve performance and employment both together, is something that has been talked about.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Nair (1980)	India and other LICs / LMICs, 1970s	Sector	Intervention: Mechanisation Type: Process innovation	Survey evidence: Descriptive analysis	Mechanisation raises unemployment in labour surplus economies. However, by reducing seasonality of labour it can raise employment.
Study summary/findings: Mechanization is labour saving. It is an effective way of reducing cost particularly in labour scarce economies where the labour cost is very high. However, in economies where labour is available in abundance mechanization may not result in a significant reduction in marginal cost. Rather it may raise the unemployment rate. The determinants of tractorisation include tractor prices, farm wage rate, farm profitability and the level of economic development though the relative significance of these variables differs from country to country. However, many other ingredients of modernization of agriculture are in complementary relationship. For example, there is complementarity between tractorisation and fertilizer consumption, which in turn has a positive impact on yield. Similarly the positive effect of irrigation on yield rate is clearly pronounced. Besides power availability has to increase in order to facilitate the application of certain modern techniques in agriculture and this can reduce seasonality of labour in agriculture.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Oberai and Ahmed (1981)	India (Punjap) 1977	Farm	Process and product innovation, measured by mechanisation, fertiliser use and introduction of HYVs	ILO household survey evidence; OLS.	Fertiliser use, introduction of HYVs and improved farming practices increase labour use, other types of mechanisation have insignificant or negative effects.
Study summary/findings: This study investigates the impact of various levels of mechanisation, the prevailing agrarian structure and migration on labour utilisation. The study utilizes evidence from a household survey carried out in 26 villages of Ludhiana, an area in the Green Revolution belt of Punjab. The study tests two hypotheses, using a multi-variate regression analysis. One hypothesis relates to labour absorption (i.e., labour use per unit farmland) and the other is about the demand for hired labour. Focusing on the first hypothesis, the study reports that labour absorption is positively related to fertiliser dose applied, percentage maize area under HYV and use of improved farm practices such as row-planting and seed treatment. Labour use per unit of farmland is negatively associated with the use of threshers; and no significant relationship is observed between labour intensity and the use of the tractor and other mechanisation packages.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Otsuka et al (1994)	Philippines 1966-1990	Farm	Process and product innovation, measured by mechanisation, fertiliser use and introduction of HYVs	Central Luzon Loop Farm Survey; two-stage least squares.	Introduction of HYVs increases labour use; but mechanisation has a negative effect. The negative effect of mechanisation outweighs the effect of introducing HYVs.

Study summary/findings:

This study investigates the employment effects of mechanisation, irrigation and introduction of HYVs in rice farming. Introduction of HYVs and adoption of new irrigation techniques were found to have a positive effect on labour use in rice farming. However, mechanisation has a negative effect. When both effects are combined, the negative effect of mechanisation outweighs the positive effect of product innovation and irrigation. Furthermore, the study tests whether the introduction of HYVs was the cause of adopting labour-saving mechanisation technology. The evidence indicates that introduction of HYVs does not explain the adoption of labour-saving technologies.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Pandit and Siddhartan (2008)	India, 1992-2001	Industry/ sector	Process innovation, measured by technology imports	Central Statistics Office survey data; generalised least squares (GLS) with panel data	Technology imports have a negative but insignificant effect on industry-level employment.
Study summary/findings: This study investigates the employment effects of technology imports and whether being part of a multinational enterprise (MNE) has an adverse effect on employment. Using a rich set of survey data from 1992-2001, the study reports that technology imports has a negative but statistically insignificant effect on employment growth. Being part of an MNE, however, is associated with a positive effect on employment growth. The authors argue that the difference is due to the arms' length nature of the technology imports as opposed to technology imports through foreign direct investment.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Raju (1976)	India - West Godawari, 1967-68 to 1970-71	Farm	Process and product innovation, measured fertilisers use, pesticides use, irrigation, and improved seeds	Survey data from a stratified sample of 400 farms; OLS	Both product and process innovation are reported to have a positive effect on employment.
Study summary/findings: This study investigates the effects of innovation on farm employment in a sample of 400 farms in West Godawari, India. The study reports that innovation is associated with a positive effect on farm employment. The positive effect holds after controlling for opening of new farmland. The strongest effect is associated with use of fertilisers, followed by introduction of irrigation, improved seeds and use of plant-protecting chemicals.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Sison et al (1985)	Philippines, 1979	Farm	Process innovation, measured by mechanisation and irrigation	Int. Rice Research Institute survey data; covariance analysis	Various types of mechanisation have a negative effect on employment, whereas irrigation's effect is insignificant.
Study summary/findings: This study utilizes a unique dataset based on a survey conducted by the International Rice Research Institute in 1979 in the Philippines. The authors utilize covariance analysis to estimate the employment effects of irrigation and two types of mechanisation - tractors and threshers. The effect is estimated for 3 types of farm operations, consisting of land preparation operations, post-production operations and all farm operations. With respect to all farm operations, the study reports a negative causal relationship between mechanisations types and employment. The effect of irrigation is insignificant. The negative effect of mechanisation holds in the case of land preparation and post-production operations.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Richards and Ramezani (1990)	Middle-East and North Africa, 1960-85	Sector	Intervention: Mechanisation Type: Process + product innovation	National statistics: Descriptive analysis	Mechanisation is associated with rural-urban migration. Migration of young males leads to increased use of female and old-age labour.
Narrative synthesis: This study examines the patterns of rural-urban migration and mechanisation. It reports that mechanization may reduce employment overall and lead to change in the composition of the labour force in agriculture. The change in composition is towards more use of female labour and male farmers of older age.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Saviotti and Pyka (2004)	General/Developing	Sector	Intervention: technology adoption Type: Product innovation	Qualitative: Analytical study	Positive effects on employment.

Study summary/findings:

This study views that the emergence of new goods and services as the result of the increasingly systematic use of innovation as a component of economic development and it amounts to a process of qualitative change within the economic system. Economic development means creation of new sectors (new goods and services) in a continuous manner. It is quite natural that as the old product or services matures employability declines. Hence, to improve the level of employment in a continuous manner innovation has to go on and new goods and services have to figure in which in turn can generate employment opportunities. In this sense, innovation and employment can go hand in hand. Hence, the ability to reap variety is economic development, which in turn can create employment steadily. Productivity growth in a particular sector may not take place indefinitely. Hence, at the country level high productivity growth can be realized by constantly pursuing efforts to create new sectors.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Sen, A. (2001, 3rd ed.)	India: 1970s	Firm Sector	Measure: Technology adoption Type: Process + product innovation	Qualitative: Theoretical/analytical study	Effect is mediated through institutional structure, mode of production and ownership structures .

Narrative synthesis:

This study (monograph) investigates the determinants of technology choice and the latter's effect on employment in developing countries. Sen conceptualises employment as a vector – i.e., as a set of numbers related to employment of different kinds of labour including informal sector employment, female employment, family employment, seasonal/casual employment and regular wage employment. He also demonstrates that technology, institutions and employment are inter-related. Even if new technological alternatives exist and are economically efficient, these alternatives may not lead to employment creation unless adequate institutions and decision-making criteria exist to facilitate the choice of appropriate factor- and product-mix that generates employment. The study argues that firms in developing countries should make use of available technologies (the 'technology shelf') more than investing in new intermediate technologies. It then goes to provide methods of shadow pricing required to determine socially optimal techniques. Although one can envisage a range of shadow pricing methods, policy-makers face two essential problems: arbitrariness of shadow prices when the objective is set by policy makers; and inconsistency of the shadow price with the employment objective when the price is derived from competitive market equilibrium. This study tends to focus on the scope for and limitations to technology and employment policies rather than demonstrating how the employment effect of innovation and technology choice can be measured.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Sharma (1990)	India	Farm	Measure: Green Revolution Type: Process + product innovation	Field survey evidence: Descriptive analysis	In the first stage, the Green revolution led to increased inequality and limited employment. In the second stage (after mid-1970s) the effect on both outcomes is positive.

Narrative synthesis:

This study evaluates the merits of the Green Revolution in the light of early pessimism about its effects on income and employment. It reports that the initial impact indeed supported the pessimistic point of view, but later developments do not. It examines in detail the changes that have taken place in the state of Uttar Pradesh, especially western Uttar Pradesh, which was one of the principal locales of the Green Revolution in India. While interregional disparities between eastern and western Uttar Pradesh widened in the early phase--from the mid-1960s to the mid-1970s. However, in the subsequent decade-and-a-half, there was a closing of the gap as the hitherto bypassed eastern region began to respond to the seed-water-fertilizer technology in the wake of improved infrastructure. Moreover, as rural incomes increased, the second-generation effects of technical change increased diversification in the rural economy. A dynamic rural off-farm sector has emerged in response to demand for local goods and services. These off-farm activities are characterized by high labour intensity and are increasingly centred in small and medium towns widely dispersed in the rural areas. Walidpur village and three case study villages were used to illustrate the mechanisms of income and employment diffusion. The experience of the four villages indicates that the increasing participation of the landless and near-landless in off-farm activities has led to an improvement in both their absolute and relative incomes. The diversification of the rural economy has important implications for employment and income diffusion among the weaker sections of the population. While their limited land base prevents the landless and near-landless from reaping the direct benefits of technical change to the same extent as the big landholders, their increasing participation in non-crop activities has compensated to some extent for their lack of land and capital. The emergence of the rural off-farm sector offers an alternative, midway between the agricultural and the urban/industrial sector, to the problem of labour surpluses.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Singh and Day (1975)	Less Developed Economies (Punjab, India)	Sector	Intervention: Green Revolution Type: process innovation	Official statistics: Simulation	Positive effect on employment.
Study summary/findings: The study employs a simulation model to estimate the composite impact of two conflicting forces on farm sector labour utilization: (i) a reduction in the demand due to the adoption of task-specific labour-saving technologies; and (ii) an increase in the demand for labour due to increase in yields and total output. The net effect on total annual and seasonal labour use is a sharp increase after 1961. This was due to increased use of double cropping, increased area sown to high yielding varieties, and use of chemical nutrients. The increase in employment coincided with a rapid rise in output. In spite of the rapid mechanization, total labour use was 5 per cent higher at the end of the investigated period.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Sigurdson (1990)	China	Industry	Measure: Technology adoption / adaptation Type: Process + product innovation	Qualitative: Analytical study	Improvement in farming techniques and technology adaptation in small industry have led to employment creation and growth in 1960s and 1970s.
Narrative synthesis: This study examines technology adaptation in China and its early outcomes in terms of development and employment creation. The use of science and technology in China took account of economic and industrial dualism, regional disparity and the need to develop advanced manufacturing and defence industries. Hence, China experimented with dual technological development. On the one hand, there was technological innovation and adaptation in large-scale sectors and these constituted the technology frontier in the country. On the other, Local and small-scale enterprises specialised in technology adaptation aimed at maximising use of indigenous technology and labour absorption. Hence rural mechanisation conformed to the intensive-farming tradition and farm machinery was designed to be usable for multiple purposes. Similarly, different technologies were used in different sizes of cement manufacturing units – ranging from the rotary-kiln technology in large plants to ground-level chambers in small-local plants. The technically less efficient local plants were economically efficient due to high transportation costs that enabled them to compete with the larger plants in their local markets. Similar dualism existed in the engineering goods sector. Here, the large plants specialised in design development and large-scale technology adaptation, while small plants specialised as units of learning-by-doing that trained the labour force in technology use and adaptation. Another distinct characteristic of technological innovation in China consists of 'social technology'. This involved institutions and management routines that required compulsory visits by planners and state officials to rural areas so that the local needs could be incorporated into technology designs and product development. Under this dual technology and innovation system, labour absorption was much higher than what would have been feasible under a unified system that favoured large-scale industrialisation and technology adoption only.					

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Stewart (1974)	LICs, 1970s	Industry	Measure: Technology transfer Type: Process + product innovation	Qualitative: Analytical study	For employment creation, technological innovation must take account of scale, skill and input requirements in specific country or industry contexts. .

Narrative synthesis:
This study examines the limitations of technology transfer from developed to low-income countries. The main conclusion is that innovation and technological development in LICs can be conducive to employment creation if it takes account of scale, skill and input requirements of the new technologies and assess whether these requirements are satisfied in LICs. Hence the author argues that technology transfer from developed countries may be inappropriate for three reasons. First, transfer of modern developed country technology involves the transfer of large-scale units of production and this is inappropriate to the needs of LICs because of small market size. Secondly, developed country technology is skill-biased – hence it ignores skill composition in LICs. Thirdly, transferred or imported technology corresponds to resource availability of developed countries – hence it ignores local materials in LICs. These characteristics of transferred technology may reinforce the dualistic nature of development, reduce the extent of employment creation and perpetuate unequal income distribution between the modern and traditional sectors.
The author also argues that technology choices made under the assumption of rigid factor requirements are not well founded. Although technology determines factor requirements in the main production processes of large-scale and modern plant/sectors, there is significant scope for flexibility in ancillary activities of these sectors/plants and in the traditional sector in general. To achieve such flexibility, research institutes must consider the nature of industry, the product range and the production scale for which their innovations are primarily intended. Appropriate innovations derive in large part from institutes, which have been primarily concerned with small-scale and traditional production, as shown in the case of the Indian Leather Research Institute and the agricultural mechanization programme at IRI. Such institutes need to be located in the area where most of the relevant industry is and to maintain continuous contact with local industry. One way of maintaining relevance and contact is to combine problem solving service with R and D. An institute prepared to answer technical queries will then automatically have an outlet for innovation, and contact should ensure relevance.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Tuyen (1999)	Vietnam, 1994-96	Female labour	Measure: New technology Type: Process	Survey evidence and workplace interviews: Descriptive analysis	New technologies in textiles, electronics and telecommunications have provided new employment opportunities for relatively young women, but they have increased the gender-based segmentation of the workplace.

Narrative synthesis:

This study is based on field research and interviews were conducted between 1994 and 1996 by a Vietnamese research team within the UNU/INTECH Project on New Technology and Women's Employment in Asia. Its findings can be summarised as follows:
New technology has brought job opportunities for young and educated women. The women are usually young (less than 40 years old).
Job creation for this segment of the female labour force was at the expense of job losses incurred by older and less qualified women.
New technologies have reinforced and aggravated gender-wise job segregation.
Women are usually crowded into a limited number of jobs in the work place.
Women tend to have relatively more managerial roles in telecommunications compared to textiles or electronics manufacturers.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Usha (1985)	LICs, 1970s	Firm	Measure: Mechanisation Type: Process innovation	Field survey and official statistics: Descriptive analysis	Policy-induced innovation in the leather industry in India has led to job destruction in the pre-tanning stage but job creation in the finishing stage of the production process.

Narrative synthesis:

This study is about the effects of an Export Trade Control Order in August 1973-which attempted to encourage the exports of high value added products of finished leather and leather products by restricting the exports of semi-finished leather-on the composition of labour in the tanning and finishing industry in Tamil Nadu. The paper is based on discussions with groups of labourers, managements, workers' and managements' associations and material collected during field surveys of tanneries in the North Arcot district of Tamil Nadu. The article also draws on evidence from census data and Annual Survey of Industries.
The author reports that the policy-induced technological change in the leather industry has led to concentration and a movement away from employment of workers with traditional skills. This was compensated by employment of new workers. The larger the tanneries, the greater is the degree of mechanisation and the larger the scope is for entry of new workers. Furthermore, when chrome tanning method is used, there is very little need for the skill and experience of hand workers though traditional labour. The pre-tanning processes are still a monopoly of traditional labour, but there is little or no scope for expanding or developing it. With the entry of new workers who are on par with management in terms of religion and are involved in better jobs, the labour force of the tanneries will be highly segmented. In the finishing process, newly installed machinery absorbed labour, but pre-tanning machines that were introduced displaced labour.

Study	Country(ies) covered / period	Level of analysis: Firm-Farm / Industry-Sector / Macro	Intervention / Type(s) of innovation	Evidence and method of analysis	Employment effect summary
Wills (1972)	India, early 1970s.	Farm	Measure: Mechanisation, high-yield seeds, irrigation and fertiliser use. Type: Process and product innovation	Field survey data: Descriptive analysis	The Green Revolution has led to increase in employment and wages, but it may also lead to increased income inequality in the absence of spill-over effects on to non-farm sector.

Narrative synthesis:
This study reports that the green revolution has increased food production, but its effects on rural employment and income are uneven. Adoption of new seeds, fertilizers, and irrigation increases employment and agricultural wages, but it also increases the disparity between incomes of farmers and agricultural labourers. This disparity will increase further if labour-saving machinery is introduced. If changes in the nonfarm sector and in agricultural production other than crop production also take place – i.e., if string backward and forward linkages emerge – the adverse effect of new agricultural technology on income disparity farmers and labourers will therefore be smaller. This is because of increased job opportunities in the non-farm sector. Interviews with survey farmers revealed that new inputs were adopted quickly. This was due to two features of the technological change in the sample area: (i) the new inputs did not substantially change the conduct of regular crop operations and hence did not cause major managerial problems; and (ii) a widespread market for privately pumped water existed, giving small farmers access to modern pumping equipment.
The total amount of agricultural employment in the block will increase 30 to 50 per cent, and average agricultural wages will rise, but the increase in agricultural labourers' incomes due to changes in crop production will be less than the corresponding increase in farmers' incomes.

Appendix 4.2.2: Meta-analysis tools and models

As indicated in Section 4.3, we conduct the meta-analysis in three stages. In stage 1, we calculate fixed- and random-effect estimates (FEEs and REEs) for weighted means of the estimates reported by each study. In stage 2, we conduct precision-effect tests (PETs) and funnel asymmetry tests (FATs) for the same cluster of evidence pooled for calculating the REEs. The PET/FAT procedure allows for testing if a particular type of innovation has a genuine effect on a particular type of employment after controlling for publication bias. Finally, in stage 3 we conduct weighted least-squares meta-regression analysis (MRA) to account for the effects of moderating variables such as study characteristics, sector, level of analysis, data period, etc.

This procedure is repeated twice: once with partial correlation coefficients (PCCs) calculated for all estimates (147 in total) extracted from 9 empirical studies; and once for a smaller set of elasticity estimates (60) reported by 3 studies. The calculation of PCCs, FEEs, and REEs is based on equations (1) – (4) below. The PET/FAT and MRA estimations are based on models (5), (7) and (8) thereafter.

The PCC for each effect-size estimate and its standard errors (se_{ri}) are calculated in accordance with equations (1) and (2) below.

$$r_i = t_i / \sqrt{t_i^2 + df_i} \qquad (1)$$

$$se_{ri} = \sqrt{(1 - r_i^2)/df_i} \qquad (2)$$

Here, (r_i) is the PCC; t_i is the t-statistic associated with the effect-size estimate and df_i is the corresponding degrees of freedom, as reported in original studies. The standard error (se_{ri}) represents the variance due to sampling error and is used to calculate fixed-effect estimators (FEEs) for study-based weighted means. The FEEs for the weighted mean of partial correlations is given by equations (3) below.

$$\bar{X}_{fee} = \sum r_i (1/se_{ri}^2) / \sum (1/se_{ri}^2) \qquad (3)$$

$\bar{X}_{fee}$ is the fixed-effect weighted mean, (r_i) is the PCC (or elasticity) and (se_{ri}) is the corresponding standard error. The FEE weight accounts for within-study variation, by assigning lower weights to less precise estimates. Hence, FEEs are more reliable than simple means; but they cannot be considered as reliable measures of *genuine effect size* (or partial correlation) if the original-study estimates are subject to reporting bias and/or affected by within-study dependence due to data overlap. FEEs assume that each

study estimates a fixed effect size, subject to sampling error captured by the associated standard error (de Dominicis et al, 2008: 663).

This assumption does not hold when each study uses different estimation methods or different model specifications to report different estimates based on the same dataset. Therefore, we also calculate random-effect estimates (REEs) in accordance with (4) below.

$$\bar{X}_{ree} = \sum r_i(1/se_{ri}^2 + \sigma^2)/\sum(1/se_{ri}^2 + \sigma^2) \qquad (4)$$

Where $\bar{X}_{ree}$ is the random-effect weighted mean; (r_i) is the PCC (or elasticity) and (se_{ri}) is the corresponding standard error reported for each estimate; while (σ^2) is the imputed between-estimate variance of the PCCs (or elasticities). Assuming independence of the estimates within each study and across studies, the random-effect estimate (REE) of the weighted mean is distributed normally around the population mean, subject to random disturbance due to within-study variation ($\boldsymbol{se_{ri}^2}$) and between-study variation (σ^2).

The assumption of independence, however, is not likely to be satisfied by the estimates reported in the original studies. One reason is the problem of within-study dependence indicated above. The other reason relates to between-study dependence, which may result from overlaps between samples of different studies with respect to countries or time-periods covered. Stated differently, REEs are efficient in taking account of within- and between-study heterogeneity, but they are inefficient in taking account of within- and between-study dependence. Hence, REEs should be considered only as descriptive evidence on employment effect of innovation rather than a true measure of genuine effect beyond bias or data dependence.

In the next step, we address the risk of bias by conducting PET-FAT and precision-effect test with standard errors (PEESE) analysis. This analysis enables us to establish whether the partial correlation coefficients derived from reported estimates are subject to reporting bias and whether they represent genuine effects beyond bias. The PET/FAT procedure involves estimating a weighted least square (WLS) model used by Stanley (2008), Stanley and Doucouliagos (2007), Abreu et al (2005), and Stanley (2005) among others. Stanley (2008) demonstrates that model (5) below can be used to test for both funnel asymmetry (reporting bias) and for genuine effect beyond selection bias. Models (5) also minimises the risk of Heteroskedasticity.

$$t_i = \alpha_0 + \beta_0(1/se_{ri}) + \varepsilon_i \qquad (5)$$

Here t_i and se_{ri} are, respectively, the test statistic and the standard error associated with each PCC (or elasticity). The FAT involves testing for $\alpha_0 = 0$ and the PET tests for $\beta_0 = 0$. The FAT is known to have low power – i.e., it has low probability of rejecting the null

hypothesis when the latter is actually false. As such, it may fail to detect reporting bias. Against this weakness, model (5) has the advantage of establishing genuine effect when reporting bias exists. Card and Krueger (1995) and Stanley (2008: 108) indicate that the bias is severe if $\alpha_0 > 2$ in absolute value.

According to Stanley and Doucouliagos (2007; 2012, chapter 4), reported effect-size estimates and their standard errors have a nonlinear relationship if the PET indicates the existence of genuine effect. In such cases, they propose a precision-effect estimation with standard errors (PEESE) to obtain a corrected estimate of β_0. The PEESE model can be stated as follows:

$$r_i = \beta_0 + \alpha_0(se_{ri}^2) + u_i \qquad (6)$$

Dividing both sides by (se_{ri}) to address the problem of heteroskedasticity, we obtain model (7) - which must be estimated by suppressing the constant term.

$$t_i = \alpha_0(se_{ri}) + \beta_0(1/se_{ri}) + v_i \qquad (7)$$

Model (7) allows for estimating the overall effect if a genuine effect is already established through the precision-effect test in model (5). The genuine effect here is corrected for the non-linear relationship between the effect-size estimates and their standard errors.

We conduct PET/FAT estimations for different combinations of innovation and skill types, provided that the number of observations is greater than 10. We estimate the PEESE model only when the PET/FAT results confirm the existence of genuine effect.

PET-FAT estimations allow for making inference about the existence or absence genuine effect for the typical study, but they assume that moderating variables that may be structurally related to study characteristics or other moderating variables are all equal to their sample means and independent of the standard error. This is a restrictive assumption. Therefore, we also conduct multivariate meta-regression analysis (MRA). Our MRA model follows Stanley and Jarrell (2005) and Stanley (2008); and can be stated as follows:

$$r_i = \beta_0 + \alpha_0 se_{ri} + \sum \beta_k Z_{ki} + v_i \qquad (8)$$ or as the weighted least square version (WLS)

$$t_i = \alpha_0 + \beta_0\, 1/se_{ri} + \sum \beta_k\, Z_{ki}/se_{ri} + \epsilon_i \qquad (9)$$

Here $(1/se_{ri})$ is precision, Z_{ki} is a vector of $(K \times 1)$ study characteristics (or moderating variables) that may explain the variation in the evidence base, and ϵ_i is the disturbance term due to sampling error. Ordinary least-squares (OLS) estimation of model (9) gives

the WLS estimates of model (8) and thereby the effects of moderating variables on the effect-size estimates reported by primary studies.

The moderating variables represent the dimensions of the research field, including the type of innovation, skill levels, levels of analysis, estimation methods, and publication type. Effect-size estimates reported by primary studies are likely to be related to these variables. Our choice of the moderating variables is informed by the theoretical debate on displacement and compensation mechanisms, skill-biased technical change literature, and best practice in meta-analysis.

Given that the moderating variables are binary with values of 0 and 1 only, the effect of innovation on employment *conditional* on the moderating variables will be equal to:

$$\beta_0 + \beta_1 + \beta_2 + \cdots + \beta_k \quad if \quad Z_1, Z_2, \ldots Z_k = 1; \qquad \text{and}$$

$$\beta_0 \qquad if \quad Z_1, Z_2, \ldots Z_k = 0 \qquad (10)$$

We first estimate the model with a wide range of moderating variables that capture the dimensions of the research filed and the evidence base. These included: general method of moments (GMM), firm-level evidence, sector-level evidence, process innovation, skilled-labour employment, manufacturing sector, South Asia data, and journal article as publication type. Then, we follow a general-to-specific modelling approach to minimise the risk of multicollinearity and over determination. The general-to-specific modelling approach involves reducing the complexity of the model by eliminating the most statistically-insignificant variables (i.e., the variables with the largest p-value) one at a time, until all remaining variables are significant. The validity of the reduction is confirmed by examining the goodness of fit and stability of the significant coefficients (Krolzig and Hendry, 2001).

We control for Heteroskedasticity by estimating model (9) with robust standard errors. To control for within-study dependence, we use one-way and tow-way cluster robust estimation. In both methods, standard errors would be adjusted upward if effect-size estimates reported by each study were correlated and the correlation was positive (Everitt et al, 2001; Hox 2002). For one-way cluster-robust estimation, the effect-size estimates are clustered within each study reporting them; for two-way cluster-robust estimation, the estimates are clustered within each study reporting them to control for within-study dependence and within each estimation methods to control for dependence between estimates obtained from the same method.

The two-way cluster-robust estimation method is reported to be well-specified in the presence of two-way dependence between observations (Gow et al., 2010). Even if it is used when there is only one form of dependence, two-way cluster-robust standard

errors are in line with those obtained from one-way cluster-robust standard errors (Cameron et al., 2006; Thompson, 2006; Petersen, 2007; and Gow et al., 2010). Although concerns are raised about two-way cluster-robust method when the number of clusters is small (as it is the case in this review), Gow et al. (2010) provide simulation results that show that the method allows for better inference than one-way cluster-robust methods even when the number of clusters is 10. Furthermore, as Cameron et al. (2006) demonstrates, having few clusters does not warrant reliance on approaches that control only for one-way dependence.

Finally, we also conduct random-effect estimation of model (9) to take account of study-specific effects. In random-effect estimation, study-specific effects are assumed to be random and independent of the explanatory variables, which include the precision and the precision-weighted moderating variables. Random-effect estimation is more efficient compared to fixed-effect estimation, but the assumption of independence may be too strong (Stanley and Doucouliagos, 2012: 103). Therefore, we present the random-effect estimation results as an additional check for consistency rather than as a benchmark for inference. Our inference will be based on Heteroskedasticity- and cluster-robust estimations discussed above.