Indirect capabilities and complex performance: implications for procurement and operations strategy

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Acknowledgements

Martin Spring gratefully acknowledges financial support in the form of an AIM Research Fellowship in Services, ESRC Grant number RES-331-27-0036 and a period of sabbatical leave provided by Lancaster University Management School. We also acknowledge comments on various drafts from Katy Mason, the patient guidance of the guest editors, and the detailed and helpful comments and suggestions of the two anonymous reviewers.

All remaining errors of omission and commission are ours.

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Abstract

Purpose – The paper argues that indirect capabilities – the ability to access other organizations' capabilities – are an important and neglected part of firm strategy in PCP (Procuring Complex Performance) settings, and that this is especially so if these settings are treated as genuinely complex, rather than merely complicated. Elements of indirect capabilities are identified.

Design/methodology – This is a theoretical paper, drawing on complexity notions and Penrose's analysis of endogenous innovation to drive a disequilibrium-oriented discussion of the capabilities required by firms in a PCP setting.

Findings – Six inter-related elements of indirect capabilities are proposed and discussed: IT infrastructure; boundary management practices; contracting; interface artefacts; valuing others' capabilities and relating direct to indirect capabilities. These are important in PCP settings and in other operations and supply settings characterised by complexity.

Originality/value – This paper reconsiders the way complexity has been treated in the PCP literature, and develops an extended discussion of the notion of indirect capabilities. It potentially provides the basis for an operations and supply strategy more attuned to the demands of shifting inter-organizational networks.

Keywords – Complexity, PCP, indirect capabilities, Penrose, networks

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1. Introduction

Alignment between the nature of the supply task and the inter-organizational relationships by which it is to be carried out is an abiding concern in purchasing and supply management. Ensuring this alignment is the basic purpose of well-known, popular frameworks such as those of Kraljic (1983) and Fisher (1997). In the emerging literature on Procuring Complex Performance (PCP), complexity is the central characteristic that describes the supply task, and PCP has been concerned with identifying the appropriate organizational arrangements by which to deal with it. Lewis and Roehrich (2011) identify two dimensions of this complexity: performance complexity, which results from 'numerous knowledge intensive activities'; and infrastructural complexity, which results from 'substantial bespoke or highly customised hardware and software elements'.

This interpretation of the notion of complexity has at least two precursors. The first is in the work on 'Complex Products and Systems' (CoPS), defined as "...high-cost, engineering- and software-intensive goods, systems, networks, infrastructure and engineering constructs [sic] and services..." (Davies and Hobday, 2005: 6-7). PCP work explicitly considers similar empirical phenomena, albeit from the procurement perspective rather than that of the producer(s). The second precursor is in the analysis of governance mechanisms, which have become the implicit or explicit dependent variable in many PCP studies. Recent PCP work often seeks to identify the appropriate combination of contractual and relational governance. In one of the most cited sources on this issue, Poppo and Zenger (2002) repeatedly use the term 'contractual complexity' to describe the nature of the contracts they studied, and this usage has been carried over into the recent PCP literature. Importantly, their operationalization of complexity, based on Macneil (1978), was the extent to which 'the formal contract is highly customized and required considerable legal work' and 'the length of the contract (in pages)' (Poppo and Zenger, 2002: 717).

For us, PCP is centrally concerned with why, when and how resources external to a focal firm are used or accessed, usually under extreme and/or uncertain circumstances. We contend that existing PCP literature, although using the term 'complexity', seems frequently to be discussing 'complicated' rather than truly complex settings. Complication arises from a system's having many parts and many connections. Complexity arises from connections whose significance it is difficult to comprehend and predict (Bloch and Metcalfe, 2011: 85) so that emergent behaviour is generated. In this paper, we explore some of the implications of this interpretation of complexity, in the PCP setting and in operations and supply more generally. Furthermore, we argue that an important yet overlooked consideration in dealing with complexity is the focal firm's indirect capabilities; in other words, how good it is at accessing other firms' capabilities. In pursuing thus argument, we relax the PCP concerns about empirical settings – we are not solely concerned with 'high value capital goods' (Davies and Hobday, 2005: 4) - but retain the focus on inter-organisational networks, and (although not exclusively) PCP's emphasis on the procurement perspective. Like the PCP literature, we take as an empirical fact that organizations source activities that, according to a transaction cost economics (TCE) logic, should be carried out within the firm (Lewis and Roehrich, 2011: 26).

The paper is organised as follows: we begin by discussing the notion of complexity as treated in PCP and elsewhere. We then review a number of approaches to understanding the management of resources and capabilities external to the firm. That section concludes by arguing that Penrose's insights about endogenous innovation in firms and operations provide a useful way to think about complexity, not just in firms but also in inter-organizational networks as found in PCP settings and, further, that indirect capabilities take on increased importance as settings become more complex. The next section outlines the basic idea of indirect capabilities, then identifies and describes an architecture of indirect capabilities comprising six distinct components. The concluding section discusses the implications of a focus on indirect capabilities for PCP and for operations & supply more generally.

2. Complexity

In this section, we outline some important aspects of complexity. First, we review some of its defining features. We then briefly examine how complexity has been treated within the operations and supply management (OSM) literature, before outlining how complexity affects some underlying assumptions in PCP concerning uncertainty and risk.

2.1 The notion of complexity

According to Herbert Simon:

> "Roughly, by a complex system I mean one made up of a large number of parts that interact in a nonsimple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole." (Simon, 1962: 468)

This notion of complexity sharpens the distinction between the complex and the 'merely' complicated. Axelrod and Cohen (1999: 15) hold that *complicated* systems have a lot of "moving parts"; so do *complex* systems, but in these, the many parts interact "in ways that heavily influence the probabilities of later events" and exhibit emergent properties. Similarly, "nonlinearity leads both to unpredictable behaviour and a rapid rate of change, because changes in one agent's behaviour reverberate to influence others in a chain reaction" (Anderson, 1999: 228). This leads to the difficulty in inferring the properties of a whole system from the behaviour of its parts. A modern car is complicated, but we can usually infer the properties and behaviour of the whole system (Sargut and McGrath, 2011): it is not complex.

It is a central tenet of complexity theory that agents' decisions are made with only local information and according to relatively simple rules, but simultaneously based on the decisions being made by other agents. Arthur et al. (1997: 3) add: "The action of any given agent depends upon the anticipated

actions of a limited number of other agents and on the aggregate state these agents co-create". Complexity theory, then, emphasises non-linearity, emergence and positive feedback (Anderson, 1999) rather than rational planning and control using negative feedback mechanisms. If this logic is transposed to a supply network consisting of many organisations all exploring, say, the make-or-buy decision, we can imagine that, even as these firms form opinions of vertical integration or disintegration, the markets about which they are forming opinions are necessarily changing: and other firms are making the same kinds of judgments and forecasts[i]. This contrasts with a typical OSM analysis of 'the vertical integration decision' which is effectively made while the rest of the world stands still and without any consideration of what other firms might do, and how that, in turn, might affect the wisdom of various alternatives.

2.2 Complexity in operations and supply management

Complexity is surprisingly rarely examined in Operations and Supply Management. Among the relatively scarce contributions, recent work has examined product portfolio complexity (Closs, Jacobs, Swink and Webb, 2008; Closs, Nyaga and Voss, 2010) and supply base complexity (Choi and Krause, 2006). The emphasis here is on the large number of and differentiation among parts (products, components, suppliers) and the added effect of interconnectedness. In the studies mentioned, these factors are combined into higher-level constructs of product or supply-base complexity. But these discussions of complexity do not draw on the central concepts of complexity as we have outlined them here.

The more specific concept of Complex Adaptive Systems (CAS) is adopted by McCarthy (McCarthy, 2003; 2004; McCarthy, Tsinopoulos, Allen and Rose-Anderssen, 2006) and Dooley (Dooley and Van de Ven, 1999; Choi, Dooley and Rungtusanatham, 2001; Azadegan and Dooley, 2011). McCarthy's work addresses manufacturing strategy, technology strategy and NPD, mainly at firm level. Dooley extends this type of analysis to inter-firm networks. In their various ways, these papers – mostly rooted in the work of Kaufmann (1995) – present elegant and abstract models of organisations and

their adaptation processes. Azadegan and Dooley (2011: 431) point to such phenomena as the growth in outsourcing, JIT/lean production and open innovation, alongside increased network connectivity, as causes of increasingly distributed control in operations and supply. These make complexity approaches more relevant than ever. Pathak et al (2007) argue that OSM has not kept pace, despite the increasing relevance of complexity approaches to contemporary operations and supply practice.

2.3 Complexity, uncertainty and risk

PCP prescriptions emphasise heavy investment by the main client in up-front design of contracts and other governance mechanisms intended to control performance through negative feedback (Howard and Caldwell, 2011: 14): if performance strays from the desired specification, these mechanisms bring it back in line. This approach is also evident in the systems integration literature (e.g. Davies, 2003), which ascribes a strong directive role to its main protagonist, the firm known as the 'systems integrator'. The predominant theme is concerned with the design and control, by the systems integrator, of a *complicated* inter-organizational system.

In contrast, we consider PCP settings as potentially *complex*, and exhibiting positive feedback behaviour as well as negative. Indeed, this can be seen as an extreme case of the pattern of development in OSM more generally. Operations are increasingly inter-organizational in nature (Hayes, 2008); PCP is by definition about greater and radically altered dispersal of activities among supply network actors. Operations are enabled by and often constituted by ICT (Karmarkar and Apte, 2007). This affects operations in a monotonic, linear (albeit sometimes very significant) manner, such as through reductions in the cost and increases in scope of process automation (leading to greater complication). But it also affects them in non-linear, emergent and unpredictable ways: as Axelrod and Cohen (1999: 26) put it, 'an information revolution is likely to beget a complexity revolution'. As such, the conditions are ripe – especially in PCP settings - for genuinely complex, rather than complicated, phenomena to occur. Complex settings reduce or remove the likelihood of settled and

accurate *ex ante* evaluation of alternatives. Hence, strategic management theorists contend that businesses must achieve evolutionary progress through improvisation within a few simple rules:

> "Managers of complex systems can only dimly see what specific behaviours will emerge when an organization's architecture is changed. Instead of relying on foresight, they rely on evolution; changes that produce positive cascades of change are retained, while those that do not are altered". (Anderson 1999: 229)

The implications of complexity and uncertainty for decision-making have been recognised for some time now. Lindblom's (1959) seminal contribution was to recognise that comprehensive decision-making in the face of complexity presents significant problems. This complexity may stem from an impossibly large number of means and ends, the lack of foresight regarding possible repercussions of pursuing particular courses of action or from other imponderables. Lindblom's (1959) notion of disjointed incrementalism suggests that decision-making in complex situations can only feasibly proceed through step-by-step efforts. As Hirschman and Lindblom (1962: 222-3) suggest: "...these processes must let themselves be guided by the clues that appear en route. Snags, difficulties and tensions cannot be avoided, but must on the contrary, be utilized to propel the process further".

This contrast between planning, order and method and the alternative approach suggested by Hirschman and Lindblom (1962) calls to mind Langlois' (2007) distinction between *risk* and *uncertainty* (Knight, 1921). Risk means being unsure about something within a well-defined information structure: most simply (to borrow Langlois' example) 'Heads or tails?' when tossing a coin. Uncertainty is a more fundamental kind of ignorance, whereby the information structures, the very parameters of knowing, are unknown. According to Langlois, uncertainty 'comes about because of the complexity of, and because of continual change in, economic activity': then, it is about the uniquely human faculty of judgment – 'the (largely tacit) ability to make, under conditions of structural uncertainty, decisions that turn out to be reasonable or successful *ex post*' (Langlois, 2007: 1112).

3. Extra-organizational resources and capabilities: the case for indirect capabilities

We have characterised and explored the PCP domain, and delineated a perspective on complexity that is somewhat at odds with the one that prevails within PCP. In this section, we wish to examine alternative perspectives on the management of external resources and capabilities, given that we see PCP as centrally concerned with using and accessing external resources under extreme and/or uncertain circumstances, and taking into account our particular interpretation of complexity.

3.1 Extra-organizational resources and asset specificity: the Transaction Cost Economics perspective

As we have already mentioned, typical PCP settings involve the outsourcing of activities that, on a TCE view, are fraught with dangers due to the risk of hold-up. (Nevertheless, TCE still casts a shadow over the PCP domain in that TCE questions are often framed as questions of governance, a term barely used in the management literature until introduced by Williamson (1979)). The hold-up argument assumes that production requires the collaboration of specialized assets with little value outside their known uses. Owners of specialized assets are vulnerable to the opportunism of potential partners owning specialized and complementary assets, who are keen to appropriate an unfair share of the rents streaming from the combined use of such assets. To avoid a stalemate, entrepreneurs are faced with the choice between investing in general-purpose assets, thereby limiting the range of productive opportunities available, or eliminating the hazards of opportunism by bringing together specialized, complementary assets under a single ownership. The firm is thus seen as an efficient response to the hold-up problem.

There are at least two problems with this argument. First, as Loasby (1996) points out, is that it creates an acute problem for the growth of productive knowledge: the need for increasingly specialized assets can only be contemplated within hierarchies, since they alone can provide adequate safeguards against opportunism. Secondly, as Loasby (1998) notes, asymmetric information, identified as a source of incentive problems in TCE, is precisely what allows a finer division of labour

and increased specialisation of assets. It is only by encouraging the specialisation of human and physical capital that we can increase the total amount of knowledge available within an economy. In a sense, the existence of PCP settings is a vindication of this view: in order that they may specialise, organizations routinely engage in the procurement of activities that appear to be perilous in terms of asset specificity and the supposed attendant risk of hold-up. One question arising from this – and one that has pre-occupied PCP researchers – is the extent to which it then becomes necessary to 'surround the transaction with an elaborated governance apparatus' (Williamson, 1979: 254).

3.2 The evolving institutions of production

Of course, the unit of analysis in TCE is the transaction, considered in relation to the assets of and information available to the firm in question. Without specific assets and therefore without the risk of hold-up, firms can use 'the market' instead of hierarchy or relational contracting. But, just as firms differ and evolve in their assets and capabilities, so do markets differ and evolve. In this regard, the work of Langlois (Langlois, 1992; Langlois and Robertson, 1995; Langlois, 2004) and of Jacobides (Jacobides, 2005; Jacobides and Winter, 2005) has demonstrated how the reconfiguration of capabilities and their connections takes place by the gradual development of more effective markets for particular factors. Langlois and Robertson (1995) argue that over time, the tacit knowledge that underpins the idiosyncratic capabilities of firms becomes increasingly codified. This codification means that once idiosyncratic capabilities are liable to be replicated and become widely available. The boundaries of the firm will shift as activities that were carried out internally can now be safely farmed out to an effective market. As such then, we must no longer think of '*the* firm' but of particular firms at particular times; nor must we think of '*the* market', but of particular markets at particular times. As Turvani (2002: 210) puts it: "Firms do not operate on an abstract entity called the 'market'; the 'market' is created by the operations and strategies of other firms". Markets and firms, on this view, are mutually constitutive and co-evolving mechanisms for developing and integrating capabilities. As such, at any given time, a firm's opportunity to access external resources or capabilities depends on the nature of the relevant markets, seen as social, institutional and technological achievements of the firms and other bodies that construct them (Langlois, 2004).

3.3 Complementary activities and inter-firm coordination

Richardson (1972) addresses the same question as TCE (where should the boundary of firms be drawn?) but builds his argument on an analysis of capabilities, rather than a concern for the supposed hazards of trading with external counterparts. In his framework, the grouping of activities can be explained by the relationships amongst the capabilities that underpin them. Activities can be complementary or closely complementary, depending on their degree of interdependence. Complementarity arises when activities have to be matched in either level or specification, and require some form of sequential coordination. Close complementarity emerges when activities are specialized to each other and require tighter coordination in the way they are combined (Richardson, 1972: 891). Activities can also be classified as similar or dissimilar, depending on whether or not they draw on similar capabilities.

Firms and markets are only two possible modes of economic coordination. Markets are best at coordinating complementary but dissimilar activities where the law of large numbers can be trusted to match activities without the need for *ex ante* planning. However, closely complementary activities require some form of concurrent coordination so that the ordering of activities can be planned and adjusted. Firms provide one such form of concurrent coordination. But firms are best at coordinating closely complementary activities underpinned by similar capabilities. In other words, the size of firms is constrained by their inability to manage highly dissimilar activities. An alternative form of concurrent coordination – combining closely complementary but dissimilar activities – is provided by what Richardson (1972: 883) called the "dense networks of cooperation and affiliation by which firms are inter-related". This mode of economic coordination can cover anything from outsourcing arrangements to formal collaboration or elaborate forms of buyer-supplier relationships.

Richardson sees particular clusters of capabilities within firms as giving rise to new productive opportunities and defining a path for the growth of the firm. The growth of firms thus entails the development of capabilities but also poses novel questions on how they should be linked. Production

processes require the development of stable connections between clusters of capabilities but these connections are always liable to be reinterpreted and reassessed. Similarity and complementarity are thus matters of perception and judgment; they have to be interpreted and managed, as Taylor and Helfat (2009) clearly illustrated, albeit in an intra-organisational context.

3.4 Complementary assets and the extended RBV

At least since Teece (1986), there has been a strand of analysis in strategic management - and lately in operations management - that recognises that competitive advantage can be derived in part from resources existing outside the firm. Teece suggests that technological innovators may need to control – in other words, own – so-called 'complementary assets' in order to profit from their innovation. In Teece's analysis, assets such as manufacturing and service functions are seen as self-evidently complementary to the R&D-based innovation he places at the centre of profit-generation. Building on this, in what has become termed the 'extended resource-based view' (ERBV), writers in strategy and, indeed, in operations management, have further considered how firms can use external assets to develop competitive advantage (Madhok and Tallman, 1998; Dyer and Singh, 1998). For example, in an analysis rooted in a conventional RBV, Lavie (2006) demonstrates that firms can derive competitive advantage from resources shared in strategic alliances. In operations management, Lewis et al. (2010) draw on the ERBV to demonstrate that both internal and external resources can lead to strategic operations success. In their account we get some insight into how this comes about and, intriguingly for what follows here, that accessing external resources may typically happen on a faster cycle than the development of internal resources.

Mathews' interpretation of ERBV (2003) is broad in scope: he sets out a resource-based view of *the whole economy*, in which he is at pains to emphasise the dynamics of resource development and transfer between firms, as distinct from the generation of rents from static resources that dominates the established RBV. In a subsequent discussion (Mathews, 2010), he draws on Penrose (1959), emphasising the role of entrepreneurial activity in bringing about such resource development and

translation: interestingly for the present discussion, he defines the entrepreneur as 'the economic agent who in principle lacks resources (but knows where to find them)' (Mathews, 2010: 224). In this way, Mathews' analysis points to a shortcoming in other asset- and resource-based views. Seen from a complexity perspective, assuming limited foresight, local knowledge and action, as well as the state of chronic disequilibrium arising from the combined effects of firms' endogenous innovative activity, it is not possible to know what the 'full complement 'of assets (in Teece, for example) should be. In other words, to get to the roots of genuinely complex phenomena, it seems helpful to track back to Penrose, the original inspiration – acknowledged to a greater or lesser extent – of the RBV and ERBV.

3.5 Operations, capabilities and complexity: insights from Edith Penrose

Penrose examined the processes by which firms develop knowledge of their resources and how these might be combined, leading to the endogenous generation of new 'productive opportunities'. This productive opportunity of a firm is defined by Penrose as 'all of the productive possibilities that its "entrepreneurs" see and can take advantage of' (1959: 31). For Penrose, 'a firm is... a collection of productive resources the disposal of which between different uses and over time is determined by administrative decision' (Penrose, 1959: 24). And, as Bloch and Metcalfe (2011: 95) point out, Penrose's managers are 'living individuals working in a world of continual information flux, not uniform automata' (Bloch and Metcalfe, 2011: 95), so the use or 'disposal' of resources gives rise to new understandings and hence new potential productive and managerial services. Thus we have the 'restless firm', generating new potential services in constant - and constantly changing - disequilibrium. In Penrose's (1959: 69) memorable metaphor:

> 'In other words, in putting together the jig-saw puzzle of resources required in an expansion programme, the firm may find that a number of awkward corners persist in sticking out'.

Although Penrose here describes the 'corners' as 'awkward', in fact they are seen as the source of endogenous growth (Loasby, 2002). These 'imbalances' are examined in a positive light by Metcalfe (cited in Turvani, 2002: 197):

> 'imbalance can take the form not only of an under-utilized capability, but of a "missing" capability, needed for the optimal exploitation of other capabilities which are present....The restless firm....creates capabilities where imbalances existed previously"

The productive opportunity arising from the generation of these free resources, and the emergent nature of this innovative behaviour makes Penrose a very fruitful source of inspiration for a complexity perspective on networks of firms (Finch and Orillard, 2005; Bloch and Metcalfe, 2011). We sympathise with the view of Foss (1999) that Penrose has too readily been bracketed with the modern RBV, which has been overly concerned with explaining rent-generation in equilibrium (Barney, 1991; Peteraf, 1993). In contrast, Foss suggests, Penrose's vision of the firm is 'disequilibrium-oriented' (Foss, 1999: 95): the productive opportunity (not the resources as such) is 'arguably the key concept of *The Theory of the Growth of the Firm'*.

Penrose's central concern was, of course, inside the firm. We suggest, however, that the seed of an extra-organizational view is already present in the concept of the 'productive opportunity' and the entrepreneurial grasp of what the connection might be between the firm's resources and the needs and practices of its customers, potential customers and other external counterparts (Zander and Zander, 2005; Pitelis, 2007). Indeed, she later indicated the growing importance of an inter-firm perspective: in her introduction to the 1995 edition of *The Theory of the Growth of the Firm* (Penrose, 1995: xviii-xx), she particularly drew attention to the growing importance of business networks. Hence, from a complexity perspective, we suggest that this 'restless' character of firms in an inter-organizational network provides a critical ingredient for autogenesis of organizational forms and capabilities (Drazin and Sandelands, 1992). Understanding this provides an additional insight into the truly complex, rather than complicated, aspects of PCP settings. And it seems that managing in this context depends on managers' ability to 'see and take advantage of' new combinations of internal and external

resources and opportunities, even while their understanding of their own resources is changing. Our contention is that, given this perspective, we need to go beyond the concept of building sets of complementary assets (for how would we know what constitutes a 'full complement', anyway?), beyond integrating *complicated* systems of external capabilities, and toward a more flexible and dynamic way to think about accessing external resources and capabilities. The concept we turn to is *indirect* capabilities, and we devote most of the rest of the paper to examining this in theory and practice.

4 Indirect capabilities

The capabilities literature provides a well-developed characterisation of how firms differ in their endowment of resources and productive capabilities. The emphasis in the dynamic capabilities literature and in such notions as 'absorptive capacity' (Cohen and Levinthal, 1990) is on bringing new capabilities into the direct control of the firm. But there is little or no treatment of how firms differ in their ability to access external capabilities without seeking to control them directly – especially important in PCP settings. These are what Loasby (1998: 149) terms 'indirect' capabilities:

> "We need not only to know how to do certain things for ourselves, but also how to get other things done for us; and just as productive activities require direct capabilities, so transactions depend on indirect capabilities"

The notion of indirect capabilities is analytically distinct from the idea of dynamic capabilities (Winter, 2003), which are about a focal firm's ability to develop new direct capabilities. It is also distinct from the so-called 'relational view' of Dyer and Singh (1998) which is exclusively concerned with long-term collaborative relationships, or 'alliance competence'(Lambe, Spekman and Hunt, 2002) which is associated with a generic capability to manage collaboration. Although some of the mechanisms discussed in the relational view and ERBV literature may have a bearing here, the indirect capabilities notion remains agnostic about the benefit or otherwise of closely collaborative relationships, and retains, as its unit of analysis, the focal firm rather than the dyad.

These various forms of capability – direct, dynamic and indirect - are related to one another (cf. Holcomb and Hitt, 2007). A firm with a great endowment of direct capabilities will have less reason either to develop new ones i.e. exercise its dynamic capabilities, or to access others' i.e. exercise its indirect capabilities. Another firm, with greater indirect capabilities, can do without direct capabilities (but see Parmigiani (2007) on concurrent sourcing). A third firm may lack direct capabilities but have greater dynamic capabilities and prefer to develop its own direct capabilities rather than accessing another's. Overdependence on direct and dynamic capabilities in conditions where change is rapid may meet the 'managerial limit' (Penrose, 1959: 44-45) and so, at some point, a firm's indirect capabilities become the only way to get done what needs to be done. As Loasby (1998: 149) puts it: "We can access more than we can control, and therefore should limit our attempts at control to those capabilities which are both crucial and manageable". Our argument here is that, given a finite quantity of Penrose's 'managerial services', the operations manager faced with Knightian uncertainty must make proportionately greater use of indirect capabilities, achieving *access* rather than or in addition to direct control.

Having outlined the idea in principle, we now propose and discuss some of the components of indirect capabilities. As a structuring device, we propose a simple model of the relationship between these elements of indirect capabilities (Figure 1). We derive from the literature four processes and structuring devices that simultaneously form and bridge interfirm boundaries (Araujo, Dubois and Gadde, 2003): interface artefacts, contracting processes, boundary management practices and IT infrastructure. We further suggest that these are deployed in multiple and shifting understandings of the relationship between direct and indirect capabilities, and of the valuation of capabilities, within and outside the focal firm. Note that we do not suggest that these elements of indirect capabilities are mutually exclusive: for example, external capabilities might be evaluated and aligned by boundary management practices, but then give rise to the development of contracts that stabilise and define the nature and terms of access. Notice also that they include aspects of the contractual and relational governance mechanisms discussed earlier, but that we add to these, through the more structural elements of interface artefacts and IT infrastructure. We also add at least part of the entrepreneurial

element of indirect capabilities that flows directly from Penrose: how managers' judgements about others' capabilities depend on their understanding of their own resources, and how they make valuations of their own and others' capabilities.

FIGURE 1 HERE

4.1 IT infrastructure

As well as providing information for accounting and transactions, information systems are increasingly providing the infrastructure by which work within and between organisations is carried out (McAfee, 2006). At a very generic level, the Internet provides the channel by which any operations requiring data transfer can be connected, particularly in data-intensive knowledge services (Metters and Verma, 2008). But many other information systems of varying degrees of specificity – to industry or technological application – potentially allow network counterparts to work together or, in other words, to access others' capabilities. We see three strands to this discussion of the way IT and indirect capabilities interact.

The first view is that the use of IT can allow work to be carried out between organizations that would hitherto only have been possible within a vertically-integrated firm. Early work in this vein was Argyres' (1999) study of the network of firms working on the B-2 stealth bomber, which argues that the use of a common information system, and the consequent use of a common 'technical grammar', allowed a network of firms to succeed. In short, 'IT can substitute for hierarchy' (Argyres, 1999: 164). Taking a TCE view, Lajili and Mahoney (2006) also argue that electronic integration may provide a viable alternative to both vertical integration and spot markets. In particular, they see electronic integration via IT systems as a substitute for hierarchy because: (1) IT systems favour *ex ante* codification of the responsibilities of each contracting party; (2) IT systems enable more timely and finer-grained measurements of output; (3) IT systems reduce the nonseparability problems of team production which provides for better assessment of individual firm-level performance measures;

and (4) a relationship-specific IT system provides a mutual sunk cost commitment that mitigates the contractual hold-up problems for which hierarchy might otherwise be seen as an efficient solution. This work then, and much of the work on IT and supply chain management (e.g. Boone and Ganeshan, 2007), sees IT as a tool for quasi-integration.

The second view is that, far from providing an integrative substitute for hierarchy, IT provides the means for almost complete dis-integration via the spot-market purchasing of IT-enabled services based on common standards and interfaces. Davenport (2005), for example, laments the shortage of business process standards: if companies define common business processes in different ways, it is difficult to specify and contract for these processes. Process standards, Davenport argues, could pave the way for more extensive and efficient outsourcing as benchmark criteria would make it easier for companies to compare their capabilities against those of external suppliers. Similarly, Merrifield et al (2008) claim that it is possible to design many common business processes as Lego-like components which can be assembled and taken apart easily. The widespread adoption of service oriented architectures (SOAs) would enable "…the transformation of companies from collections of proprietary organisations into a collection of standard plug-and-play activities" (Merrifield et al, 2008: 75). Malone et al (2011) paint an even more radical picture of hyperspecialisation, envisioning a digitalized putting-out system with workers ready to be mobilised, on demand, by dedicated intermediaries such as Amazon's Mechanical Turk.

The third view reflects a more mixed and perhaps messy picture. IT implementation is difficult to achieve and the adoption and effective linking, between divisions or between firms, of even supposedly common IT packages, is fraught with difficulty. The way IT is used varies from work-group to work-group, depending on many contextual factors (Leonardi, 2007) and so the information *services* perspective – as distinct from the information *systems* perspective – may offer a better reflection of contemporary IT practice, emphasising as it does the highly situated, day-to-day use of a variety of IT artefacts, often in combination with others, rather than any totalising information system designed and implemented as intended across work-groups and firms (Mathiassen and Sørensen, 2008). Jeffers et al's (2008) observation, in a Penrosean spirit, that the value of IT-derived

capabilities should be understood in the context of how they interact with the non-IT capabilities of the firm, is consistent with this view. Thus IT can indeed replace some of the functions of hierarchy but not without significant effort in identifying the specific attributes of IT applications and how they might fit in a specific business process.

IT-related indirect capabilities are likely to inhere in all three of these views. Argyres' emphasis on the value of a common 'technical grammar' suggests that indirect capabilities within particular industry domains is likely to be enhanced by investing in and developing skills in using IT that is common to that domain. Examples might include the use of Unigraphics CAD (Computer-Aided Design) in the aerospace industry. Note that this is not to suggest that simply learning to use such a package will lead to instant seamless collaboration, rather that it will provide 'common ground' (Srikanth and Puranam, 2008) on which particular routines for inter-organizational working might more readily be built. In some circumstances, the use of 'plug-and-play' services using IT might be highly appropriate: for example cloud-based data storage services can quickly be accessed by SMEs. And the third view, that of highly situated information services, requires an ability to access external IT-mediated capabilities, adapt and translate them and combine them with internal activities so as to carry out work internally and/or for customers. In the settings we discuss, this improvisatory and localised work is likely to be an important indirect capability.

4.2 Boundary management practices

In a complex business system with significant emergent behaviours, it is essential to complement the more concrete embodiments of indirect capabilities such as IT infrastructure and contracts with the capabilities of managers to span boundaries and interpret, respond to and shape emergent phenomena. In Penrose (1959), managers' ability to 'see and take advantage of' a productive opportunity is critical. And yet we might be forgiven sometimes for thinking that, in PCP, management boils down to informal governance mechanisms.

Normann (2001: 164-167) contends that complex situations call for leadership, not just technocratic management, at the highest levels of the organisation,. That may well be so. He adds that "[The] lack of boundaries, this haze....paradoxically requires us to *think more, not less*, of boundaries" (Normann 2001: 270). This concern with boundaries is indeed what motivates our argument here. We contend, though, that many in the organization other than upper echelon leaders have to carry out a contemporary version of Aldrich and Herker's (1977) 'boundary-spanning'. If complexity and disequilibrium call for judgement, these people are the technicians of judgment, who carry out the 'small, cheap probes' called for by complexity theorists: business development managers, product managers, purchasing managers, operations managers. What is the nature of this activity? We review two examples.

Hagel and Seely Brown (2005) discuss Li and Fung as an example of a firm with highly developed process orchestration skills, and attribute this to a significant degree to their policy of hiring managers from the sectors from which they wish to source capabilities. This gives these managers an ability to quickly assess the capabilities of potential suppliers and other counterparts, as they have an intimate understanding of cost structures, production technologies and other key issues relating to the suppliers, leading to so-called 'forward trust'. This is trust based on an understanding of capabilities to carry out future tasks, rather than trust based on past demonstration of performance, which may be no guide to the performance of future tasks in a dynamic environment.

Parker and Anderson (2002) study the shift in the skill-set of staff as Hewlett Packard shifted from carrying out detailed product design in-house to sub-contracting detailed design and only retaining higher-level conceptual design and overall project management in-house. They found that too much knowledge of detail design was an impediment to these managers, who needed rather to have broad conceptual design and project management skills, and the soft skills necessary to persuade and cajole suppliers in the absence of direct managerial control. Interestingly, these managers found they needed basic OM knowledge – "operations 101" as one respondent put it – to enable them to understand basic operations parameters when dealing with sub-contractors.

4.3 Contracting

Inter-organisational arrangements to trade or otherwise allow access to capabilities usually involves some form of contract and this is, as we have seen, a predominant theme of PCP (Lewis and Roehrich, 2011). From a TCE perspective, contracts are treated primarily as mechanisms to align incentives and forestall opportunism (Williamson, 1979). Gilson (1984), for example, saw lawyers as transaction cost engineers with potential for creating business value. Adopting an RBV approach, Bagley (2008) regards "legal astuteness" as a capability of top management teams, and a potential source of competitive advantage. Similarly, DiMatteo (2010) provides an extensive survey of how contracting capabilities can provide competitive advantage. These treatments all construe contracts as all-round protective devices in both competitive and collaborative situations. As DiMatteo (2010: 729) puts it: "...contracts can be a strategic tool in obtaining a competitive advantage, or they can be a tool to support collaboration by minimizing the opportunities for advantage taking".

In other treatments, contracts are seen as plans and repositories of knowledge (Collins, 1999; Mayer and Argyres, 2004) as well as tools for the intermittent stabilisation of interactive service development (Selviaridis and Spring, 2010). Gilson et al (2009) start from the empirical observation that we are witnessing an increasing degree of vertical disintegration in industries where producers recognise that they can no longer sustain capabilities in each of the fields they require for competitive success. However, the forms of contracting that support this trend do not match what TCE would have predicted. Instead, contracting to support collaboration between firms combines explicit and implicit terms, and adapts to the uncertainty inherent in innovating processes, namely the inability of the parties to specify the nature of what is to be produced or its performance characteristics, as often mentioned in the PCP literature (Howard and Caldwell, 2011; Lewis and Roehrich, 2011). This means that performance specifications are determined by the very governance process created by the contract (Gilson et al 2009: 435). In addition, as Jennejohn (2010) has shown, contracts governing these forms of collaboration eschew conventional litigation in courts in favour of a system of arbitration clauses embedded in complex escalation procedures.

As a capability, contracting can also be honed and developed over time. As Mayer and Argyres (2004) show, successive rounds of contracting between parties has the potential to lead to improved performance through a gradual and mutual adaptation of contracting terms. Their study followed one pair of firms over successive rounds of contracting: as such, it is not clear how much of this learning might be transferrable to contracting with other counterparts. In the PCP environment, Hartmann et al (2011) present interesting findings on the process by which organisations may accumulate contracting capabilities from project to project. We should also be aware, of course, that capabilities may dissipate as well as accumulate (Benkard, 2000).

In summary, we suggest that contracting capabilities represent an important component of indirect capabilities. We should not limit contracting capabilities as simply the recourse to wise legal counsel or see the role of formal contracts purely as safeguards against opportunism. The forms of vertical disintegration and interfirm collaboration we observe in PCP environments place emphasis on what Gilson et al (2009: 435) called the "rich braiding of explicit (i.e. legally enforceable) obligations and implicit (i.e. legally unenforceable) obligations", as well as the ability of firms to accumulate and develop contracting capabilities over time.

4.4 Interface artefacts

Capabilities and knowledge may be embodied in artefacts: for example, machine tools could be seen as embodiments of their builders' capabilities and knowledge. In a sense, a client firm using such a machine is accessing another's capabilities. Increasingly, however, IT-based systems allow not only the basic function provided by the machine – e.g. cutting metal – to be provided in the form of an artefact, but also maintenance and support such as condition monitoring, diagnostic advice and procedures, operator instructions and the like. Hitherto, some of this kind of 'service' could only be provided by (expensive, non-scalable) field service staff: now, this can be effected by the provision of information systems to allow users to carry out more of the service for themselves. This draws

attention to the multiple forms in which others' capabilities might be made available, and the fluidity of the boundaries between roles.

As the use of capabilities is often profoundly situated in the user's work context (von Hippel, 1994; Orr, 1996), this may well be the most effective means by which to provide access to capabilities. Passing the repetitive element of the work over to the user also reduces the provider's variable costs. For all these reasons, companies such as Amazon Web Services and Apple provide what von Hippel and Katz (2002) would term 'user toolkits' e.g. software application developer protocols, so as best to enable users or third parties to develop their own solutions. More generally, organizations can astutely delimit their own entanglement in others' processes by providing platform-like 'offerings' (Normann, 2001: 113-124), which contain 'a "code" for value-creating activities' (Normann, 2001: 119). Of course, some customers explicitly require 'total solutions' but even these must, at some point, connect with the customer's own processes. A critical indirect capability, then, is working out where to 'freeze' the focal firm's offering (Normann, 2001: 122), how to provide the right 'code' to allow co-production and, perhaps, how to bring third parties to bridge the gap in capabilities between provider and client (Langlois and Cosgel, 1998; Flowers, 2007).

Delimited and standardized forms of interaction between firms is also achieved in the routine processes of purchasing, through the everyday artefacts such as Invitations to Tender (ITTs). Well-designed and effective ITT and similar documents (or online equivalents) make it easier, quicker and cheaper to establish and manage contracts with suppliers, distributors and other counterparts, and ensure that relevant performance and quality issues are captured. In project and contract-based industries such as construction and oil and gas exploration, the ability to quickly invite tenders in a controlled and consistent way is an absolutely critical aspect of indirect capabilities; the ability then to trace and control what follows from the tendering process is, in some cases, a legal or pseudo-legal requirement (e.g. in public sector procurement or safety-critical settings such as aerospace). Embarking on a policy based on the use of indirect capabilities requires confidence that those indirect capabilities extend to the control, monitoring and ability to scrutinise and be held accountable for, in Loasby's (1998) words, the 'other things [we get] done for us'.

4.5 Valuing others' capabilities

We wish here to suggest that a critical and pervasive element of indirect capabilities is to understand and manage the interplay of institutional and other mechanisms in valuation. Work in the PCP canon has a good deal to say about the incentivizing effect of price structures – fixed price versus cost-plus, for example - and other financial mechanisms (e.g. Hughes, 2011). It also adopts the notion of value co-creation to characterise the interactive process that is often present between the provider and client in typical PCP settings. But strangely absent is any consideration of the process of valuation: in other words, how the assets, capabilities and activities of the counterpart are valued in order to arrive at a price in the first place, or how value *extraction* in hard financial terms follows from the suggestive but inconclusive notion of value co-creation. A characteristic of complexity, as we have seen, is for it to be difficult to understand the properties of a system from the knowledge of its components. Thus the provision of a genuinely complex service will present extreme problems of valuation to a potential buyer or 'accessor'. Under conditions of risk (in the sense of Knight), valuation is not without difficulty, but at least the difficulty is reasonably well characterised: given a somewhat unpredictable demand pattern for my finished products, what would be the value of contracting for next-day delivery from supplier X? But under conditions of Knightian uncertainty, even the structure of the problem is not clear: then, as we have seen, it is about judgment (Langlois, 2007: 1112), and judgment calls on various schemes of valuation.

Valuations are also performative in the sense that they do not simply describe the world, they shape and change it (Stark, 2009; Beckert and Aspers, 2011). Valuation is, of course, not simply a cognitive achievement of individual managers, but is also framed by various information systems and accounting procedures – those of the potential counterpart firm as well as those of the focal firm. Information systems such as ERP serve to demarcate and classify cost elements, revenues, items and services to be bought and sold, and will, as a result, exclude others. The speculative or less-easily identified or measured may be neglected (Dubois, 2003). Operations and supply managers will use accounting information in order to understand costs and profitability: as these are enrolled into decision-making in various contexts, they are subject to translations by organisational coalitions, and,

far from merely reporting accounting outcomes, they come to determine actions by virtue of the very way they frame and structure decisions and roles (Mouritsen, Hansen and Hansen, 2009). The interplay between information and accounting procedures and the way work is organised provide structure to information that would otherwise be subject to Knightian uncertainty. This is not to say that these structures are necessarily helpful: for example, Bidwell (2010) describes how work on information systems at a large bank was framed as separate projects, not because the projects were genuinely separate pieces of work, but primarily as an accounting device to allow some basis for allocation of costs. The hiring and management of external consultants was accounted for by these 'projects', then, but in fact the consultants worked very flexibly on a broad application area, shifting from one project to another. This created a dysfunctional framing of decisions about which work to outsource, resulting in over-dependence on expensive contractors.

Furthermore, such judgments are rarely simple unilateral valuations by one firm of another firm, its offerings or assets. Extra intermediaries, standards bodies, and simultaneous mutual valuations cloud the picture even further, and so valuation may be not only about the potential supplier's capabilities, but also about the quality of another's valuation of the supplier's capabilities e.g. through third-party quality systems accreditation. Here we recall Lyotard's 'metaquestion of legitimacy: "What is your 'what is it worth' worth?"' (Lyotard, 1979: 54). In the face of structural uncertainty such as this, indirect capabilities are entangled with multiple layers of contingent schemes for valuation.

4.6 The relationship between direct and indirect capabilities

As we are only just beginning to understand the nature of indirect capabilities, it should come as no surprise that there is no existing research on the relationship between direct and indirect capabilities, construed as such. But it is possible to identify some relevant elements of this debate. The discussion above of boundary management practices suggests two opposing arguments about the relationship between direct and indirect capabilities. One is that the 'poacher makes the best gamekeeper': one with experience of one side of the relationship is the most effective exponent of the role on the other

side (Hagel and Seely Brown, 2005 on Li and Fung). The other argument is that too much direct experience of the activities to be accessed from outside the firm can prevent innovation (Parker and Anderson 2002 on HP); this may result from cognitive bias and inertia (Tripsas and Gavetti, 2000) or 'not-invented-here' syndrome (Lichtenthaler and Ernst, 2006).

As well as a cognitive dimension, these arguments have a techno-economic one, too. Firms' direct capabilities are embodied in equipment, codified and uncodified processes, routines and activities that lead to the creation of products and services. In this sense we have some idea of what their direct capabilities are. But there is a complication. What a firm does may not correspond to what it knows how to do. In some respects, firms may 'know more than they make' (Brusoni, Prencipe and Pavitt, 2001), for example by developing and retaining know-how in manufacturing components that they choose to buy rather than make themselves. Is such a firm better at buying these components than one who never had those direct capabilities?

A related question concerns generic as opposed to specific indirect capabilities. For example, if contracting is part of indirect capabilities, do firms have and develop contractual mechanisms that serve equally well for all types of external resource (e.g. raw materials and consultancy services), from all types of network counterpart (e.g. both large and small, supplier or joint-venture partner), or are these very specific, situated capabilities? If, as seems reasonable, indirect capabilities bear some relation to Penrose's notion of 'entrepreneurial services', Pavitt's (2001: 15) comment cast doubts on the existence of general-purpose indirect capabilities

> '....it can be argued that entrepreneurship in practice cannot be separated from the particular knowledge on which it is based.... there are differences in entrepreneurship between chemical firms and electronic firms. Both are knowledge-based, but they exploit different bodies of specialised knowledge, and explore new knowledge in different directions. Knowledge-based entrepreneurship is not therefore a general-purpose management skill that can be deployed in all places at all times.'

Of course, 'know-how' is not a binary but a continuous variable, and firms may also choose to carry out functions that they are not particularly good at, for example to fill capacity at times of low demand. Furthermore, the fact that firms may choose to buy inputs even though they lack the necessary *indirect* capabilities - they 'buy more than they know' (Flowers, 2007) - might support Pavitt's argument about the absence of general-purpose indirect capabilities. The mismatch between the capabilities of buyers and suppliers in these markets leads to entrepreneurial opportunities for intermediaries who can bridge these gaps (Langlois and Cosgel, 1998).

5. Conclusions and implications

We have begun – but only begun - to set out an account of what complexity means for PCP and for operations and supply more generally. Our starting point was to make clear distinctions between complicated and complex systems, uncertainty and risk. Complexity, non-linearity, emergence and positive feedback require responses other than rational planning and control using negative feedback mechanisms. We identified the world of PCP as involving extended networks and timescales, and situations of chronic uncertainty. In these settings, managers must proceed by interacting with their closer network neighbours, attempting to understand and value internal and external capabilities, how they can be combined and mobilised, all without being able to infer the properties of the whole network, whilst their counterparts are doing precisely the same. This is not to suggest that all organizations are equally affected by working amidst complexity. Complexity is, to some extent, in the eye of the beholder, and individuals' and organizations' abilities to (a) intuit a situation as complex and (b) deploy effective action will vary according to many path dependent factors[ii]. Indeed in suggesting, as we do, that indirect capabilities become increasingly important in complex settings, this differential ability to cope with complexity can be understood, in part at least, as a difference in indirect capabilities. More specifically, we have identified some forms that indirect capabilities seem to take. We do not claim, however, that the aspects that we identify exhaust the possibilities or are the most elegant and parsimonious set that might be identified. We do, however, suggest that these are

increasingly the kind of strategic bets that senior operations managers are required to make and that will have a great bearing on their operations' future ability to deal with complexity.

In setting out this preliminary characterisation of the elements of indirect capabilities, we wish to build on existing theory in at least two ways. First, we provide a more concrete account of what goes on between organisations involved in PCP settings than the abstract generalisation of, for example, Poppo and Zenger's (2002) 'contractual' and 'relational' mechanisms. For example, knowing relational governance 'occurs through social processes that promote norms of flexibility, solidarity and information exchange' (Poppo and Zenger, 2002: 710) doesn't provide much insight on the capabilities and managerial work involved in coordinating operations across organizational boundaries. Note however that we seek to do this without resorting to prescriptions for particular functions e.g. the purchasing function should carry out supplier development. Second, we provide a perspective on capabilities that is complementary to that of, say, Winter's (2003) discussion of 'zero-level' capabilities and dynamic capabilities. The capabilities literature shows an overriding empirical and theoretical concern with what capabilities firms have (zero-level or direct) and how they develop new ones (dynamic). In contrast, the idea that firms don't always need or want to develop capabilities they may lack, but merely to access them, and that that access requires particular – i.e. indirect – capabilities, seems to be a blind spot in the RBV.[iii] We conclude by discussing the implications for PCP in particular and for Operations and Supply in general.

5. 1 Implications for PCP

We suggest that the characterisation of PCP settings would prove more productive if the fuller interpretation of complexity we set out here were taken seriously. In PCP settings, however much time is spent 'up front' and however complicated the governance mechanisms put in place, emergent and unforeseeable behaviours will inevitably arise in the network. Direct capabilities may drive a focal firm on, provide the basis for its viability and continued role in the network and broadly establish its relationship with other firms with complementary capabilities. However, indirect

capabilities become increasingly important as a way not only to adapt to emergent behaviours in the network, but also to drive them in certain (possibly new) directions once these behaviours manifest themselves. Contracting capabilities constitute one important component of indirect capabilities and it is understandable that researchers have so far focused primarily on the transactional complexity and the governance structures to remedy PCP deals (Lewis and Roehrich, 2011). But in PCP settings, technical and structural drivers of complexity are frequently combined with political and social drivers (e.g. in military or healthcare domains), making other forms of adaptation all the more important[iv].

A broader focus on indirect capabilities directs our attention elsewhere, namely to the conception and management of boundaries between different types of activities and the mechanisms required to coordinate these activities. Our attempt at sketching an architecture of indirect capabilities offers a number of examples on how different types of interfaces can be enabled to facilitate interactions and provide access to other's capabilities. This focus doesn't just invoke the need for the procurement of extra-organisational resources to sustain novel sources of competitive advantage, as the extended RBV would have it, but a Penrosean concern with how particular combinations of direct and indirect capabilities can broaden the scope of productive opportunities available in a network. From a focal company's perspective, suppliers or subcontractors are not compliant bundles of well-understood and valuable resources waiting to be enrolled and told what to do, but are Penrosean firms in their own right, restlessly seeking to redefine their own productive opportunities, while their network counterparts are doing the same.

In short, the procuring of complex performance is a manifestation of indirect capabilities but, we suggest, it is much more than upfront procurement, and an achievement of all the organizations involved, not just the focal client-as-procurer. A Penrosean conception of innovation suggests that systems integration, from which PCP borrows so much of its logic, is a less hierarchical and more distributed affair than the one envisaged by the systems integration literature. In this lies a much wider set of opportunities for innovation and adaptation to the dynamics of changing customer requirements over long time frames, based on evolving definitions of performance that underpins PCP

projects (Caldwell and Howard, 2011). However, systems integration without systems integrators is also the source of potential difficulties – in complex systems the effects of actions are always multiple, extend over time and often have unintended consequences.

5. 2 Implications for Operations and Supply

As discussed, although PCP settings are propitious ones for the engendering of complexity, so are many others in operations and supply. The elements of indirect capabilities that we outline can constitute the decision areas of a new operations strategy based on the coordination of multiple operations (Hayes 2008). Our call for attention to indirect capabilities is not to suggest: (a) that these have only just become relevant; or (b) that there is no longer any need to be concerned about direct capabilities. But it does suggest some rebalancing. Wickham Skinner memorably described operations strategy as '999 variables and 998 equations' (Skinner, 1992: 22): a complicated problem, but one that could be solved, and solved based on the logic of consistency. A complexity perspective calls this endeavour into question.

Operations management becomes much more about using indirect capabilities to combine a few direct capabilities with the capabilities of others. In doing this, managers must accept that capabilities of all sorts are conjectures, particular forms of organization and process are likely to be temporary, and that consistency, equilibrium and the 'correct' process type are impossible to achieve and, furthermore, impossible to recognise anyway. Developed at the right level of specificity, indirect capabilities provide the means to connect with and disconnect from others' capabilities and thereby ride, control and possibly shape the behaviour of complex inter-organizational networks. Notice that, because of the evident connection between direct capabilities – many of which are rooted in operations – and indirect capabilities, we contend that indirect capabilities cannot be left to functions other than operations. Operations strategy then shifts its emphasis to the indirect capabilities we have identified rather than being primarily concerned with planning and controlling stable technologies, stable processes and stable capacities, largely within the boundaries of the firm. It is also more than adding

'supply' to 'operations': although upstream and downstream connections are doubtless important, complementary, horizontal connections and links of other types are also part of the picture.

Almost by definition, this analysis also calls for operations on the one hand and supply on the other to be inextricably linked: they are simultaneously mutually constitutive and (sometimes) barely distinguishable. The boundaries of the firm are indeed multiple, blurred and dynamic (Araujo et al., 2003) but, we contend, so are those of operations management. We are a long way from a concept of operations as the buffered 'technical core' of the organization (Thompson, 1967): while 'unbuffering' has been evident at least since the adoption of Japanese-style partnership supply, and through planning and control innovations promoting routine information-sharing (Danese, 2007), what we hope to convey here is something different. It is an operations and supply management that is pre-eminently concerned with making and, as necessary, breaking exploratory and emergent connections to the capabilities of other organizations, often without a clear understanding of the precise outcome. It also suggests a heightened sensitivity to the nature of problem-solving and decision-making in networks which has to find ways to cope with interdependencies whilst risking increasing interdependencies (Skarp and Gadde, 2008).

To understand this emerging world requires both theoretical and empirical moves. From a theoretical perspective, it suggests revisiting the logic first suggested by Lindblom (1959, 1979) and Hirschman and Lindblom (1962) of favouring incrementalist, limited comparison approaches to problem solving rather than the synoptic, planning approaches that have held sway in much of the OSM literature and beyond. A number of recent empirical studies (Kowalkowski, Kindström, Alejandro, Brege and Biggemann, forthcoming; Hultén, 2012) have used variants of incrementalist approaches to explain how manufacturing firms make transitions to services or how "muddling through" as a problem solving strategy can help create value in business relationships. On the empirical front, more work along the lines of Parker and Anderson (2002) could be used to better understand the nature and practices of this new form of operations and supply entrepreneurship.

We suggest that these two moves may also bring a different perspective to studies in the PCP 'tradition', as it suggests that systems integration is a dispersed phenomenon, evolving through incremental and diffuse problem-solving strategies. As such, although PCP necessarily focuses on the purchaser, there is a need to understand in greater depth the emergent behaviour of the wider network in understanding the truly complex product-service innovations that fundamentally characterise PCP settings.

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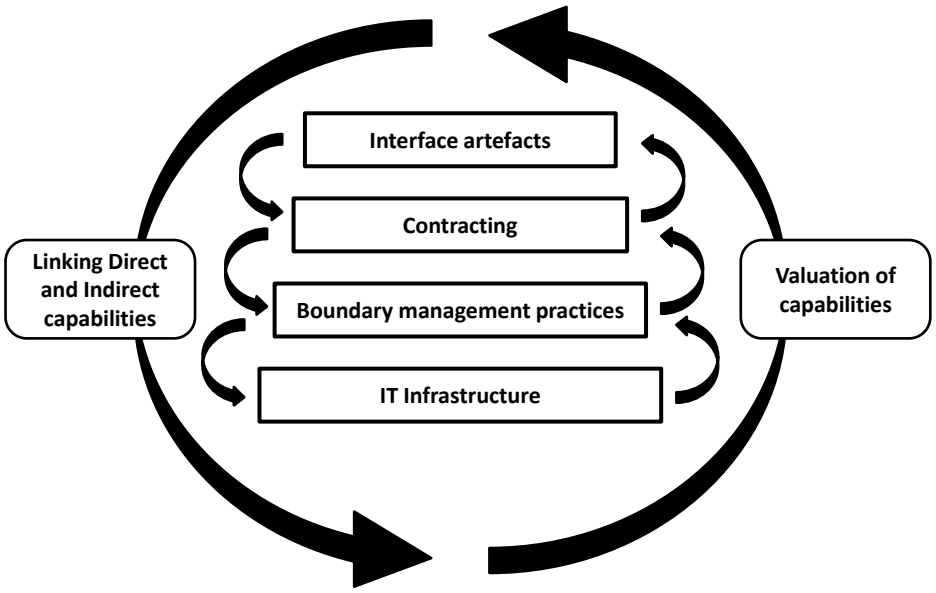

Figure 1 – An architecture of indirect capabilities

[i] Winter (1993: 191) remarks: "At any particular time, the costs and benefits of adjustments in governance modes for particular modes of transactions are substantially influenced by the network of transacting patterns already in place. Thus, the process of change in a firm's way of doing things most typically involves incremental adjustment in a complex, interdependent system. Such a process may well produce progress, but it does not produce an 'answer' to any well specified question or list of questions as to how activity should be organised". See also Garud and Munir (Garud, R. and Munir, K. (2008) From transaction to transformation costs: The case of Polaroid's SX-70 camera. *Research Policy,* 37, 4**,** 690-705.) for an empirical example of the cascading and unintended effects of boundary changes in the case of a radical innovation.

[ii] We are indebted to one of the anonymous reviewers for drawing our attention to this point.

[iii] Two wide-ranging assessments of RBV and its evolution (Barney, J.B. (2001) Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view. *Journal of Management,* 27, 6**,** 643-650, Barney, J.B., Ketchen, D.J. and Wright, M. (2011) The future of resource-based theory. *Journal of Management,* 37, 5**,** 1299-1315.) make virtually no reference to either extra-organizational resources or indirect capabilities.

[iv] Again, thanks to our anonymous reviewer for emphasising this.