The impact of technology changes on production and performance of Konkola Copper Mines, Zambia, before and after privatization

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The paper evaluates the impact of technology used before and after privatization (1991–2010) of the copper mining sector in Zambia, in particular Konkola Copper Mines plc (KCM). The paper reviews the technology inputs and the resultant operational and financial performance of KCM's assets before and after the privatization. KCM was a joint venture private company run by the Government of Zambia, Anglo American Corporation plc (AAC), and the Commonwealth Development Company (CDC), which took over from the parastatal Zambia Consolidated Copper Mines Ltd (ZCCM) in 2000. In November 2004, Vedanta Resources of India took over KCM as majority shareholder.

The operations include underground mining and open pits as well as concentrators, smelting, acid plants, and metallurgical refining complexes. The study found that since privatization, underground mines have deepened and increased in trackless mechanisation. In the open pits, smaller dump trucks have given way to larger dump trucks. For mineral processing and metallurgy, new environmentally-friendly state-of-the-art concentrators and smelters have been built. Substantial changes in human resource organization are noted but not studied.

The operational and financial performance of KCM, due primarily to changes in technology after privatization, have improved:

- Annual production of ore has increased by over 25%
- The annual return on capital employed has risen from an annual average of 15% before privatization to 41%
- The annual gross profit margin has increased from 5% before privatization to 15% after privatization
- The annual capital investment in the operations at KCM has risen by 89%.

The study concludes that there is sufficient evidence that KCM has performed better in the post-privatization period 2000 to 2010, due to substantial investment in technology and capital.

Keywords: Zambia, KCM, Konkola, copper, privatisation, technology, ROCE.

Introduction

Recent years have seen a move away from state ownership towards more reliance on private markets to supply goods and services, including goods and services traditionally supplied by the state, such as telecommunications, water, electricity, and mining activities (Blundell and Robinson, 2000).

Simubali (2012) sought to evaluate the type and impact of technology used before and after privatization in 2000 on the copper mining sector in Zambia, in particular Konkola Copper Mines plc (KCM), in terms of the associated operational and financial performance. This was to answer the frequently asked question in the industry and in the whole of Zambia alike: has foreign direct investment (FDI) in KCM, since privatization, been credible and produced worthwhile results?

In April 2000 the Nchanga, Konkola, and Nampundwe mines that were previously owned by Zambia Consolidated Copper Mines Limited (a Government majority-owned company) were privatized and transferred to KCM, which was formed by the Government of Zambia, Anglo American Corporation, and the Commonwealth Development Company, as well as a small number of public investors. At the time of privatization, KCM's fully integrated copper operations included a number of open pit mines, large underground mines, concentrators, and a tailings leach plant at Nchanga mine. At Konkola, a large underground mine was operated with two shafts and a concentrator on site. The underground

mine and concentrator at Nampundwe near Lusaka produced pyrite concentrate for use in the smelters. At Nkana in Kitwe, KCM operated a smelter, a refinery, and an acid plant, which serviced the whole group. Since privatization, substantial technological investments in all KCM mining and metallurgical functions have taken place, creating a very large integrated operation (Figure 1).

The study described in this paper undertook to identify and analyse the post-privatization technological and capital inputs into KCM, in order to contextualize their influence on KCM's production and financial performance in respect of copper ore, copper in ore, and copper metal production.

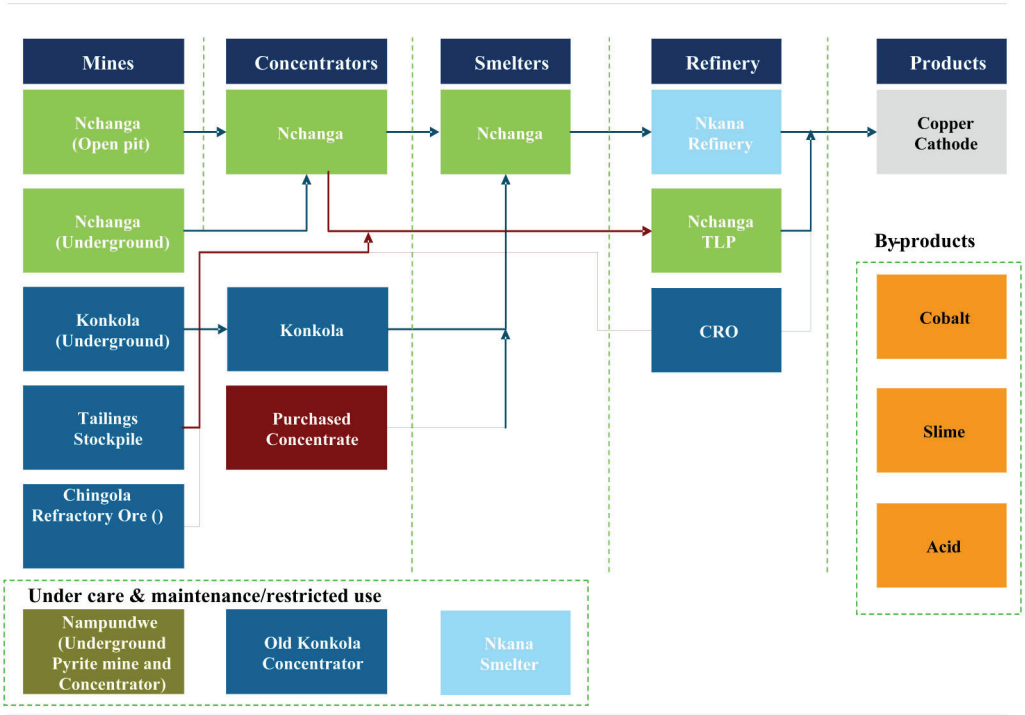

Figure 1. Schematic Structure of KCM operations

Statement of the problem

Prior to the privatization of state-owned mines (SOMs) in Zambia, the SOMs faced serious challenges, including a lack of new capital investment and mismanagement, which led to a decline in operating efficiency.

With access to debt and equity financing that would come as a result of private ownership, former SOMs were expected to perform better after privatization. It was hypothesized that there would be enough capital for technological solutions that would assist the mines to operate more efficiently. Given the increased supply of financing, total FDI in the Zambian copper sector increased from an average of US$200 million per year to US$331 million per year (United Nations, 2006). However, to a sceptical Zambian public and media, there did not appear to be a corresponding increase in 'real production' to justify the increase in technology and capital expenditure after privatization. This view extended to senior government officials and politicians, as exemplified by a budget speech by the Zambian Minister of Finance (GRZ, 2011) and various assessments (The Post, 2012; Chileshe, 2013 ; Zambian Ministry of Finance, 2000). It was imperative, therefore, to assess impartially the effect and impact of technology used before and after privatization *vis-a-vis* operational and financial performances of KCM, in order to clarify and determine the scale of the problem.

Research objectives and proposition

Research objectives were structured in the form of a research proposition, that the technology employed by KCM after privatization improved the operational and financial performance of the company.

The indicators are

- Copper ore and copper-in-ore production, which scale the level of activity
- Finished copper production, which measures revenue
- Financial analysis by way of margins and return on capital employed (ROCE).

Research method

The research was undertaken through questionnaires, internet searches, searches of the ZCCM and KCM archives as well as library systems, supplemented by consultative visits, interviews, and site visits to mines in the Zambian Copperbelt. The questionnaires targeted mineworkers, engineers, and managers as well as suppliers, contractors, and manufacturers.

Findings

Technological status of KCM assets before and after privatization

Underground mining

Prior to privatization at ZCCM Nchanga and Konkola Divisions, the future privatized KCM assets, only the open pits and Chingola B mine at Nchanga as well as experimental cut–and-fill stopes at Konkola No. 3 shaft used advanced mining technology. The rest of the mining at Nchanga underground mine and Konkola No. 1 shaft, which contributed about half of the metal production, was biased towards gravity- and scraper-assisted low-technology mining systems. The outstanding feature of mining before privatization was that it was very highly labour-intensive. KCM technology inputs after privatization shifted the balance in mining technology from 'definitely' low-tech towards advanced trackless technology.

Shaft and primary accesses to new orebodies and extensions

After privatization, KCM-Vedanta Resources raised financing and partnered with overseas-equipped contractors to sink the KDMP Super-shaft No. 4 complex at Konkola, which opened up mining access to 30 years of high-grade copper ore resources. Similarly, KCM-Vedanta Resources hired foreign-equipped contractors for the extension of lateral access from the existing almost-exhausted workings into the future mining area of the Upper Orebody (UOB) at Nchanga underground mine. The UOB access extended Nchanga's mining potential of medium-grade copper for another twenty years. Both KDMP and the UOB would be highly mechanized trackless mining systems. The UOB and KDMP would ensure that Nchanga and Konkola mines, respectively, would continue sustainable and profitable underground mining for the foreseeable future, assuring a well-founded bedrock for KCM.

Drilling

In the decade leading up to 2010, drilling technology changed vastly. Before privatization, primary and secondary development drilling were conducted mainly with pneumatic jackhammers, while stope and undercut drilling were done with bar drifter machines, which were all labour-intensive and low productivity. After privatization, this type of equipment was phased out, while the use of high-productivity face- and longhole-drilling electro-hydraulic jumbos increased. Aging low-technology drilling systems that could not be phased out from scraper- and gravity-assisted mining methods at both Nchanga and Konkola were programmed for abandonment as the need for them fell off, with the shift to new mining methods at the UOB and KDMP.

Blasting

Development and stope blasting before privatization relied mostly on ANFO, dynamite, and gelignite fracture explosives. Emulsions and watergels were just coming in before privatization. Blasting accessories were mostly based on safety and electric fuses as well as detonating cord. After privatization, fracture explosives were dominated by ANFO, emulsions, and watergels. Blasting accessories were mostly non-electric shocktube detonators and snaplines, as well as electronic detonators. Blasting efficiency rose substantially, because modern explosives are mostly liquid and are able to achieve complete combustion of the ingredients, compared to the solid explosives used before privatization which were prone to incomplete combustion. Incomplete combustion, apart from inefficiency, resulted in an excess of carbon monoxide and nitrous fumes, leading to numerous fatal underground gassings, which became rare occurrences with liquid explosives. KCM contracted explosives companies to bring in modern explosives and necessary equipment such as mobile manufacturing units.

Loading

Before privatization, the loading for Nchanga open pits was mainly through electric rope shovels, and to a lesser extent, front-end loaders. After privatization, loading, in the open pits shifted to hydraulic excavators and contractors in the Chingola pits and a new open pit, worked intermittently, called Fitwaola. Hydraulic excavators were more versatile. For underground, rocker shovels or air loaders predominated in primary development, with scrapers and hand-lashing in secondary development. In underground decline areas at both Nchanga and Konkola mines, trackless loaders and rear dump trucks were employed for a minority of ore production. After privatization, trackless mechanization was implemented, especially, at Konkola with a combination of drilling jumbos as well as load-haul-dump units and dump trucks. At Nchanga underground, the traditional scraping mining methods continue, but face extinction with the coming of the highly mechanized UOB project, which is scheduled, reportedly, to take over the bulk of production by 2018.

Ground support and slope monitoring

Support equipment did not change significantly in underground mines, owing to the innovative steel set and grouted rockbolt approaches taken by the pre-privatization company, except for the introduction of fibre-reinforced grouting for rockbolting. However, in the open pits the loss of ten miners in the Nchanga Open Pit slope failure disaster in April 2001, one year after KCM took over, resulted in major tactical and technological changes in slope management. The major technological input after the disaster was the installation of open pit slope monitoring radar (Groundprobe, 2013), the cutting-edge technology for monitoring and warning of impending life-threatening ground movements, assuring safe working even with more profitable steeper slopes.

Transport

Before privatization, the main method of transporting ore and waste from the development ends and production stopes underground was locomotive haulage from gravity-pulled loading boxes serving gravity stopes and scraper drifts. These were both electric and diesel locomotives. After privatization, the use of trackless equipment was ramped up especially at Konkola Mine. For open pits, the largest dump trucks used were 200 t, while 400 t trucks were introduced after privatization.

Table I summarizes the underground mine technology that existed before and after privatization of the mines at KCM.

Table –I. Underground and surface mine technology changes at KCM, 2000 to 2010

Unit or functional process	Before privatization	After privatization
Shafts and hoisting, UG primary new access, KCM pen its	Primary shaft depth at Nchanga up to 1000 m, with decline access for a further 150 m. Konkola was shallower. Rock hoisting capacity of No. 1 and No. 3 shafts at Konkola approximately 3.5 Mt/a, Nchanga underground approximately 3.5 Mt/a. KCM Nchanga Open Pit production ranged from 4–6 Mt/a with waste stripping capacity 80 Mt/a.	KDMP deepened to 1500 m to open up 300 Mt of copper ore resources; KDMP potential production capacity 6–9 Mt/a. Material and ore transport introduced through portals at Konkola; UOB access at Nchanga extended to open up over 20 years of copper and cobalt resources. UOB potential production capacity 2.5 Mt/a; KCM open pit production potential 4–6 Mt/a. Majority of stripping capacity contracted out. Renewed mining at Chingola open pits in addition to Nchanga Open Pit as well as new mining at Fitwaola Open Pit near Chilila Bombwe,
Drilling	Jackhammers in primary development and bar machines in stope and undercut drilling, except for trackless operations at Chingola B mine in Nchanga and experimental post-pillar area at No. 3 shaft at Konkola. Nchanga Open Pit drilling of 17 m deep 305 mm diameter blastholes with mast drills on patterns from 7 m × 8 m to 9 m × 10 m	Nchanga underground mine and Konkola No. 1 shaft retained jackhammers and bar machines while Konkola No. 3 shaft accelerated trackless mining including backfill technology. Jumbo drilling increased at No. 3 shaft for both face and stope drilling, and planned for UOB and KDMP. Additionally, Chingola open pit hydraulic drilling of 8 m deep blastholes with crawler drills on pattern of 4 m × 5 m.
Blasting	Blasting accessories were primarily electric and safety fuses as well as detonating cord. Fracture explosives were dynamite, gelignite, and ANFO. Emulsions and watergels were at introductory stage and minor for wet blast-holes	ANFO as well as emulsions and watergels firmly established. Blasting accessories primarily shocktube detonators and snaplines. Widespread use of contracted mobile mixing units in the open pits. Electronic detonators introduced in the open pits
Loading or excavating	In the open pits electric shovels and front-end loaders. Underground, LHDs in a few areas, otherwise scrapers and gravity.	In the open pits, contracted hydraulic excavators and mine electric shovels. Underground, LHDs very common and to dominate the future
Haulage or tramming	Diesel or electric locomotives underground serving gravity stopes and caving blocks, except for HSI at Nchanga and PPCF area at Konkola where LHDs and dump trucks operated. In the open pits the largest rear dump trucks were 200 t	Diesel or electric locomotives underground serving gravity stopes and scraped drifts, still continued, except for HSI at Nchanga and CAF area at Konkola where LHDs and dump trucks operated; In the open pits the largest rear dump trucks were increased to 400 tonners
Ventilation	Surface primary fans with exhaust arrangements underground	No major changes, but additional shafts mined at Konkola. Use of emulsions and watergels in blasting reduced gassings.
Ground support and slope management	Underground support based on steel sets and grouted rockbolts, with wire lacing and/or mesh-wire	Underground support similar to pre-privatization, except for introduction of fibre-reinforced grouting for rockbolting. Open pit slope management revolutionized by the introduction of slope stability monitoring radar, which allowed safer working even with steeper or dangerous slopes
Mining methods	A mix of conventional gravity-assisted stoping at Konkola and scraper drift block caving at Nchanga, with limited trackless operations at No. 3 Shaft Konkola and HSI/Chingola B at Nchanga. Open pit mining focused on Nchanga Open Pit, with limited backfilling in the last 8 years before privatization	Pre-privatization technology continued in areas that could not change at No. 1 Shaft Konkola and Nchanga block caving mining; Trackless operations accelerated at No. 3 shaft/KDMP and Nchanga UOB, and were planned to completely replace conventional operations within a few years. All mining at KCM would be trackless in future, with extensive backfill at Konkola. Open pit mining added Chingola and Fitwaola open pits, with plans for Mimbula
Dewatering	Konkola was among the wettest underground mines in the world, with the most elaborate pumping arrangements for 300 000 m^3/day. Machinery run down due to financial constraints.	Replacement of long-overdue underground pumps and casings, and beefing up standby power generation in case of catastrophic national grid power failure. Elaborate all-year open pit dewatering systems in Chingola pits introduced in addition to rainy season sump pumping

Surface mining

Surface mining at KCM underwent many technological changes in its unit processes, as shown in Table I. Widespread importing of technology and marshalling of human resources through international contractors took place as owner-mining operations were substantially replaced by contractors

Mineral processing and metallurgical plants

The copper ore processing concept changed significantly from the one that was used before privatization. Before privatization, the ore was concentrated at the Konkola and Nchanga mines, with a smelter, an acid plant, and a refinery at Nkana in Kitwe. After privatization, additional, completely new concentrators with SAG mill technology were built at Konkola and Nchanga, and a new smelter and acid plant at Nchanga. Technology changes after privatization are shown in Table II. The atmospheric emissions at Nchanga smelter reduced by 90% compared to those at pre-privatization smelters in Kitwe. Acid, as a by-product of the new Nchanga smelter and acid plant, became almost free after privatization, compared to the pre-privatization cost landed on the Copperbelt of US$200 per ton. The new metallurgical complexes at Konkola and Nchanga were well positioned to support life–of-mine operations at the new UOB and KDMP extensions, as their production expectations eventuate.

Table II. Technological changes in the processing plants at KCM

Unit process	Before 2000	After 2000
Crushing	Large mill balls used (25-200 mm).	Size of mill balls reduced (20-150 mm)
	Small feeders	Large feeders, allowing huge feeds to be crushed at once
	Crushing was divided into secondary and primary	Both primary and secondary crushing done in SAG mills
	Using ordinary steel mill balls.	High-chrome mill balls in use
	The concept remained unchanged	
Thickening	Small thickeners	Large thickeners
Flotation	Mainly fatty acids and oils used	Concept remained the same.
		Change is in chemicals/ reagents
Filtration	Drum filters	Larox filter
	Concentrates came out wet and it has to be dried (wet cake)	Concentrates dry
	Conveyer distance long	Conveyer distance is shorter
	Single stream of conveying	Two streams used
Smelters	Capacity approximately 150 kt/a.	Capacity now 300 kt/a
	Two reverberatory furnaces;	Direct to blister process
	old technology, slow.	Smelting capacity increased (new smelter)
	Only copper circuit; small in size and not environmentally friendly	Copper and cobalt circuits Environmentally friendly, 96% sulphur fixation
Chingola refractory ore heap leach (CRO)	Considered as an option but not possible owing to inadequate acid	Serious option now with plentiful acid supply from the Nchanga smelter acid plant

Operational performance of KCM assets from 1991 to 2010

Given all the changes in technology instituted after the privatization of KCM assets, we assessed the operational performance of KCM by means of three key performance indicators (KPIs). These are copper ore production, copper-in-ore production, and finished copper production.

Table III and Figure 2 compare copper ore, copper-in-ore, and finished copper production statistics before and after privatization. These statistics show that:

The average annual copper ore production during the pre-privatization period was 8.9 Mt, whereas that for the post-privatization period was 11.2Mt

The average annual copper-in-ore was 203 kt during the pre-privatization period, and 250 kt after privatization

The finished copper production during the pre-privatization period was 144 kt/a , and after privatization it was 183 kt/a

The percentage increases in copper ore, copper in ore, and finished copper were 25.7%, 23.4%, and 25.7% respectively, a clear increase after privatisation, despite falling ore reserves and production grades.

Table III. KCM copper production statistics (*ZCCM and KCM Annual Reports)*

Before privatization			
Year	Cu ore (t)	Cu in-ore (t)	Finished Cu (t)
1991	5 744 675	151 176	122 227
1992	7 537 260	203 710	171 301
1993	9 391 855	234 796	173 923
1994	10 276 150	238 980	165 744
1995	9 977 445	181 408	160 927
1996	10 281 155	293 747	149 002
1997	10 573 885	257 900	170 547
1998	9 694 455	176 263	102 047
1999	8 700 940	167 326	110 138
2000	6 894 095	127 668	116 849
Total	**89 071 915**	**2 032 974**	**1 442 706**

After privatization			
Year	Cu ore (t)	Cu in ore (t)	Finished Cu (t)
2001	9 226 954	245 417	196 805
2002	9 763 971	262 859	222 010
2003	10 165 627	251 275	187 555
2004	14 265 003	335 064	228 311
2005	10 101 549	182 144	163 778
2006	9 862 904	278 307	142 365
2007	9 426 050	229 610	150 488
2008	12 910 952	233 759	135 615
2009	13 442 152	253 810	169 642
2010	12 783 233	237 776	216 499
Total	**111 948 396**	**2 510 019**	**1 813 067**

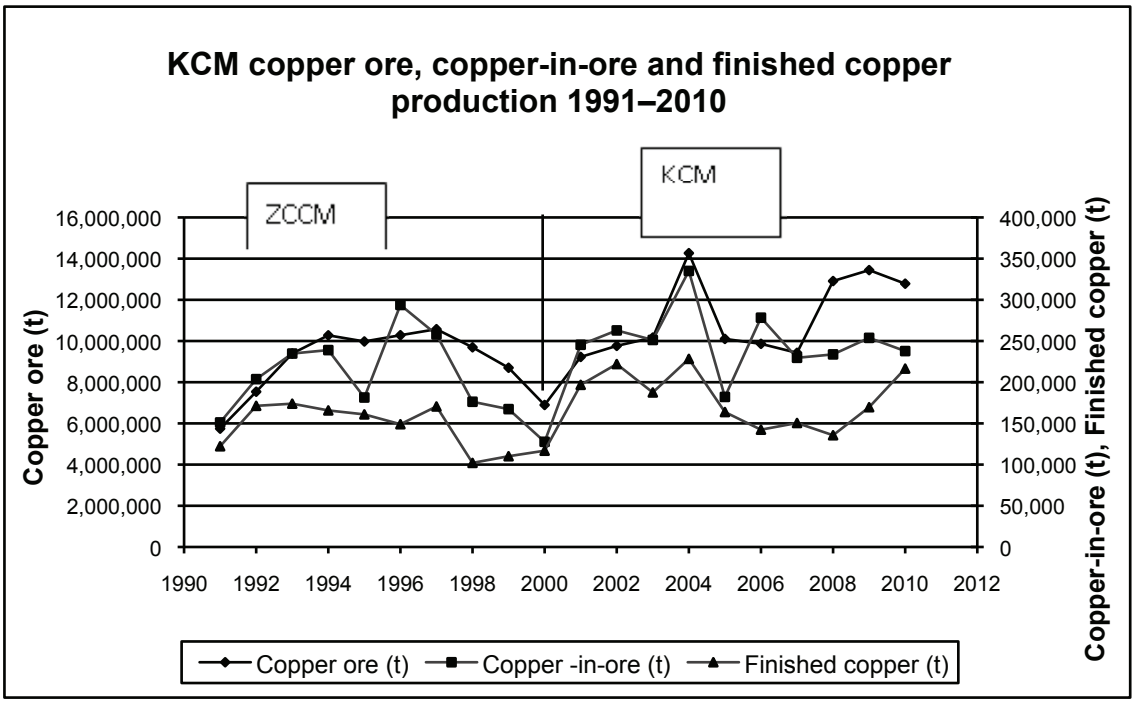

Figure 2. Production of KCM assets, 1991–2010

The graphical presentation (Figure 2) of the production statistics in Table II shows that there had been an upward trend in copper production, as evident from the graphs for copper ore, copper in ore, and finished copper. From Table II, after privatization, copper ore production exceeded 9.2 Mt/a every year for ten years, peaking at over 14 Mt/a in 2004. In contrast, for the last ten years before privatization, copper ore production exceeded 9.2 Mt/a in only six years, peaking at 10.7 Mt/a in 1997. Copper-in-ore production after privatization exceeded 200 kt/a every year except for 2005, peaking at 335 kt/a in 2004. In comparison, for the period before privatization, copper-in-ore production exceeded 200 kt/a in five years only, peaking at 293 kt/a in 1996, and thereafter plunging down over three years to 128kt/a. It was from this trough figure that copper-in-ore production was increased after privatization in 2000 to the level of 335 kt/a achieved in 2004.

To reflect more closely the realities on the ground for the two eras, it may be more appropriate to compare the last three years of each period. Copper ore, copper-in-ore, and finished copper production for the last three years before privatization totalled 25 289 490 t, 471 257 t, and 329 034 t respectively, while ten years later in the privatized era, taking the last three years under consideration, copper ore, copper-in-ore and finished copper production was 39 136 337 t, 725 345 t, and 521 756 t respectively. The numbers translate into increases of 55%, 54%, and 59% in copper ore, copper-in-ore, and finished copper production for the last three years of each era, ten years apart. Qualitatively, the ZCCM assets, now styled KCM, were technically bankrupt under Government of Zambia support, while the same operation by 2010 was well capitalized and resourced.

Copper ore, copper-in-ore, and finished copper production were three of the indicators chosen in the research objectives to confirm or disprove the proposition that the technology employed by KCM after privatization has significantly affected the operational and financial performance of the company. The increases in copper ore, copper-in-ore, and finished copper production after privatization suggest that the implementation of technology has improved performance.

Financial performance of KCM assets from 1991 to 2010

Ratio analysis

The technological changes instituted after privatization had financial implications for KCM. We assessed the financial performance of KCM as a result of the technological changes. In evaluating the financial performance of KCM, summarized in Table IV, we used return on capital employed (ROCE). It should be noted that several factors affect the financial performance of KCM other than technological changes, such as cost structures and organizational culture. These factors are assumed to be constant in this paper.

Table IV. Financials before (ZCCM) and after privatization (KCM) (US$ million) (*ZCCM & KCM, 1990– 2010)*

Year	**2000**	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**	**1991**
Revenue	220.38	220.17	203.89	387.99	341.66	472.48	383.70	521.60	481.19	353.48
Cost of sales	(165.30)	(165.10)	(152.90)	(291.00)	(256.20)	(354.40)	(287.80)	(391.20)	(360.90)	(265.10)
Gross profit	55.08	55.07	50.99	96.99	85.46	118.08	95.90	130.40	120.29	88.38
Administration	(44.10)	(44.00)	(40.80)	(77.60)	(68.30)	(94.50)	(76.70)	(104.30)	(96.20)	(70.70)
Net profit before tax	**10.98**	**11.07**	**10.19**	**19.39**	**17.16**	**23.58**	**19.20**	**26.10**	**24.09**	**17.68**
Year	**2010**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**
Revenue	1895.66	982.06	417.29	1214.59	716.81	516.88	701.83	319.41	347.89	332.99
Cost of sales	(1,232.20)	(638.30)	(271.20)	(789.50)	(465.90)	(336.00)	(456.20)	(207.60)	(226.10)	(216.40)
Gross profit	663.46	343.76	146.09	425.09	250.91	180.88	245.63	111.81	121.79	116.59
Administration	(379.10)	(196.40)	(83.50)	(242.90)	(143.40)	(103.40)	(140.40)	(63.90)	(69.60)	(66.60)
Net profit before tax	**284.36**	**147.36**	**62.59**	**182.19**	**107.51**	**77.48**	**105.23**	**47.91**	**52.19**	**49.99**

Return on capital employed (return on assets ratio)

The return on capital employed (ROCE) or return on assets ratio (ROA) is considered to be an overall measure of profitability. It measures how much net income was generated for each $1 of assets the company has. ROCE or ROA is a combination of the profit margin ratio and the asset -turnover ratio. It can be calculated separately by dividing net income by average total assets or by multiplying the profit margin ratio by the asset turnover ratio. Figure 3 shows the numbers after computing the same for KCM. ROCE has risen from an annual average of 15% before privatization to 41% after privatization.

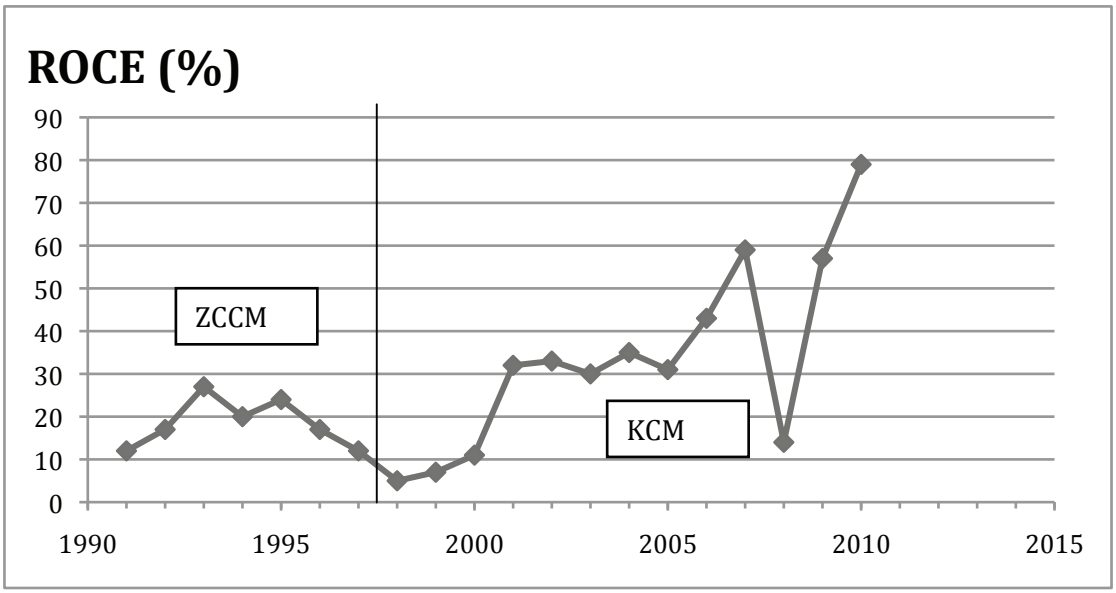

Figure 3. ZCCM and KCM ROCE (1991–2010)

ROCE was identified in the research objectives as a key indicator for testing the research proposition. The increment of ROCE from an average of 15 per cent for the ten years before privatization to 41 per cent for the period after privatization suggests that the proposition holds.

Capital expenditure from 1991 to 2010

We assumed in our study that the capital injection as in Figure 4 drove and underpinned technology acquisition or upgrade, and thus translated technology into financial terms. The average annual capital expenditure was $130 million

before privatization, and $246 million after. This shows that there was an 89% increase in the capital invested at KCM, which equates to an increase of 89% in technology inputs in various forms. The increase in capital expenditure accounts for the increase in the equipment and infrastructure purchased and installed at KCM and the upgrades in the mining projects and processing plants, such as the UOB, new smelter, acid plant and concentrator at Nchanga, as well as the new concentrator and KDMP at Konkola.

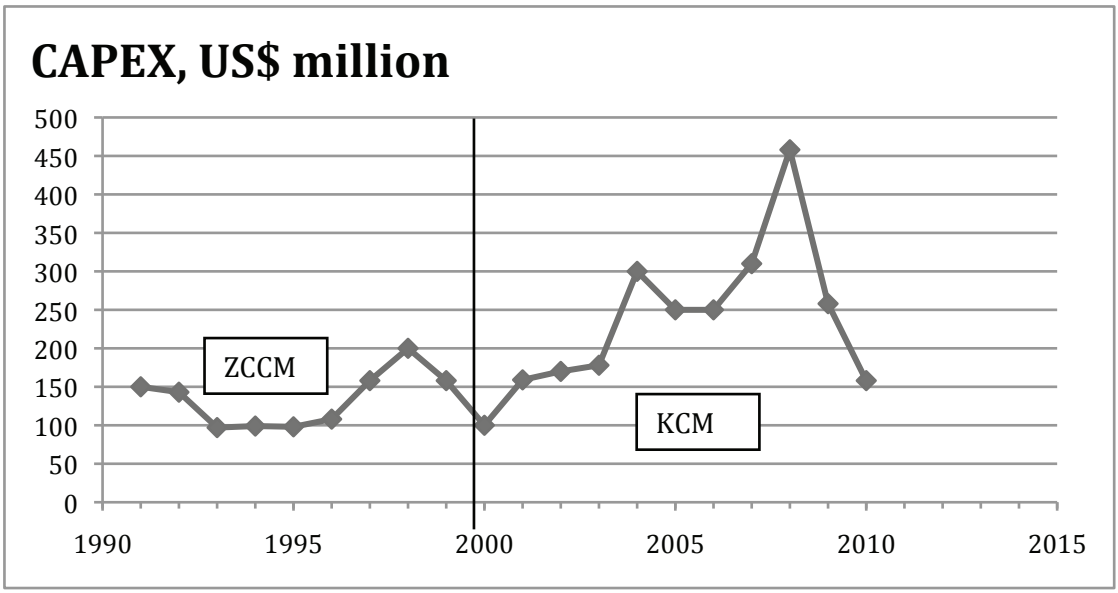

Figure 4. ZCCM and KCM capital investment, 1991–2010

Capital investment at KCM took an upward swing from the year 2000. Before privatization, for nine years, the annual capital injection was less than US$159 million. Capital investment from 2000 to 2010 was above US$159 million per year, peaking at US$458 million in 2008. For the last ten years before privatization, capital expenditure totalled US$1.3 billion compared with US$2.46 billion for the ten years after privatization.

As a measure of the technology input selected for the study, the capital injection after 2000 demonstrates a very significant upward trend beyond the levels before privatization. The question really is whether it had any effect on copper ore, copper-in-ore and finished copper production after privatization.

Comparative analysis of production and financial performance

The question that needs answering is whether KCM's post-privatization increases in production ie. 25.7% for copper ore, 23.4% for copper-in-ore, and 25.7%, for finished copper (10-year average), or 54.75% for copper ore, 53.9% for copper-in-ore, and 58.57% for finished copper (last three years per era), and, justifies the 89% increase in capital expenditure and technology.

The indicators selected to test the proposition were copper ore, copper-in-ore, finished copper, and financial analysis.

- Capital investment over the ten-year period after privatization increased by 89% compared to the last ten years before privatization. Qualitatively, on the ground, the effects of increased capital investment in plant, machinery, and infrastructure can be seen in from the data presented in this paper
- Production of copper ore, copper-in-ore, and finished copper over the ten years after privatization has increased by 25.7%, 23.4%, and 25.7% respectively, compared to the ten years before privatization. Re-stated over the last three years of each era, copper ore, copper-in-ore, and finished copper production increased by 54.75%, 53.9%, and 58.57% respectively,
- Financially, ROCE has increased on average from 15% to 41% for the ten-year periods before and after privatization. The gross profit margin has increased from 5% before privatization to 15% after privatization.

The increases in production and improved financial performance at KCM since privatization correlate with the implementation of technology after privatization. We suggest that the new technology had a role in bringing about the improvements.

This proposition has been corroborated by the changes in the production and economic data from one period to the next.

- Deeper mining: the average mining depths increased in the post-privatization period. The turnaround period after privatization increased by more than half. With these increases, more spare parts, more tyres, and more fuel are required (SRK. 2010)
- The grade and type of mineralization of the copper orebodies have changed. During the pre-privatization period the grades of copper production areas were about 2 –5%, whereas after privatization the grade of copper was around 1.5–4 %. The cut-off grade for KCM was 1% before privatization, but it was revised to 0.9% after privatization. Consequently, increased ore production has not necessarily translated linearly into greater metal output
- Copper prices on the world markets have risen substantially since 2004, so much so that, despite the global economic crisis of 2008/2009, ore resources which could be converted into mineable reserves have increased, thereby providing the company with extra production capacity and flexibility that were not available before privatization.
- Capital gestation is an important concept in mining where the production maturation period is measured in decades for large-scale projects such as the KDMP, which has consumed most of KCM's capital investment, and the UOB. Large investments translate into increased metal production only in graduated tactical steps over long periods of time. As such, the hundreds of millions of US dollars in FDI spent on the KDMP and UOB since 2000 will unlock metal production only over the following thirty-year period. However, it is just this kind of investment that has been identified as the most critical for prosperity in the mining industry as it unlocks substantial mineral resources for sustainable and profitable life-of-mine planning, design, and production (Garcia and Camus, 2011). These capital investments tend to bear fruit in the long term rather than short term, thereby precluding a direct linear relationship between capital and production.

Statistical analyses of production and financial performance

Simubali (2012) used three tools of statistical analysis to establish a relationship between capital investment and production, in order to understand and partially explain the impact of the technology used before and after privatization. These were ratio analysis (return on capital employed and profitability), value-chain modelling, and regression analysis. Value-chain modelling and regression analysis have not been used in this paper. Both require further work in establishing a statistically acceptable relationship between the capital investment and production.

Conclusions

- Since privatization, a very diversified portfolio of substantial changes in underground and surface mining technology have been made by KCM, including new accesses to new copper ore reserves through the KDMP and UOB projects at Konkola and Nchanga, respectively
- In mineral processing and metallurgy, new concentrators, as well as a new smelter and acid plant with the latest environmental friendly technology, were built after privatization.
- The operational and financial performance of KCM have improved greatly compared with the pre-privatization period, with an average 25% annual increase in copper ore produced
- The return on capital employed has risen from an annual average of 15% before privatization to 41% after privatization.
- The gross profit margin has also risen from 5% before privatization to 15% after privatization.
- The capital invested in the KCM operations has risen 89% after privatization compared to the pre-privatization period.

The study concludes that the significant production increase at KCM since privatization in 2000 is related to technology changes and capital investment. The question arises as to why this has not increased even further.

- Capital gestation in mining is long-term, which means that a substantial part of the capital investment since privatization will bear fruit over the life of mine, running into two to three decades
- Other important factors, which were not examined, include changes in commodity prices, human resources, purchasing and supply agreements for goods and services, metal sales pricing agreements, and ethics.
- Corporate malaise, due to delays in privatization, in the period 1991 to 2000, was such that the assets became extremely degraded. Very substantial parts of the operations were headed for collapse, such that they could be taken over under privatization only on the condition that the new owners would be allowed to shut them down.

Recommendations

We recommend that benchmarking should be conducted, which includes a comparison of the performance of the KCM mine and unit operations before and after privatization with industry norms ,and the performance after privatization compared with that of former state-owned mines in Zambia.

To allow the company to understand itself better, in order to strategize accordingly, consultant and academic studies should be commissioned to examine the issues of capital gestation, human resources, purchasing and supplier agreements, metal sales pricing contracts, and ethics.

On the academic side, much more work needs to be done in establishing a statistically significant relationship between various copper production types and capital investment for KCM and, possibly, other companies.

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References

Blundell, J. and Robinson, C. 2000. Regulation without the state… the debate continues. *Readings* 52. Institute of Economic Affairs, London.

Chileshe, P.R.K. 2013. Mine contribution and tax modelling in Zambia. *Zambian Journal of Chemical Engineering),* vol.2, no. 1. pp. 49-63.

Fundanga, C. and Mwaba, A. 1997. Privatisation of Public Enterprises in Zambia. African Development Bank, *Economic Research Paper* no. 35.

Garcia, J.M. and Camus, J.P. 2011. Value creation in the resource business. *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 111. pp. 801 – 808.

Government of the Republic of Zambia (GRZ). 2011. 2012 Budget Address by Honourable Alexander B. Chikwanda, MP, Minister of Finance, delivered to the National Assembly on Friday 11th November 2011. http://www.parliament.gov.zm, 24 March 2012. 15 pp.

Groundprobe. 2013. Slope Stability Radar (SSR^{tm}). http://www.groundprobe.com/products-and-services/slope-stability-radar-ssr 18thJuly 2013.

KCM. 2001. Consolidated Financial Statements. PricewaterhouseCoopers, KCM Archives.

KCM. 2002. Consolidated Financial Statements. PricewaterhouseCoopers, KCM. Archives.

KCM. 2003. Consolidated Financial Statements. PricewaterhouseCoopers, KCM Archives.

KCM. 2004. Consolidated Financial Statements. Deloitte Touche, KCM Archives.

KCM. 2005. Consolidated Financial Statements. KPMG, KCM Archives.

KCM. 2006. Consolidated Financial Statements. KPMG, KCM Archives.

KCM. 2007. Consolidated Financial Statements. KPMG, KCM Archives.

KCM. 2008. Consolidated Financial Statements. Deloitte Touche, KCM Archives.

KCM. 2009. Consolidated Financial Statements. Deloitte Touche, KCM Archives.

KCM. 2010. Consolidated Financial Statements. Deloitte Touche, KCM Archives.

Lusakatimes.com. 2007. KCM builds a new mine. http://www.lusakatimes.com/2007/07/17/kcm-builds-new-mine-to-boost-output/

Simubali, M.K. 2012. The impact of technology used before and after privatisation of Konkola Copper Mines plc (KCM). Unpublished MBA thesis, Copperbelt University, School of Graduate Studies, Kitwe, Zambia.

The Post. 2012. Economic growth without jobs. *The Post*, no, 5632, 20 March 2012. *http://www.postzambia.com*. p. 20.

Salvatore, D. 2007. Managerial Economics in a Global Economy. 4th edn. Thomson South Western. pp. 148-172.

SRK. 2010. KCM's Minerals Expert Report. Unpublished company report, KCM Archives.

United Nations. 2006. Investment policy review Zambia. New York and Geneva. pp. 3-5.

Zambian Ministry of Finance. 2000. Interim Poverty Reduction Strategy Paper.

ZCCM. 1990. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1991. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia

ZCCM. 1992. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1993. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1994. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1995. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1996. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1997. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1998. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 1999. Consolidated Financial Statements. ZCCM Archives, Ndola, Zambia.

ZCCM. 2000. Consolidated financial statements. ZCCM Archives, Ndola, Zambia.

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